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Significance and Functionalities of the Stakeholders' Processes at Lower Layers of Integrated Aviation Industry-Wide Risk Management Systems

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Abstract

The idea of integrated aviation industry-wide safety (risk) management system and control mechanism require a common development level of the relevant sectors of included stakeholders. To construct such a system the three structural layers must be well defined, understood and functional. These are intra organizational, inter organizational and industry layer. As the name suggests, intra organizational layer include individual aviation organizations, subjects, their structure and systems. Inter organizational layer focuses on mutual relations between individual organizations or subjects, while industry layer includes a high-level mechanism controlling current state of safety and leading a strategic development. This paper focuses on the intra and inter organizational level by bringing a closer look into individual organizations' processes and mechanisms used as a tool for a creation of the path leading to integrated safety (risk) management system, described in more detail in previous articles. It introduces a new approach and systematic changes needed for gathering more valuable safety related data, required for proactive management of the internal processes. Airports and other systems closely connected to them are taken as a main subject for the analysis. The main goal is to provide an explanation on how such internal structure should be set in order to become an efficient element of the proposed system.
KEY WORDS: *safety management, risk management, safety data collection*

1. Introduction

Handling safety always was a challenge. Effective tools were developed in order to manage safety knowledge, for instance safety management system [1]. Various entities used various systems. Creating integrated aviation industry-wide safety or risk management is a complex process, highly dependent on the individual stakeholders and their ability to adapt to the new environment and procedures. The main principle in any kind of integration process is common for various industries and it is usually performed in several phases, giving involved parties time and manoeuvring space to find and develop their role within new system. Safety management, including all managing systems and principles are not an exception. ICAO supports the member states to implement safety management systems [2]. Constant changing of an approach to safety management recorded some improvements [3][4].

The previous article brought an overview of current situation in this area, explaining the existing issues and insufficiencies which are common for safety management on the local and global level within aviation industry. The conclusion derived from current state analysis was clear, there is a strong need for more aviation industry-wide solutions and initiatives, but on the other hand the whole process of integration is highly demanding. The main idea contains a goal to establish a globalised system of internally coordinated and cooperating systems established for effective safety data collection, sharing, analysis and improvement based on system and everyday operation requirements. European union supports the establishment of State safety plans and programs form member states [5].

In order to establish a firm structure of logical and mutually connected elements, a solution divided potential stakeholders into three building layers each containing a group of clearly given rules and requirements for all individual stakeholders. The solution defined inter, intra and industry layer, each representing a platform for logical organisation of the involved parties, giving a comprehendible structure of tasks, responsibilities, actions and benefits for all involved stakeholders. While goal of previous paper was to provide information regarding overall system functioning, with a focus on industry layer, it is now important to present other two layers in terms of their significance and active involvement in system functioning.

While industry layer is primarily focused on common control and oversight mechanisms, developed with an intention to ensure and maintain a satisfactory level of compliance, other two have a clear role, to maintain and actively develop a particular activities, those influencing everyday operations and having a direct influence on stakeholder's safety. Practically speaking, industry layer have a monitoring and controlling role, while other two are active elements, directly influencing a future direction of system development. The goal here will be to present these two layers in more detail, emphasising their significance and functionalities necessary for proper functioning of such kind of management systems. Talking about these two layers we are focusing on particular organisations, taking into account a practical processes, procedures, activities, issues, etc. In comparison to the industry level, other two are strictly practical, where any solution or recommendation is a result of facts analysis and gained experience from real operations. This fact opens a possibilities for more proactive approach to system change, where based on actual company needs a manager will be able to focus on issues more accurately and at the right time. To enable such options, a systematic structuring of these two layers must be well performed and in many cases tailored for individual organisation, however in such extent which do not influence systematic structure.

2. Coordination Between Different System Layers

The foundation of the proposed system is created by the lowest level stakeholders, individual aviation organisations. The intra organization level is the most dynamic layer comparing the numbers of performed activities and active processes that are taking place. Each organisation has a certain level of self-dependence, which is observable only from the "inside". These will be discussed later in more details. The following figure (Fig. 1) illustrates the defined integrated systems layers.

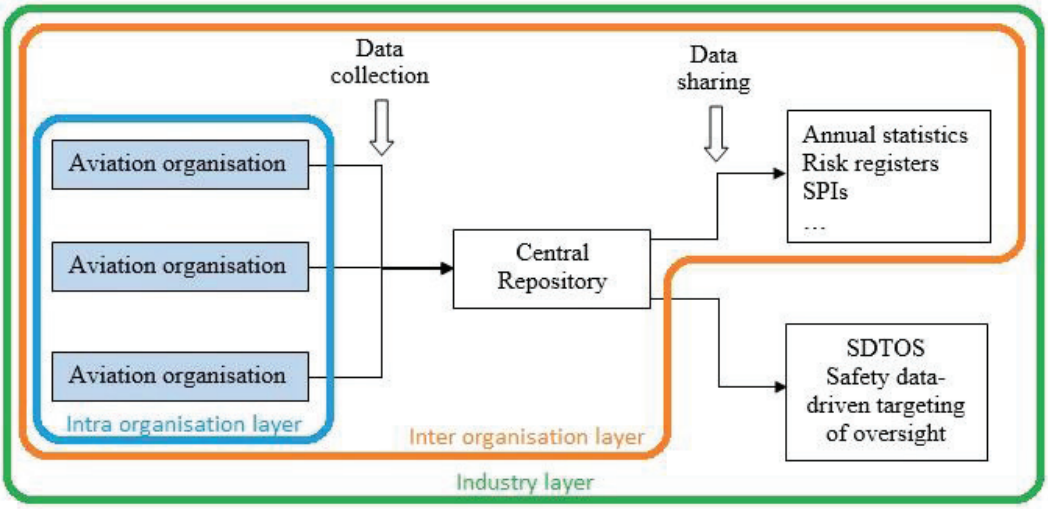

Fig. 1 Integrated industry-wide management system layers

The different levels of organisations development as well as their size, purpose, economics, types of environment in which they operate do not create a homogenous layer, in contrary, it creates a potentially chaotic and weak structure of mutually incomparable entities, without a common goal or purpose. That is a reason why intra organisational layer theoretically is not a functional structure but a frame involving entities with a same or similar intentions, for instance to provide specific services within aviation industry. This is a reason justifying a need for existence of the inter organisational layer that could be understood as a driving mechanism for some processes within individual organisation or within a group of them. The following figure (Fig. 2) represents a schema of the basic integrated system with implemented industry-wide mechanisms or features such as SDTOS or Safety data-driven targeting of oversight.

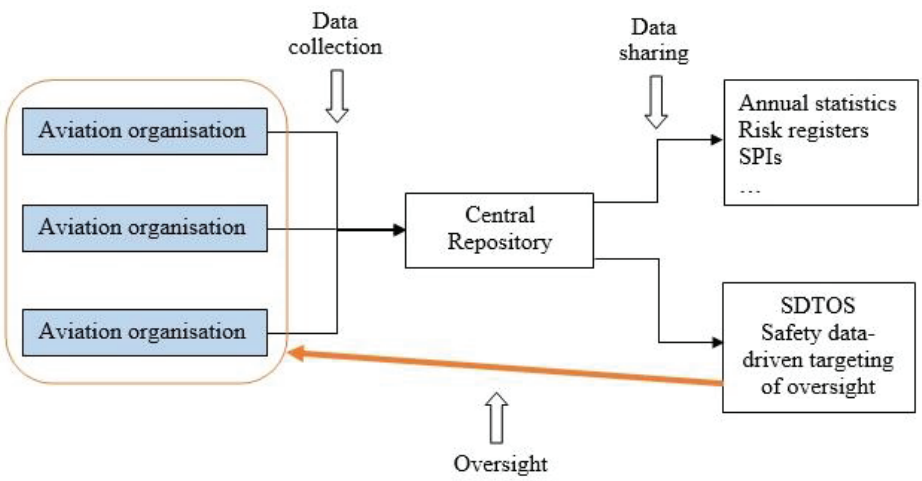

Fig. 2 Intra, inter and industry elements of integrated industry wide system

The main power enabling effective functioning of feature such as SDTOS is an effective data collection and sharing system. ICAO placed a requirement that each state should establish a voluntary and mandatory reporting [6]. As previously mentioned, different levels of development among various aviation organisation is quite a significant problem for any deeper coordination and cooperation between them, however, common safety date collection and sharing platform is not just a simple form of data interchange but a crucial point that interconnects various entities. It practically means that the common mutually interchangeable element for any aviation organisation within intra organisation layer is created and could be strongly beneficial as a source of safety data, both sensitive and general ones depending of the agreed level of coordination and cooperation.

The practical use of such feature is proposed SDTOS, enabling an existence of industry layer, where main role play a states or organisation responsible for oversight and other monitoring processes. This way, a whole industry becomes and one living organism where all individual elements cooperate in accordance to a given platform, in this case data collection, sharing and utilization.

3. Active and Meaningful Safety Data Collection and Management at System Stakeholders' Level

From the functional perspective, the intra organisational layer is much more activity-oriented then the inter organisation layer. The second one primarily exists in order to recognise "meeting points" among individual aviation organisation from the intra organisation layer.

Therefore, the existence of inter organisational layer is conditioned by existence of the intra layer. By taking a closer look into an intra organisation layer all processes could be sufficiently mapped and analysed in order to find out whether these could be recognised as common element for most of the analysed organisation or whether they contributes positively or negatively to organisation overall performance. Some of these could be evaluated as unnecessary or useless and in that matter excluded. Due to a fact that article focuses on both given layers it is necessary to focus on those aspects of the individual organisation processes that have some relevance, meaning that they are required for creation of the inter organisational mechanisms and processes.

The following figure (Fig. 3) represents relevant elements of the typical organisation from the intra organisation layer. These are the building blocks for any kind of coordination and cooperation between organisations. The green box shown on the figure (Fig. 3) represents a common platform for reporting for all organisations within intra layer, meaning that all of these are supposed to reach a certain development level of data collection and analysis mechanisms. European initiatives as well as local legislation requirements are forcing individual organisation to establish a functioning and effective systems designed for these purposes.

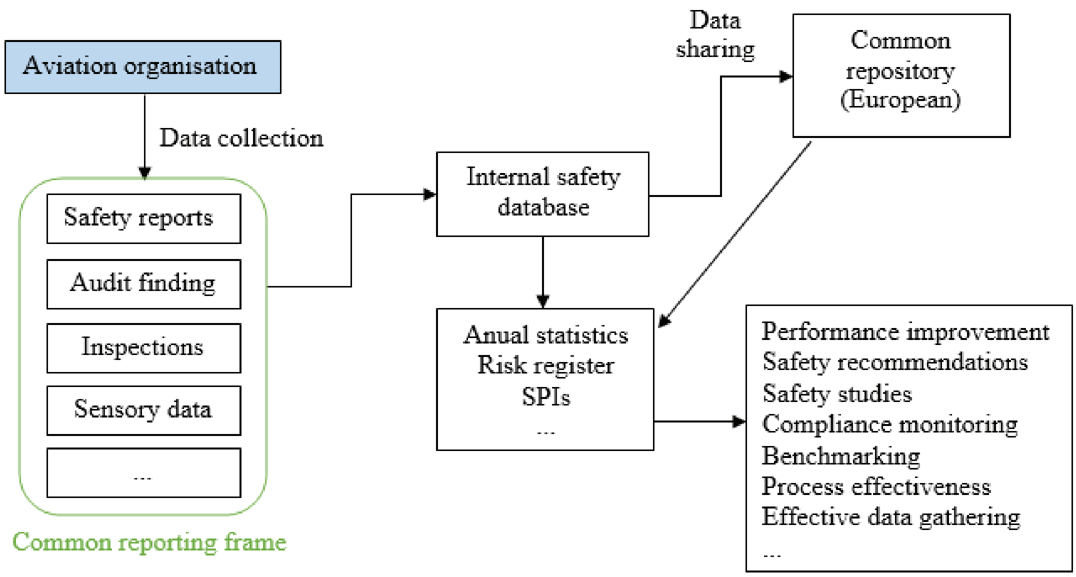

Fig. 3 A common structure of the organisation at the intra organisational layer

Individual organisations have developed their own safety and risk management systems with internal safety databases used for storing relevant and systematically collected safety related data. The crucial requirement for any integration steps is systematic and ontological structure of collected and stored data. In order to establish any kind of data sharing among various entities, the compatibility of data must be ensured and maintained.

It is of a great concern to prepare a structured platform that will enable collection of various types of safety related data such as incidents or accidents reports, investigation reports, audit or inspection data, various kinds of sensory data, etc. All of these are universal for many organisations from this domain and therefore a potential for their structuring and representation should be adequately utilized.

4. Understanding the Lower Level's Features and Mechanism Usable for System Integration

Taking into account all stated possibilities and a fact that all collected data could be structured in a common way and later on shared, creates a conclusion that there is no special need to focus on the individual entities separately but to create a integrated system able to cover all common frames from the involved entities.

On the previous figure (Fig. 3) the elements that are out of the green box are the features that individual organisations utilize for proper safety management processes however they are not critically needed for effective integration at the inter organisation level. Such fact however does not limit any organisation to use these features for deeper integration.

By analysing internal safety database (in many cases these databases obtain more detailed data then these shared within European one) the data regarding annual performance, risk registers or current state of the safety performance indicators could represent an effective tool used for various kind of benchmarking or comparison among similar organisations. Analysis of the available data from European Central Repository suggested that countries are on the different level of development [7, 8]. Safety performance indicators are separate subject which require special approach and research. A good foundation for creation of SPIs could be found on several sources [9, 10]. Also international organisation such as ACI created a guidance for proper SPIs setting [11, 12].

The starting point for common, integrated solution is ontology. Ontological modelling of the safety events as well as all subject, object or relations relevant from the safety point of view, creates a structure of well-defined and systematically ordered terms that are supposed to be used by various entities in an exactly similar way [13]. This fact ensures that all data are understood and represented in one unique way, ensuring that chances for any misinterpretation are at the minimal level. Representing data in such way increases their value, meaning that become interchangeable and that there is no need for any further actions regarding data readability. The whole approach then makes more simple analysis and research such as causal modelling in aviation safety [14].

Any kind of system data could and should pass through such restructuring. The goal is to create a certain framework for any organisation (entity) on how to set their internal system to be able to integrate into greater, industry-wide system. An expectation is that the small and developing entities will express the highest interest into such development. The reason for such prediction is understandable, a need of these entities to reach the required level of safety financial performance in the shortest amount of time.

5. Only Internal Versus Holistic Approach Benefits

Taking into account an existence and importance of sensitive safety data, as well as market competition, need for investments into potential structural changes and overall business strategies, brings to a conclusion that operational systematic decision-making process within safety management does not necessarily have to be influenced, however the same process on the strategic or long-term horizon could be on the other side severely impacted. This impact could be understood as an absence of dynamic and flexible structure, created on the ever-changing environment.

In order to make integrated system functional and effective a role of every individual stakeholder has to be adequately presented and understood. There is a potential that many aviation organization due to such progressive development will have a feeling that now with all these developed mechanisms they are becoming self-sufficient and do not see a point in any kind of industry-wide approach. On the other side, other organisations that are at the significantly lower level of development will not be able to comply even with basic principles and procedures.

What is a solution than? Given the fact that majority of world aviation organization use as a reference a numerous international legal documents and recommendation the holistic approach is a logical and also natural way on how to set such a complex and nowadays a really globalised industry such as aviation. Developing inner solutions and using them exclusively for internal purposes are a powerful way in problem solving and management process, however it does not have any impact at a global level.

It is a matter of perception whether for instance an air navigation service provider understands the need of an nearby airport for data regarding safety events that happened at the given airport but which were caused by ATC mistake. Such kind of safety data are in many cases strictly protected within these individual organisation, while their combination and cooperation between involved entities could be beneficial for both of them. Internal approach in this example is maybe beneficial for ANSP but taking a look at a "whole picture", it could be evaluated as insufficient for the aviation industry.

6. Conclusions

Modern world is globalised world. A majority of human activities nowadays represent just a small peace in the large chain controlled by common integrated systems. Aviation as such is a great example of global industry, where safety as such is an inseparable part. Valuable data sets and enormous amount of data that everyday operations produce is an essential source for smart, effective, and cheaper measures that need to be performed in order to prevent high-impact safety events.

By taking each aviation organisation individually, a conclusion regarding what aspects or processes require change, could be made. However, it is much tougher task to evaluate impacts that these could have on other stakeholders within given domain.

This was a main guidance for proposed solution, which takes and integrated approach as the most logical, but all conclusions build with respect to individual needs, requirements and specifics of the involved entities. It is of a great concern to respect this principle, which will then guarantee an acceptable level of satisfaction among interested entities. A solution with three proposed layers respects the given principle and also makes a whole system more flexible and more resistant to sudden and unexpected impacts.

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Competitive Tendering in the Rail Passenger Transport Focusing to the Long Distance Lines

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Abstract

A fundamental step in the liberalisation of the rail freight market has been the separation of railway infrastructure managers from railway companies and consequently providing non-discriminatory access of the railway companies to railway infrastructure in all Member States. The partial liberalisation of the rail market in the European Union (EU) was already underway in 2010, when all European railway companies gained access to all railway infrastructures in the EU. Opening up the market to new private railway operators means that several transport operators can compete directly for selected lines at the same time. Given that passenger transport is a State instrument of transport, regional and social policy to provide transport services, it is still largely controlled by the State.
The paper aims to the next step in liberalisation process. The opening up process of domestic rail passenger transport markets according to the fourth railway package has variety of level in Member States. This process is requested to done not later than 2019, while making public tenders for transport service contracts compulsory, in the public interest. The paper is focused to steps of tenders, implementation in long-distance rail passenger transport on the example of selected EU Member States and is more aimed on how the ordering of public services. There is need to analyze the technical and other obstacles and threats to the operation of long-distance rail services entering the competition. The idea is to meet the objectives of the EU White Paper on transport and The Regulation (EC) No 1370/2007 of the European Parliament and of the Council of 23 October 2007 on public passenger transport services by rail and by road and repealing Council Regulations (EEC) No. 1191/69 and 1107/70.
KEY WORDS: *liberalization of passenger transport, public tender, public interest*

1. Introduction

The current EU transport policy is based on the 'White Paper on the Single European Transport Area - Creating a competitive, resource-efficient transport system' that includes forty initiatives to create an efficient transport system. The area of the allocation of public services includes an initiative to open up the domestic rail passenger market to competition, including the compulsory award of public service contracts through competitive tendering. The rail transport market has undergone several transformations. Those achieved economic efficiency of rail transport, reducing the financial burden on the state budget, streamlining the management of the railway company and create the conditions for a market orientation. The aim was to increase the flexibility of rail transport to the needs of the customer. The requirements of liberalizing the rail passenger market and harmonizing the conditions for access to this market resulted in the adoption of the so called Fourth Rail Package. The Fourth railway package provides the obligation to tendering the public passenger transport services on the basis of results of a fair public tender. In justified cases, assigns public service performance in rail passenger transport by direct assignment for the selected railway undertaking (carrier). This topic deals with the papers of authors Kvizda (2015), Mašek et al (2015), Pečený et al (2016), Dolinayová et al (2016), Stopka et al (2015).

2. Analysis of the Market Opening Legislation

The basic secondary legislation, which provides for the allocation of public services is the European Parliament and Council Regulation (EC) No. 1370/2007 on public service contracts by rail and by road from October 23, 2007 and Regulation (EU) No 2016/2338 of the European Parliament and of the Council amending Regulation (EC) 1370/2007 as it regards the opening of the services market national rail passenger service on 14 December, 2016. [1].

This Regulation lays down the conditions under which competent authorities when imposing or contracting obligations arising from the public service provided by the suppliers pay for costs incurred and/or grant exclusive rights in return for fulfilling the obligations arising from the public service. The Regulation applies to national and international public passenger transport services in rail passenger transport, other passenger rail and road passenger transport. Exceptions are services which are provided mainly for their historical or tourist value. [1].

The amended version of the Decree from December 2016 introduced the definition of public service. It is done a public railway passenger transport where they concern transport by rail, with the exception of other track-based modes such as metro or tramways. Public service performances are provided by a public or private undertaking for passengers or carriers on the basis of a public service contract concluded between the railway undertaking and the competent public authority or authority with such competence. This authority in the Member State concerned has the right to interfere with public passenger rail transport. [1, 2].

Contracts are awarded either directly to a selected railway undertaking over which a competent authority control or another possible ways. The competent authority decides itself to provide services in the context of public services in railway passenger transport, and these performances are entrusted to a third party by tender. [11]. The procedure adopted for competitive tendering shall be open to all operators, shall be fair and shall observe the principles of transparency and non-discrimination. Following the submission of tenders and any preselection, the procedure may involve negotiations in accordance with these principles in order to determine how best to meet specific or complex requirements. If subcontracting takes place, the operator entrusted with the administration and performance of public passenger transport services in accordance with this Regulation shall be required to perform a major part of the public passenger transport services itself [12]. A public service contract covering at the same time design, construction and operation of public passenger transport services may allow full subcontracting for the operation of those services. The public service contract shall, in accordance with national and Community law, determine the conditions applicable to subcontracting. [1, 2].

Before a public tender is started a decision may be taken by the competent authorities limiting the number of contracts with the same railway undertaking.

3. Entering Performances in the Public Interest

Direct awarding of rail passenger transport services (in long distance lines too) is possible if their estimated average annual value is less than 7.5 mil. € or their range would be less than 500,000 kilometres per year. If the term of validity of the awarding does not exceed 10 years, the Contracts relating to rail passenger transport (excluding metro and tram) may be directly awarded. This period may be extended by up to 50% in respect of asset depreciation conditions when a service provider as a public service under the contract provides assets that are significant in terms of total assets. They are necessary for the performance of the services and the assets associated with these services in the public interest. The competent authority may decide to direct award of public service contracts even if the justification for the direct award, given to the relevant structural characteristics and geographic markets and networks (such as the size and characteristics of demand, complexity networks) [7]. It can also decide if the direct award led to an increase in service quality and cost efficiency. This may also be a combination, and the time of such a Contract may not exceed 10 years and may be extended by up to 50% for the above conditions. The competent authority may also directly enter into the public service contract, even temporarily, if it already provided several public tenders. It may be affected by the number of bids roots are present, but especially their quality. Direct input is necessary for optimizing the delivery of public services. The time of such contracts, which are strictly limited, can not exceed 5 years. [1, 6].

The validity of public service contracts in rail passenger transport which are not specified above does not exceed 15 years. The validity may be extended by a maximum of 50%. For example, as in the case of a contract that is entered directly. These are depreciation conditions or reasonable costs resulting from a specific geographic location. It is then possible to extend the treaty to a maximum of 50% in the outermost regions. If justified by the amortisation of capital in relation to exceptional infrastructure, rolling stock or vehicular investment and if the public service contract is awarded in a fair competitive tendering procedure, a public service contract may have a longer duration. In order to ensure transparency in this case, the competent authority shall transmit to the Commission within one year of the conclusion of the contract the public service contract and elements justifying its longer duration [1].

The competent authority shall take measures to be able to publish in the Official Journal of the EU, its identification data (at least the name and address) for at least a year before the launch of the invitation to tender procedure or one year before the direct award. He is also required to disclose the type of award. Also, the services and areas that are to be subject to the Agreement must also be disclosed, the planned date when they want to apply the Services Agreement in the interest of their own. Should this information change after its publication, the competent authority shall publish a rectification accordingly as soon as possible. This obligation does not apply to public service activities less than 50,000 kilometres per year. The competent authority is required to publish within one year the name of the contracting carrier (or bodies performing inspection), term of the contract description provided service for rail passengers and parameters of financial compensation, quality objectives (accuracy, reliability), rewards or penalties and conditions on major assets. The competent authority shall publish all this, in the case of direct award of public service contracts. [1].

The competent authority which is responsible may require the railway undertaking to comply with certain qualitative and social and emission standards or criteria relating to specific public passenger transport services in rail passenger transport. These standards / criteria must also be published in both the tender documents and the public service contract. [12, 13].

4. Specification of Obligations in the Contract

Each contract must contain a clear definition of the obligations arising therefrom, and which have been established by the competent authority. It must also contain solved geographical area; Parameters for calculating payment for public service performance and possible exclusive rights. Methodology of determining the cost that is associated with the provision of services such performances in public interest (in particular the costs of staff, energy, infrastructure, maintenance and repair of vehicles used in the security of public services, fixed costs and a suitable return on capital) must also be specified in the contract.

Contracts that are directly awarded also contain performance requirements such as punctuality of services, frequency of train movements, quality of rolling stock, transport capacity for passengers. The Provider undertakes in the Contract to provide the competent authority with the information necessary for the award of the Public Service Contract. The Competent Authority is required to make available relevant information that is necessary for the preparation of a tendering procedure for all interested parties to ensure the legitimate protection of confidential business information (for example, information on passenger demand, fare, freight and revenue in public passenger transport covered by Public tender and detailed information on infrastructure specifications). The aim is to enable to the parties that are interested the opportunity to develop good business plans. [3].

Following the adoption of the Amendment to the Regulation, the tender requirements for rolling stock were introduced. The competent authorities shall evaluate the purpose of the tendering procedure as to whether measures are necessary to ensure effective and non-discriminatory access to suitable rail rolling stock. It is necessary to assess whether the relevant market present the companies that leased rolling stock or other market players who provide leasing of rolling stock. Evaluation will be reflected in the evaluation report, which should be made public. [8].

Competent authorities may decide, in accordance with national law and in compliance with State aid rules, to take appropriate measures to ensure effective and non-discriminatory access to suitable rolling stock. Such measures may include:

a) the acquisition by the competent authority of the rolling stock used for the execution of the public service contract with a view to making it available to the selected public service operator at market price or as part of the public service contract;

b) the provision by the competent authority of a guarantee for the financing of the rolling stock used for the execution of the public service contract at market price or as part of the public service contract, including a guarantee covering the residual value risk;

c) a commitment by the competent authority in the public service contract to take over the rolling stock at predefined financial conditions at the end of the contract at market price; or

d) cooperation with other competent authorities in order to create a larger pool of rolling stock.

If the rolling stock is made available to a new public transport operator, the competent authority shall include in the tender documents any available information about the cost of maintenance of the rolling stock and about its physical condition [2, 3].

The comparison of the basic requirements for long-distance rail passenger transport contracts according to the way they are entered is dealt with in Table 1.

Table 1

Comparison of the essential requirements according to their assignment

Requirements		How to enter the contract	
		Direct award	Public tender
Maximum average annual value of performance		to 7.5 mil. €	Not specified
Maximum annual amount of performance		to 500,000 kilometres	Not specified
Maximum time of the contract		10 years	15 years
Opportunity and reason for the extension of the Contract	Depreciation of assets	yes, maximum to 50%	yes, maximum to 50%
	Geographical location	no	yes, maximum to 50%
	Amortization of capital	no	yes, necessary justification
Obligation to publish a pre-announcement in the EU Bulletin for an output range of 50,000 kilometres or more		yes, 1 year before direct awarding	yes, 1 year before starts public tendering

Supporting secondary law of EU that affects the allocation of public service performance, in particular in terms of the level of quality of service provided, are the Technical Standard EN 13816 ‘Transport. Logistics and services. Public passenger transport. Definitions, objectives and measurement of service quality’ as well EN 15140 ‘Public passenger transport. Essential requirements and recommendations for systems to measure service quality’.

By Regulation No. No 1370/2007 EC governs the general conditions applicable to the Public Service Contract - the procurement, content and reimbursement of services provided under the Treaties. The precise and clear public procurement rules for the award of public service contracts are not specified in the Regulation and remain within the competence of the Member States. The obligation to have contracts entered into in accordance with the requirements of the Regulation from December 2023 (postponed by the amendment of the Decree of December 2019) has been introduced. Some Member States currently allocated performance in rail passenger transport by tender for routes long-distance and regional traffic. [4]. Examples of countries conducting tenders for the allocation of performance in rail passenger transport are shown in Table 2. [5, 9, 10].

Table 2

Examples of access to the rail passenger market in some European countries

Country	Public tender	Direct entry	Administrative Monopoly
Belgium		x	
Bulgaria		x	
Czech Republic		x	
Denmark	x	x	
Germany	x	x	
Estonia		x	
Ireland		x	
Greece		x	
Spain		x	x
France		x	x
Italy	x	x	
Latvia		x	
Lithuania		x	
Luxemburg		x	
Hungary		x	
Netherlands	x		x
Austria		x	
Poland	x	x	x
Portugal	x	x	
Romania		x	
Slovenia		x	
Slovakia		x	
Finland		x	x
Sweden	x		
Great Britain	x		

Source: [5]

5. Conclusion

Outsourcers tenders in the Member States may be at varying levels of state administration as well as can vary the conditions of operation of public tenders (due to the various networks of railways, e.g.) Different traction power supply system used on railway lines, various signalling systems etc.). Requirements for safety and interoperability must be common to all Member States with regard to the common EU legislation and technical specifications for interoperability (TSI).

One of the barriers to such public tenders is the absence of a single legislative basis for the conduct and operation of public passenger transport competition. Also, there is currently no uniform methodology for allocating performance in rail passenger transport on the basis of a public tender.

Under the terms of the conditions for the award of public-service performances in long-distance rail passenger transport, it is possible to determine the conditions for the execution of public tenders for the award of long-distance rail transport services. Within the limits imposed, it is necessary to adopt a methodology for the functioning of public tenders and its specific application in individual national railway markets. It is important to define gradual steps leading to the conclusion of public service contracts for individual long distance lines, the identification of responsible operators and their activities, the way in which the requirements and conditions of tenders are determined and the course of the tender itself. The aim is to provide quality services in public transport at a reasonable price.

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Decision Making Scenarios in Military Transport Processes in Refers to Military Security. Part 1 - Approach to Logistics and Transport Costs

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Abstract

This 1. part of the article is an attempt at evaluating decision scenarios in transport processes, determined by the cost criterion. The whole of the considerations relates to the security of transports carried out for the purpose of military operations, that is to say, military security, understood as a safe and reliable implementation of a military operation, which must be preceded by the movement of troops into theater operations. In that part of the article there were considered such issue as identification and optimization of logistics cost; decision making process and systematic approach to logistics and transportation costs. In the subsequent step (provided in the next second part of the article) there will be described approach to decision making in military transport.
KEY WORDS: *transport system, logistics cost, decision making process*

1. Introduction

The dynamics of change in the contemporary world affect all areas of life. These changes are occurring in many areas directly or indirectly related to cross-border material flows and, on the other hand, has imposed and forced the need for continuous changes in the optimization of decision-making processes that are adequate to increasingly complex challenges.

Decision making process, decision-making games or game theory, all contains in theory and practice of decision situations as a specific arrangement of tools (guidelines) for rationalizing and optimizing the expected effect. In many cases (crisis operations, military operations, training, educational etc.) the decision-making games are being used in order to focus on assist decision-making process at each stage of a prepared decision [12]. The instrument to do so might be, among others, computer simulation systems, which are effective tools designed to support the decision in modern training centers, military command and staff, public administration as well as many other [11]. Properly constructed, programmed and correctly used decision models are an expression of intellectual dominance over a potential opponent.

The main purpose of this article is to introduce a reader to decision making scenarios taken in military transport processes with particular emphasis to logistics and transport costs.

2. Identification and Optimization of Logistics Costs

Logistics, as core function of an organization is tasked to optimize the system of goods and information flow not only within the subject but also throughout the supply chain (in macro terms also in networks). All processes connected with goods-information flows, which are: planning, implementation and monitoring, are in interest of logistics. Any tasks accomplished within whole logistics system as well as each of its subsystems generate costs, which are called logistic costs.

Including the cost of operation of logistics system allows to view the complexity of its forming in the whole chain of delivery as well as in single link of the delivery chain. Costs of logistics in an enterprise indirectly contribute to the assessment of the effectiveness of modern logistics management methods, understood as the management of all related activities of the flow of materials, goods and services from the source of supply to the user (consumer) to improve the operation of the system as a whole. In other words, the idea of logistics management is planning, integrating, coordinating and control in the logistics field so that the recipient would be supplied in an optimal, cost effective way. Often, however, the separation of logistics costs from other costs is extremely difficult due to the excessive level of coherence of processes that are "entangled" in the administrative and organizational procedures (this hinders the clarity of the logistics costs of the organization). The reason can also be too complex structure of logistics costs.

The Accounting Bill defines cost as probable reduce economic benefits of reliably defined value during the reporting period. In the form of a decrease in the value of assets or an increase in the value of liabilities and provisions that will lead to a decrease in equity or an increase in its deficit other than the withdrawal of funds by shareholders or owners. Many authors point to different sources and types of costs, which are manifested mainly in defining concepts, interpreting the essence, scope, structure, and valuing of particular elements of logistics costs.

Lack of full agreement in defining the essence and scope relates especially to costs of logistics, logistics management, logistics, logistics transformation, flows and costs of goods and information circulation, freight flows, supply chain. This is primarily due to omitting the differences between the two. The cost is also called the value-added consumption of the company's asset resources borne to achieve a particular effect (product, service, etc.). The concept of costs can be extended to the so-called costs of lost profits, which represent a hypothetical amount of alternative opportunities for action to be taken into account in the assessment and the choice of action. They may be: lost (unrealized revenue), unrealized (possible) result (profit) as well as cost difference.

Optimization is one of the activities of system analysis directed at the arrangement of variables (analysis area), whose task is to obtain the most advantageous results under certain (fixed) structure and parameters of the system under consideration. There are many classifications of analyzes, for example due to the number of variables and parameters (optimization range) can be distinguished: one-dimensional analysis (one-parameter analysis) and multifaceted analysis (taking into account several process parameters). In addition, a multi-faceted analysis is distinguished (With a large number of variables) and multivariate analysis (with the so-called conflict aspect) [10].

The systematic approach and recognition of logistics cost structure is critical for decision-making across the logistics system. The detailed definition of the level and structure of costs and expenditures on the implementation of logistic functions and processes leads to a correct logistical efficiency calculation and the methods of its improvement. Systemic analysis of inputs and costs for carrying out a number of logistic tasks (functions) provides the opportunity to achieve not only higher profits but also the so-called synergistic effects or conjugated effects as a result of the interaction of individual companies, phases of activities and processes in the sphere of logistics.

3. System Analysis in Decision Making Process

The issue of decision-making lies in the broader context of the systemic analysis, which are methods and methods of description and analysis and synthesis of systems with high saturation variables. The system term itself, though directly linked to the general theory of systems, has not always been clearly distinguished[1]. Nicholas of Kuza introduced the concept of "coincidentia oppositorum", which deals with the opposite between the parts of the whole that form a higher order unity [8].

According to the view that the system is a generic model, it can be stated that the use of analog models or structures is a method commonly used in science, also in cognitive processes [1]. In Mesarovič's approach, based on axioms[2], general systems are treated and understood as any relation on a group of abstract sets having input and output parameters [9]. The system can be determined as internally coordinated (due to a specific function and showing a specific structure) collection of elements.

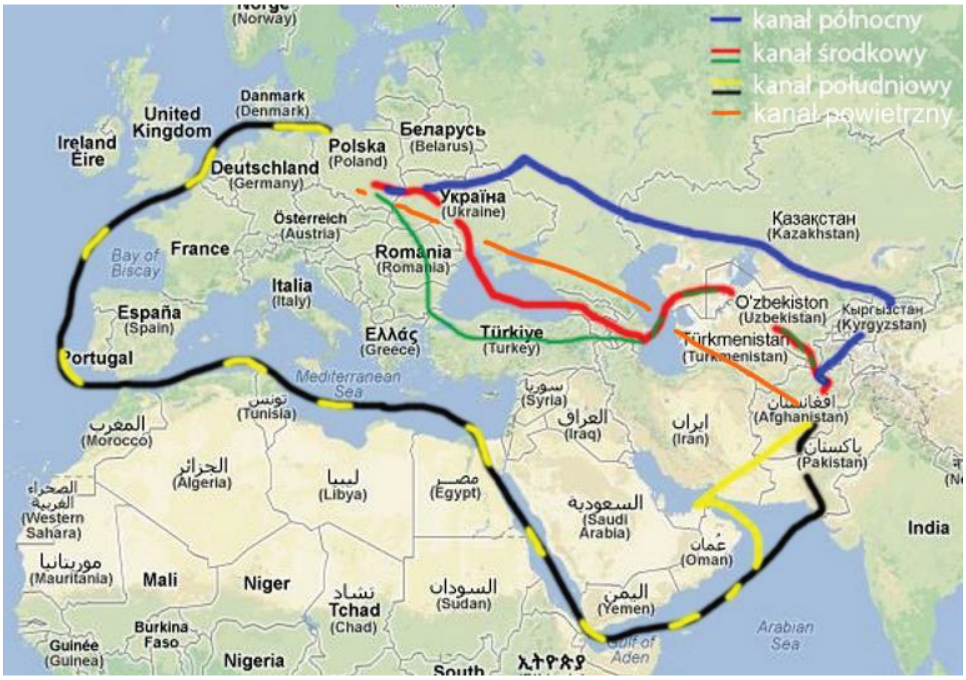

Fig. 1 The considered possible corridors of ISAF redeployment for Polish Army [4]

[1] Initially subordinated to the hierarchical order introduced by the Christian mystic Dionysius Aeropagit.

[2] In logic, the assumption that is accepted without proof in the deductive system and which serves to prove other theorems of that system, the dogma, belief; Source: *Wielki Słownik Wyrazów Obcych PWN*, Warszawa 2005, p. 31 (In Polish).

When approaching the problem of functioning of a particular logistic system, it should be stated that an approach will be characterized by an analytic-synthetic dichotomy, where the analysis will be closer to the process taking place within the system, and the holistic synthesis of the whole problem and macroscopic connections (both upper- and super-systemic). Analyzed and researched subsystem will not only characterize existing real objects but logical relationships and associations. In the definition of the system it is very important to give its function, because the set of elements itself is not yet a system, but an intra-system link already does. System elements are interrelated, their relationships and functions are precisely defined.

In the present context, the directive (deductive) statement states that multi-faceted turbulence contributes to increased decision uncertainty, while at the same time necessitating the optimization of decision-making processes in the area of effectiveness based on the probability within theory of games. More details on the base of case study were described in the article [6] (Fig. 1).

4. Systematic Approach to Logistics and Transport Costs

The key importance for decision processes across the logistics system has the systematic approach and recognition of the cost structure. Searching for and analyzing corporate logistics costs is a consequence of an analysis of the overall functioning of an organization. The scale of the problem is illustrated in the Fig. 2, which shows the costs and transportation time of a 20 Foot container from Mombasa to Nairobi (Kenya).

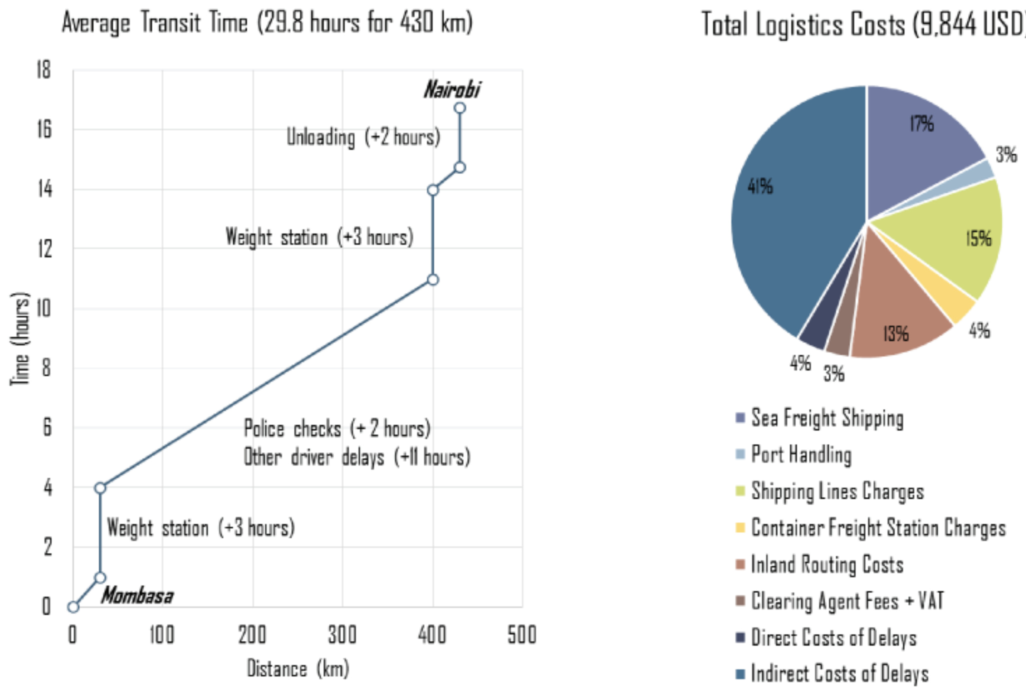

Fig. 2 Logistics Costs and Average Transit Time of a 20 Foot Container, Mombasa - Nairobi (Kenya) [3]

In the systemic current, in line with Bertalanffy's or Klira's concept, systemic analysis distinguishes such stages as: identification, shaping the system and probable implementation of changes (modifications). One of the identification phases is the classification of subsystems and their processes and the hierarchical structuring together with the separation of components and system interactions (correlation).

Systemic approach to organization determines the systemic recognition of costs occurring in individual subsystems. After identifying (naming) subsystems it is possible to analyze the physical consumption of their components and the monetary expression of expenditures on their functioning, which is extremely important from the point of view of business activity and the possibility of making accounting entries, records or statistical presentations. The detailed definition of the level and structure of costs and expenditures on the implementation of logistic functions and processes leads to a proper assessment of the effectiveness of logistics and the ways in which it might be improved.

The systemic analysis of the inputs and costs incurred for carrying out a number of logistic tasks (functions) makes it possible to achieve not only economic benefits, but also the so-called synergistic effects or conjugated effects as a result of the interaction of individual entities, phases of activities and processes in the sphere of logistics. From a systemic point of view, it is important to optimize the organization's activities. One can therefore try to measure system efficiency with cost. Additionally, attempts to optimize business activities by reducing costs in individual functional divisions often end up with a different result from the intended one. Each of the logistics cost components presented is similarly sensitive to changes in other components. Cost reduction in one logistic subsystem can cause cost increases in another logistics subsystem. Finding the lowest cost carrier often leads to an increase in storage costs, which can result in an increase in total (global) cost. There is a conflict of cost objectives (cost dichotomy problem). Therefore, while optimizing the logistics system of the organization, the attention should be also paid to logistics costs by looking at it through the prism of the system and general costs.

Logistics costs are systemic costs, resulting from functional logistic subsystems. Logistics costs include also costs direct related with system costs. These are service level costs (e.g. costs of lost orders, costs of complaints) and costs of batches of goods (e.g. parts of costs of procurement, costs of change). According to Blaik, the cost of logistics in an enterprise is the sum of the costs associated with the individual logistical functions performed. This represents the Blaik's mathematical formula:

$$LC = FMC + PSC + SC + TC + SFC + PPC + IFC + SC + IC, \quad (1)$$

where LC – logistic costs; FMC – flow management cost; PSC – logistics planning and directing the program and production structure cost; SC – storage cost; TC – transport costs; SFC – supply forming cost; PPC – product preparation cost; IFC – information flow cost; PPC – product preparation cost; SC – service cost; IC – incapacity cost.

Duck, Krause and Schulte make a simplified cost breakdown in logistics by distinguishing three types of logistics costs [4]: material costs - supplies, material costs, and costs of all departments within the material management.

From the point of view of this basic analysis (proposed by the authors) the division is: the costs of the type resulting from the transport function, the costs of auxiliary processes and the cost of losses (vis maior).

The largest share of the logistics cost structure (especially in the analyzed case) is the generally recognized transport costs. There are many transport cost divisions, and the most popular is the Twarog split: global transport costs (GTC), internal transport costs (ITC), external transport costs (EXT) and transport handling costs (THC).

The main factors that have a significant impact on the transport costs can be the transport sector, the mode of transport, the quality of the road, the distance to be traveled, the type of cargo, the size of the lot. Transportation costs include the involvement of all resources necessary to carry out transport tasks within and outside the enterprise. This involves engaging in the preparation and readiness to carry out transport tasks, i.e. investments in infrastructure and support systems for transport, transport planning and execution, use of external transport and auxiliary services.

The specific categories of transport costs result from the need to include:

- Preparation of means of transport and readiness for transport, (hanged contracts, costs of preparedness);
- Check of vehicle performance, installation of specialized equipment (maintenance costs in maintaining ready to use state), etc.;
- Feeder costs (cost of drive to lading destination);
- Stopovers - waiting for loading or unloading (waiting costs);
- Loading and unloading operations (transport costs of auxiliary processes);
- Empty return to the starting point of the route (the cost of the empty semi-pendulum);
- Enforced stoppages resulting from transport regulations (extraordinary costs and costs arising from vis maior).

In practice, the actual impact is: the number of orders (needs of customers in the cargo *pull* system), the number of deliveries (in logistic NATO networks it is a multiplication of charters) or the number of admissions (handling costs).

Transport costs can be expressed as follows:

$$TC = DVC + DWC + MFEC + OC + IC + RMC + LC + OTBC + OTC, \quad (2)$$

where TC – transport cost; DVC – depreciation of vehicles and building of vehicle bay cost; DWC – work of drivers (pilots) and transport service with overheads cost; $MFEC$ – materials, fuels and energy consumption associated with the use of cars cost; OC – office cost; IC – insurance cost; RMC – repairs and maintenance of means of transport cost; LC – lease cost; $OTBC$ – other omitted costs of so called transport base; OTC – outsourced transport costs.

Transportation costs do not consist solely of fuel costs, driver's compensation (pilots, service) and depreciation of transport. These also include:

- The cost of adapting the means of transport for the carriage of cargo with special transport requirements, e.g. the installation of refrigerators on vehicles, the cost of renting / buying a trailer for transporting propellants, adapting the encapsulated space;
- Repair costs of means of transport;
- Costs of periodic reviews;
- Costs related to tolls for motorways, bridges, tunnels, airport charges, diplomatic consents, administrative fees;
- Costs of natural defects in loads that may result from long routes or during accidents or road accidents;
- The costs of unplanned stops due to random events (forced landing), difficult or even impossible to predict;

In addition, the record of internal and external cost must be kept. The unit of calculation can be a kilometer, a vehicle kilometers traveled or an hour.

5. Problem Situation and Decision Problem

The decision-making situation (problem situation) is the starting point for the decision. Thus, the source of the decision-making process is the perceived decision-making situation and the decision-making background that has arisen on it. The decision situation refers to the functioning of an organization or any part thereof at a given moment or time [5].

The problematic situation (decision situation) is a situation that includes the elements of difficulty, uncertainty, ambiguity, insufficiency of information, conflict, needs and aspirations, necessity of selection etc. [2]. The emergence of a problematic situation that prompts to do something about it is reflected in the formulation of the problem to be solved [13]. Decision-making situation is a conscious lack of knowledge, which can be expressed in the form of a question or set of questions for which answers are sought, because it is unknown and one wants to know what one wants or need, whether for purely cognitive or practical reasons. Where a difficulty or barrier is encountered, if the way of overcoming it is known to us, there is no problem [2].

The emergence of a problem situation raises the need to formulate question / questions about the reasons for its occurrence and the possibility of overcoming it. A problematic (decision-making) situation transformed into a question or a set of questions becomes a problem, the solution of which is to find the right answer and take actions aimed at overcoming the difficulties [2].

The decision problem can be defined as the deviation between the desired state (what should be) and the actual state (what is in reality). This deviation should be related to two cases: the deviation that actually occurred (exists), and the deviation that is expected to occur (in the future). In the first case, when the deviation is judged to be favorable, it should be maintained or sought to be simulated, but when it is judged to be unfavorable, it should be eliminated or at least minimized. In the second case where a positive deviation is expected, it is desirable to create conditions conducive to its production, and when a negative deviation is expected, try to prevent (block) its occurrence [5].

Making a decision means settling a decision-making problem. The basis for the decision is a collection of information characterizing the decision problem. Therefore, in order to solve the problem, it is necessary to recognize and evaluate the decision problem. In order to properly formulate a decision problem, it is necessary to consider it from different angles. The factors that make it possible to characterize the problem include, among others [5]: object, degree of structuration, extent, degree of complexity, place of occurrence, frequency of occurrence, and importance to the efficiency of a given system.

The manager (executive, leader) who chooses the solution is called the decision maker, and the decision maker is the entity that chooses the alternative (a solution to a specific problem) and assumes responsibility for the choice. If we assume that the decision maker bears the consequences of his choices, there are "material and moral incentives" that cause him to become interested in accepting that alternative that is consistent with his goals. Otherwise, this decision could be accidental [7].

6. Conclusions

Studies and analyzes show that it is possible to model transport taking into consideration the cost of specific cargo mass to areas of peacekeeping operations (UN mission, NATO, EU) using services provided by carriers operating on the transport market.

Key role in decision processes, with many multicriterial variables (e.g., technical and economic group) are Decision Support Systems, a derivative of advanced logistics and transport information systems.

In addition, any action in international arrangements requiring a high level of cooperation and coordination necessitates the application of advanced storyboarding, or scenarios based on different variants, depending on the influence of turbulent factors on compact systems.

With the simultaneous support of such activities, there is a likelihood that the "good practices" of international co-operation are likely to be maintained, and consequently, the reduction of military spending and the reduction of the costs of peacekeeping operations outside the European continent, where the main driver of the cost of operation is strategic transport.

Prior to taking decision all key information must be collected which describe the decision problem. The decision problem has to be recognize and evaluate as well as consider from different angles. As it was mentioned before, the factors that make it possible to characterize the problem include, among others: object, degree of structuration, extent, degree of complexity, place of occurrence, frequency of occurrence, and importance to the efficiency of a given system. One of a method that can be used to take decision is multicriterial analysis which can be algorithm and transform into Decision Making System understood as IT tool supporting decision maker.

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Decision Making Scenarios in Military Transport Processes in Refers to Military Security. Part 2 – Approach to Decision Making in Military Transport

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Abstract

This 2. part of the article is the next approach to decision making in military transport after the 1. part entitled: - approach to logistics and transport costs. In this part factors in a decision making process were considered and simplified algorithm of decision making was developed. Then, the scenarios matrix were proposed according to Wald and Hurwicz criterion as well as calculation of expected benefits were developed. In the subsequent steps (provided in the next papers) there will be described decision making process determined by the cost criterion on the example of military transports.
KEY WORDS: *transport system, logistics cost, decision making process*

1. Introduction

The dynamics of change in the contemporary world affect all areas of life. These changes are occurring, on the one hand, in many areas directly or indirectly related to cross-border material flows and, on the other hand, has imposed and forced the need for continuous changes in the optimization of decision-making processes that are adequate to increasingly complex challenges.

To make the right decision the knowledge of all facts is not necessary, but one needs to know what information are missing to evaluate the risk of selected decision and acceptable degree of precision of the proposed course of action. The excellence and accuracy of decision is defined by quality and range of information used to prepare it. It is emphasized by perception of decision, according to which the information used in decision-making process should be relevant to the problem, true, not accidental and verifiable. In conditions of rising dynamics and changing environment, the ability to make a decision fast, as well as time of data collection is gaining more and more importance. It is vital in situations, where quick reaction is necessary and the problem involves the displacement of large amounts of matter over long distances, while maintaining the economic efficiency [6].

The main goal of this article is to continue research on decision making scenarios taken in military transport processes, which has begun in the 1. Part of the article, with particular emphasis to decision making in military transport.

2. Turbulent Factors in a Decision-Making Process

The method of rolling horizon planning is one way of coping with uncertainty in decision-making processes. The essence is based on periodic planning in the planning horizon, assuming that pre-prepared plans can be changed as a result of unexpected changes [4].Turbulent factors include those that affect material flow control in the new economic, political or climate-sensitive areas, as well as the dangers of migration from external and internal armed conflicts. In

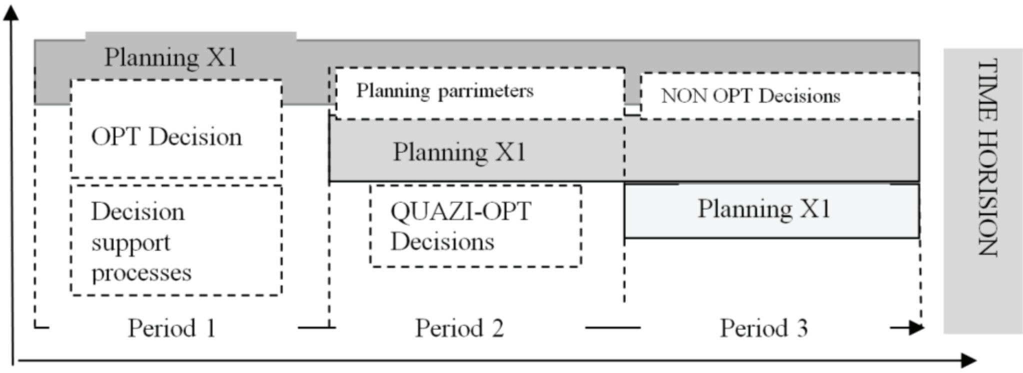

Fig. 1 Decision processes in rolling horizon planning [4]

such a situation, it is assumed that the development of an action plan for several future periods will be backed up by the optimum decision for the closest period, so that even though decisions are taken within the planning horizon, the plan itself is only implemented for the immediate period. In subsequent periods the values of the planning parameters are updated and the plan is re-developed for the entire horizon. It is additionally extended by the parameters determining the permissible values of their changes in the sequentially devised plans (Fig. 1).

The added value of such a solution is to limit the potential for changes in subsequent changes to a suitably balanced resource load, which has one drawback of reducing flexibility. The rolling planning was explicitly formulated by Baker [1] and preceded by observations in the area of production planning in the finite horizon of planning developed by Holt and Modigliani [5]. Use of the above in decision-making processes in the areas of displacement (i.e. mainly transport and material) for military solutions seems reasonable. First, forecasts for the distant future as a rule, they seem to be unreliable and therefore their usefulness is limited. Second, the practical side of the development of supply plans is based on limited information on the future.

To sum up the essence in such activities play all kinds of simulations in efficiency areas, based on the optimization of logistics processes, which is primarily related to the aim of minimizing total costs in the implementation of the goals.

In the decision-making process, there is a problem of rationality (sense) of its taking. It is considered that rationality in the point of view of decision-making is based on the choice of a variant whose implementation leads to the intended goal, and the decision transformed into action is in line with reality and with the laws governing it and the conditions of action (Figure 2). Such a process encounters a number of barriers, including information, resource, personnel, competence, social, organizational, bureaucratic and competitive barriers [11].

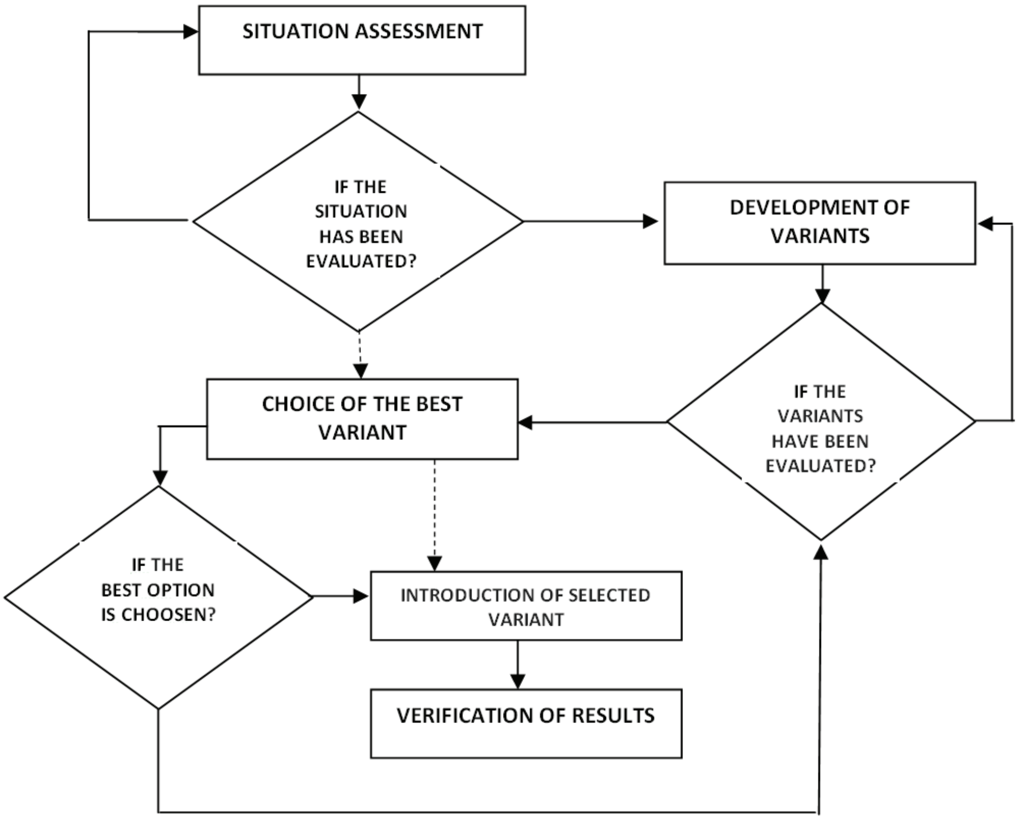

Fig. 2 Simplified algorithm of decision-making

In the decision-making process, there is often a problem of difficulty resulting from exceptional circumstances (new variables - variables). Perhaps the best decision in this situation is to delay the selection (not always possible). There is even a saying in an Anglo-Saxon culture: *take a counsel from your pillow.*

3. Decision in the Process of Military Transport in Uncertain Conditions

Making decisions under uncertainty of some factors is characterized by the fact that actions that one need to be selected from may lead to different (unforeseen) consequences and the decision maker does not know what will happen. Uncertainty is related to the occurrence of so-called states of things (states of nature) that cannot be predicted and which are independent of the decision maker. Weather conditions (temperature, precipitation, natural disasters, etc.), economic changes, technological breakthroughs or new types of fashion can be counted among the things that are unpredictable. A special class of states of nature are the strategies of competition. Taking into account the state of affairs in decision theory, decision making under uncertainty refers to [3]:

- playing with nature;
- play with a competitor (here not analyzed).

The analyzes carried out at the University of Louvain (Fig. 3) show a drastic increase in natural factors, which, as a consequence of these considerations, may mean an increase in the involvement of humanitarian aid providers in disasters. It is advisable to approach this type of research with caution, especially if it covers a period of about a hundred years and it not entirely known how effective measuring tools were then and what criteria defined the concept of natural disaster.

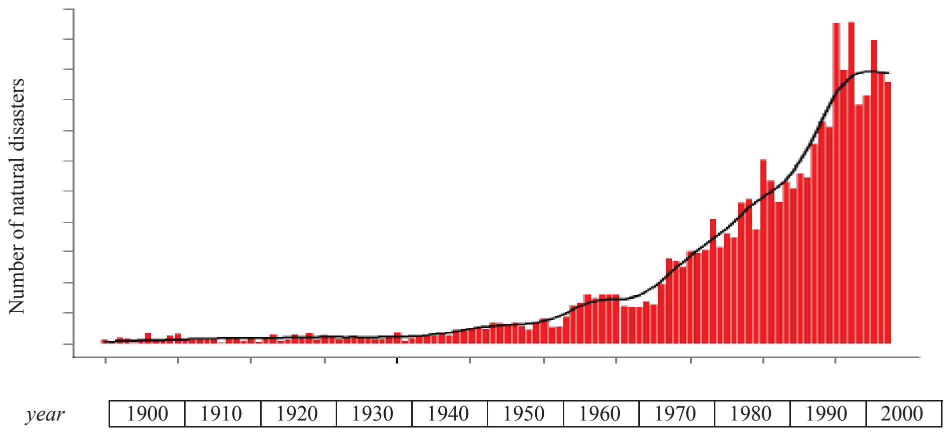

Fig. 3 Number of natural disasters noted in years 1900-2007 [10]

However, this does not change the fact that such "conditions of nature" are in the group of turbulent factors, which are the criteria for decisions. Developed (based on such and other criteria) decisions are preceded by tedious scenario analysis (for specific variants). Also, economic (including cost) factors are part of "decision constraints", and decision-making based on such criteria can be characterized by "playing with nature".

Within the above games, the decision maker chooses between the adopted strategies of action (options). In the case of a decision on nature, the basic premise is that the state of nature that will occur will be independent of the manager's choice of strategy (option). In the case of nature games, the decision maker draws up a matrix for specific "pairs of own strategies" and "states of nature" [2].

To decision-making under uncertainty applies decisive rules based on Wal-pessimism, Hurwicz's optimism, Savage's least proficiency, or the criterion of "lack of sufficient reason" (called Laplace's rule)

According to the Waltz criterion, the decision maker should behave as if nature was always malicious, so the decision maker should be pessimistic. This means that the decision maker should assume that regardless of which strategy he chooses, he will always experience the state that will bring him the worst result. According to this criterion, it is necessary to determine the minimum benefits for each strategy and choose the strategy for which the minimum benefit is greatest. Therefore, the decision maker chooses "the best advantage from the worst ", so either maximizing minimum profits or minimizing maximum costs [9].

According to the Hurwicz criterion, the decision maker behaves like an optimist, meaning he is guided by the belief that no matter which strategy he chooses, he will always show the most favorable condition that will bring him the best possible result. According to this criterion the decision maker should choose the best decision from the best (or maximizing the maximum profit or minimizing the minimum cost). The decision maker does not have to be the extreme optimist, but can determine his or her individual optimism for the situation, and then maximize the weighted sum of the two components: the smallest and greatest utility.

According to the Savage criterion, the decision maker analyzing decision problems is driven not by the category of profit (or loss) but by the "category of grief" (disappointment, dissatisfaction). The decision maker draws attention to how he feels when the decision is made and the result is achieved. To this end, the decision maker determines for each strategy of action and state the possible loss that is the difference between the highest payout obtainable at the state of affairs and the result obtained in that state at the chosen strategy of action. This size is referred to as loss for lost profit. This results in a matrix of lost benefits that Savage proposes to apply the Waltz criterion.

According to the Laplace criterion, based on the principle of insufficient reason, if the decision maker does not know the probability of distribution on a set of states of affairs, he should assume that they are equally probable. This principle is based on the assumption made by Bayes that if we have no reason to believe that there is a difference between the probabilities of different states, then we can assume that each with mutually exclusive states it may occur with the same probability. With this assumption, the criterion of maximizing the expected value or utility can be used as the selection criterion.

Using real historical data, a cost sample can be attempted for specific scenarios. Transport scenarios were considered, grouped according to the category of initiative (two of them are international and one is based on own resources). Based on analysis (according to specific theories) it was stated that using the Pessimism criterion (Wal criterion), we should choose the S3 strategy, setting a low cost (Table 1).

Within existing initiatives. This decision is due to the designation of the worst strategy for each strategy and the choice of the strategy that sets the best of the worst in the discussed example, $ 3.1 million. With historical data however, ex post analyzes show that such a criterion does not take into account the technical characteristics of the goods being transported and therefore does not determine the necessity to adapt the means of transport complying with the cargo hold criteria.

Table 1

Scenario matrix (for the Wal criterion)

Program / initiative	Strategy of action	Cost structure (million USD)		
		Base cost	**Situation improvement**	**Situation deterioration**
S1 SALIS[1]	High cost	7,5	**6,2**	**8,9**
S2 SAC[2]	Medium cost	3,36	**2,1**	**5,5**
S3 Own resources	Low cost	1,08	**0,8**	**3,1**

Source: own elaboration based on data from STiRW - CKRW[3]

Using the criterion of optimism (Hurwicz criterion), assuming total optimism, S_1 strategy should be chosen as a low cost (Table 2) within existing initiatives. This decision is based on the designation of the best strategy for each strategy and the choice of the strategy that determines the best result (decision of extreme optimism), in the example discussed 0.8 million USD.

Table 2

Scenario matrix (for the Hurwicz criterion)

Program / initiative	Strategy of action	Cost structure (million USD)		
		Base cost	**Situation improvement**	**Situation deterioration**
S1 SALIS	High cost	7,5	**6,2**	**8,9**
S2 SAC	Medium cost	3,36	**2,1**	**5,5**
S3 Own resources	Low cost	1,08	**0,8**	**3,1**

Source: own elaboration based on data from STiRW - CKRW

The results of the analyzes indicate that (as in the first case for the Wald's' criterion), the best scenario appears to be the S3 scenario based on the use of own resources. A similar result is obtained assuming that the decision maker is not an extreme optimist, which is preceded by the necessity of determining the optimism factor - **Iopt**[4].

The optimism coefficient is determined by the "lottery" between the highest and the lowest cost. Based on this factor, the probability of the lowest cost is determined, at which the decision-maker is willing to "participate in the lottery". This probability is the coefficient of optimism of the decision maker. In the analyzed example the coefficient of optimism was defined as 0.4. After analysis, choose strategy S3 (Table 3).

Table 3

Calculation of expected benefits

Strategy of action	Expected benefits with optimistic coefficient – **Iopt**
S1	(6,2 × 0,4) + (8,9 × 0,6) = 2,48 = 5,34 = 7,82
S2	(2,1 × 0,4) + (5,5 × 0,6) = 0,84 + 3,3 = 4,14
S3	**(0,8 × 0,4) + (3,1 × 0,6) = 0,32 + 1,86 = 2,18**

Source: own elaboration based on data from STiRW - CKRW

Using the Laplace criterion, the probability (0.33) of the occurrence of the state of nature (cost level) of the analyzed initiatives was the same. Using the assumed probability value, the expected values for the individual strategies were calculated, which is the mathematical calculation of Laplace's matrix:

$$OW(S1) = 7,5 \times 0,33 + 6,2 \times 0,33 + 8,9 \times 0,33 = 7,46$$

[1] SALIS - Strategic Airlift Interim Solution.
[2] SAC - Strategic Air Lift Capability.
[3] STiRW-CKRW – Transportation and Movement Command – Coordination Centre of Movement on the Theatre
[4] Iopt – Coefficient of optimism (symbol given by the author for calculation purposes).

OW (S2) = 3,36 × 0,33 + 2,1 × 0,33 + 5,5 × 0,33 = 3,61

OW (S3) = 1,08 × 033 + 0,8 × 0,33 + 3,1 × 0,33 = **1,64**

According to the principle of maximizing the expected value (here the minimization of costs as a decision optimization), choose strategy S3, which gives the lowest value - the expected value.

It is clear from the analysis above that some of the scientific criteria for profit / loss analysis treat "literally" the cost of making a decision for a particular scenario and do not take into account the other system criteria (technical parameters, availability of resources, other variables generating costs). Decision-making, as the analysis suggests, is a complex process that should take into account all possible (including uncertain) factors. The case study based on the analysis of the case study indicates a completely different choice of scenario variant, taking into account also the external criteria.

This approach in the future will lead to changes in the logistics system without the need to spend a great deal on the purchase or hire of transport resources needed to carry out the transport function at the strategic level. Logistical processes that take place in an international system require interpersonal cooperation and consequently appropriate relations and a high level of coordination (Figure 4), which change should be determined by the extent of responsibility.

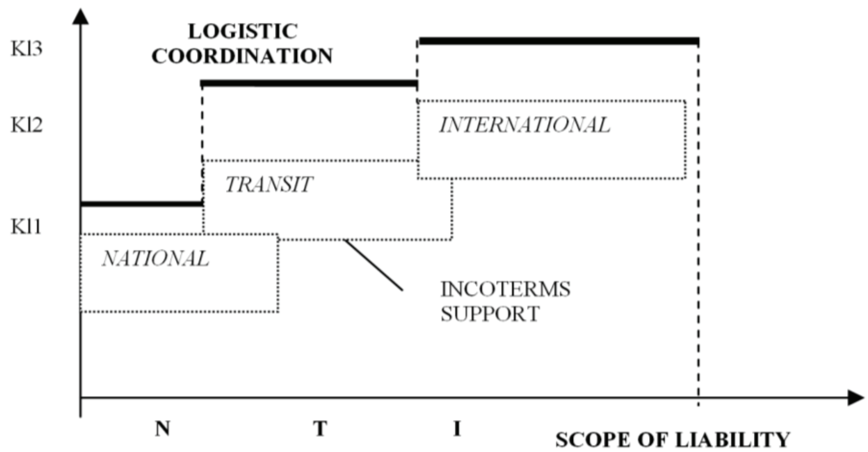

Fig. 4 Change the level of logistics coordination depending on the scope of responsibility

4. Conclusion

Decision making scenarios in military transport processes are conducted should include turbulent factors, for example the method on rolling horizon planning is one way of coping with uncertainty in decision making processes. The essence in such activity play different kinds of simulations in efficiency and security areas, based on processes optimization. The excellent example of such approach based on computer simulation is IT system called ADAMS that is used in NATO armies to plan and organize of military transport processes [8]. Furthermore, more and more proposals are generated in regards to decision-making, including risk analysis [7].

However, making decision under uncertainty conditions, different approaches can be considered. One of the most popular possibility is decisive rules based on Wal's pessimism and Hurwicz's optimism as well as Savage's least proficiency, or criterion of "lack of sufficient reason" (called Laplace's rule).

The described approaches, in the 1. And 2. parts of the article entitled "Decision making scenarios in military transport processes in refers to military security", focused on taking into consideration logistics and transport costs as well as decision making. In the subsequent steps (provided in the next papers) there will be described simulations of decision making process which are determined by the cost criterion and security conditions. The decision making scenario will be provided on the example of military transports executed for the purpose of any military operations.

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Protection of Critical Infrastructure Component Against a Vehicle Attack

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Abstract

Attack of the object with a vehicle is one of the possible manner how to cause a damage or endanger people. Utilization of this type of attack is typical for organised crime or terrorist activities. Unfortunately, protection against terrorist activities and attacks is essential capability in present time. The analysis of manners which can protect people is important from this point of view, too. This paper is focused on analysis and utilization of stationary or mobile components and equipment against vehicle attacks.
KEY WORDS: *barriers, obstacles, vehicle, protection*

1. Introduction

Protection of important objects or open space areas with high concentration of persons against an attack is currently serious nowadays problem. Protection of important objects or open space areas with high concentration of persons against an attack is currently serious problem [1].

Utilization of a vehicle like a weapon is one of the possible manner. From this point of view, the protection has to sufficiently secure these important objects or open space areas with high concentration of persons. Utilization of vehicle like a weapon is probably one of the most extensive terrorism way how to endanger people without utilization of a weapon. Transport means are during these terrorist activities used very differently from the original purpose of these vehicles. Mostly is this “weapon” used in combination with a lethal weapon – like guns, explosives etc. Automobiles are very often use in these attacks, because they are easily accessible.

Unfortunately, global worse security situation of the world and especially Europe leads and increase a numbers of terrorist activities. Resent attacks in Europe show the importance of internal security of each country and city.

2. Vehicle Aggression

A vehicle “aggression” becomes evident during a vehicle approaching to a protected object and mainly to an open space area with high person concentration (squares, parades, sport competitions, celebrations etc.). This “aggression” is given by kinetics energy of the vehicle mass moving by significant speed. We can expect that during terrorist attacks are manly used vehicles with maximal weight moving as fast as it is possible, yet light or small vehicles or vehicles moving by lower speed are for unprotected peoples very dangerous, too [2].

During resent terrorist attacks were utilized different vehicles – from the passenger SUVs (Sport Utility Vehicle) to heavy trailer trucks. Usual extend of weight and maximal speed of selected vehicle categories are presented in the Table 1. Stated vehicle categories have a high probability of their misuse – instead of weapon. Presented magnitudes of the kinetics energy were computed for boundary minimal and maximal values.

Table 1

Weight and speed of selected vehicle categories [3]

Vehicle type	Weight, t	Max. speed, $km \cdot h^{-1}$	Kinetics energy, MJ
Passenger cars (SUV, OFF-ROAD)	2,0 – 3,5	120 – 130	1,1 – 2,3
Trucks	12,0 – 20,0	80 – 120	2,9 – 11,1
Semitrailer´s sets	20,0 – 40,0	80 – 100	4,9 – 15,4

Maximal speed achieving during the approaching is usually very difficult, especially in urban areas. A dependence of the kinetics energy of selected vehicles on the vehicle speed is beneficial and is presented in the Fig. 1. The graph represents vehicles with the maximal magnitudes of the weight.

From Table 1 and Fig. 1, it is clear that the kinetic energy values for each vehicle category may range in the MJ. Further, Fig. 1 shows that the decisive factor is speed.

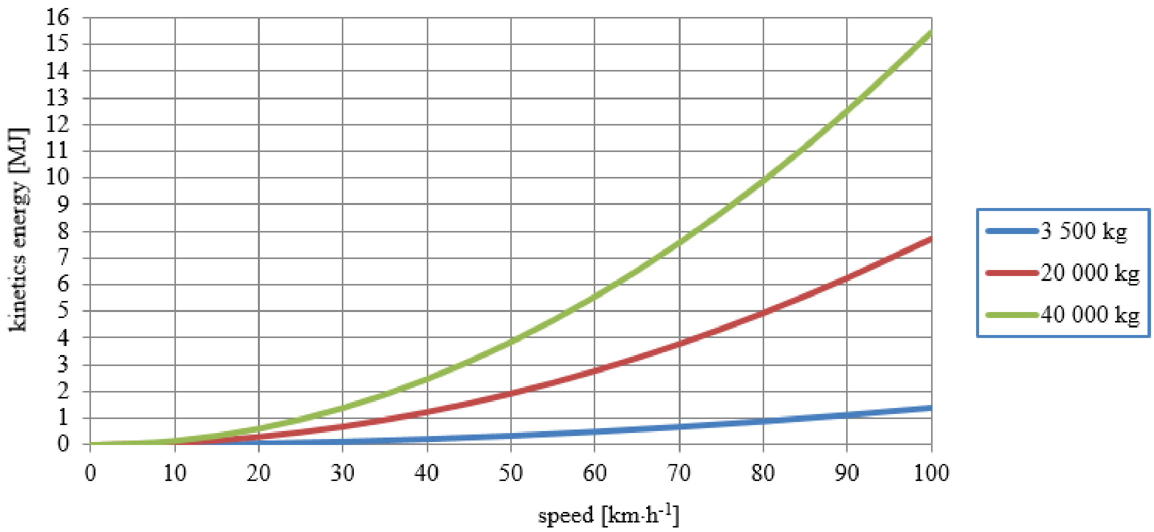

Fig. 1 The dependence of the kinetics energy on the vehicle speed

3. Equipment for Vehicle Stopping

The following means may be used to prevent or at least decelerate the movement of the vehicle:

1. **Creating of an insurmountable obstacle** - these are artificially created obstacles by means of fieldwork (ditches, embankments, perpendicular steps, or ditches). However, these obstacles can´t be created by chance. Their parameters must be chosen on the basis of vehicle parameter analysis. Developed obstacles must be insurmountable for the category of vehicles that could be used for the attack. In order to prevent the obstacle from overcoming the vehicle, this analysis must be carried out fundamentally in order to capture a part of the vehicle with the obstacle surface and a vehicle getting stuck. This means is very effective but very costly to build. Its further disadvantage is the large dimensions and the fact that its utilization is possible only outside the built-up and populated area for critical infrastructure objects [4].

2. **Utilization of a stable barrier** - again, these are very effective elements (concrete pyramids, barrier barriers, etc.). As a permanently installed artificial barrier in the urban area, it is possible to use various reinforced, commonly used elements. For example, concrete benches, prepared flower pots, reinforced waste bins, decorative pylons, etc. Their disadvantage is considerable cost and larger dimensions. In urban areas they can´t be installed in all the necessary places without interfering or creating an undesirable impression of the "fortified city" and creating an atmosphere of fear [6].

3. **Utilization of mobile barrier** - Under this term is meant a wide range of existing means from permanently installed removable barriers which are activated as necessary to portable fence barriers and nail stop belts used mainly by the police. Their effect may be different. From high, heavy to removable barriers, to small (for example at fence barriers). The common disadvantage of utilization of these means is that the risk of attack must be known in advance so that these resources can be activated.

4. Possible Solution of the Barrier

A possible solution is a barrier that is permanently installed, the appearance of the obstacle is adapted to the environment and its effect will not have an effect until the moment of impact. It is a combination of a stable and mobile barrier.

Barrier function

The barrier forms a weldment made of steel profiles. Its scheme is illustrated in Fig. 2. The base (1) of the barrier is anchored just below the ground level so it is hidden beneath the surface. Above the road surface only protrudes the "initiating" strut (2) attached to the base [5].

When the vehicle is struck on the strut (2), the barrier is pulled out of the road and the whole structure is rotated by the angle α. The rear part of the barrier (3) with the toothed rack engages the vehicle chassis and pushes the plate (4) with the toothing into the ground of the road. In this position (marked dashed), the whole structure is maintained by a strut (2) which also wedge into the chassis or the front of the vehicle. Thus, the braking effect is greatly increased by the resistance of the road material, which is squeezed by the plate (4) similar to the blade.

In order to achieve this effect, some conditions have to be met. First of all, it is a choice of suitable dimensions for individual barrier elements. The base length a must be greater than the clearance height f. The length of the strut b must be greater than the height of the bumper. The width of the rear e must allow the bottom of the vehicle to be locked. The dimensions of the slide plate c, d buried in the roadway shall be sufficient to produce the necessary resistance of the road material against sliding.

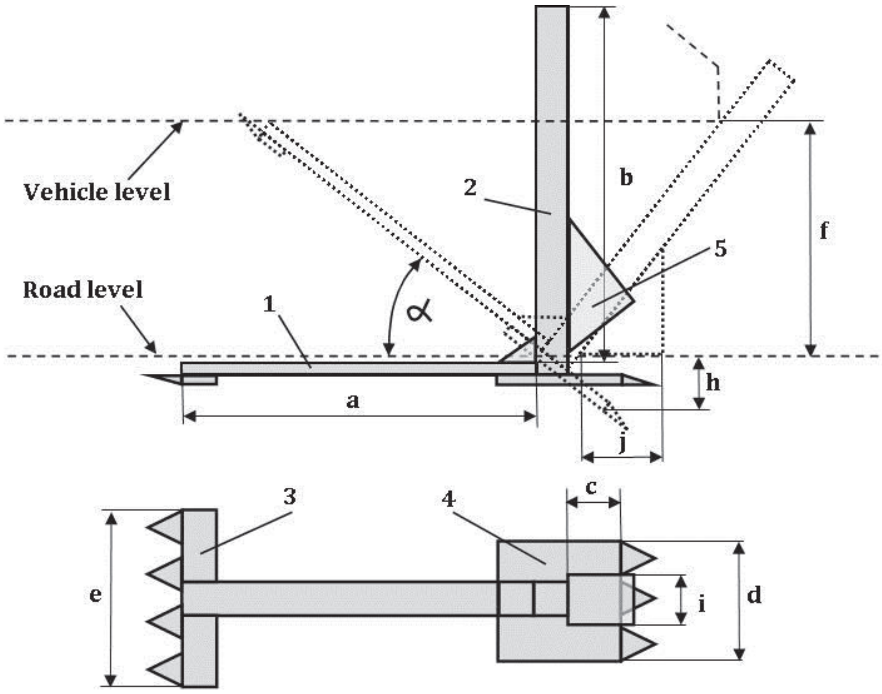

Fig. 2 The barrier schema

No less important condition is to ensure sufficient stiffness of the whole structure. The above mentioned facts must be verified by simulation calculations and then by practical tests.

Barrier efficiency

The barrier should be so effective as to stop the vehicle on the shortest possible path. During calculating individual values, the following assumptions can be made:

- For each vehicle category we consider the maximum weight according to Table 1.
- Approach speed for urban development can be considered 70 km·h^{-1}, for the following reasons:
  - o The maximum permitted speed in the city is 50 km·h^{-1};
  - o If the driver does not want early warning, he should keep it;
  - o It can only accelerate in the last moment of the raid;
  - o This is an estimate of probability because exact determination is impossible.
- When impacting a barrier, it is highly probable that the driver will try to break it and the vehicle will be constantly driven, with the drive force on the wheels reaching the adhesion limit.
- When the barrier under the vehicle is wedged, the front part of the vehicle is slightly raised and relieved. It is very likely that half the weight of the vehicle will affect the barrier and half the drive wheels. But it depends on which wheels are driving, and at which point the chassis will collide with the barrier.

In case (assuming the mentioned assumptions) that the vehicle is only the wedged into the barrier yet the barrier is not sink into the road, the following formula can be used to calculate the path needed to stop the vehicle [3]:

$$S = \frac{E}{F_B} = \frac{E}{F_{fr} - F_{ad}} = \frac{E}{\frac{m \cdot g}{2} \cdot (f_1 - \varphi_2)}, \tag{1}$$

where S - the path needed to stop; E - kinetic energy of the vehicle at the moment of impact; F_B - braking force; F_{fr} - the friction force of the barrier on the road; F_{ad} - adhesion force of driving wheels; m - vehicle weight; g - gravitational acceleration, f_1 - friction coefficient steel-asphalt contact; φ_2 - adhesion coefficient of tire-asphalt contact.

For the usual state $f_1 < \varphi_2$, there is a situation where the vehicle is slowed down after the impact, but the barrier is not able to stop it. Roadblocking is therefore absolutely necessary because the braking force applied to the vehicle consists of the friction of the road barrier and also of the shear strength of the road material in the slipped area. In this case, the equation 1 passes into the next form:

$$S = \frac{E}{F_B} = \frac{E}{F_{sl} + F_{fr} - F_{ad}} = \frac{E}{\tau \cdot D \cdot S + \frac{m \cdot g}{2} \cdot (f_1 - \varphi_2)}, \tag{2}$$

where F_{sl} - the road resistance force; D - the length of the cut surface of the soil in the transverse direction; τ - shear strength of the cut material.

This equation can be used to calculate the required S path to stop the vehicle. The product $\tau \cdot D$, which is given in equation 2, depends on the substrate on which the barrier is installed. For its calculation can be used schema in the Fig. 3, where a cut-out surface h is marked.

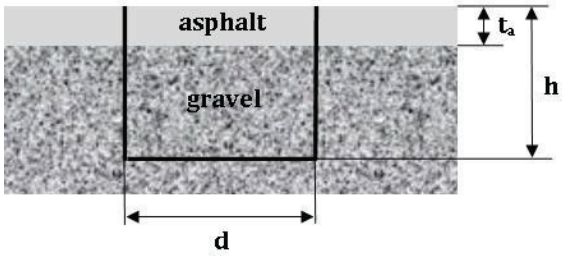

Fig. 3 The barrier substructure schema

If the subsoil is not loaded with normal force, it means in the sliding support (5) is not installed on the "initiating" strut (Fig. 2), the product $\tau \cdot D$ can be expressed by next formula:

$$\tau \cdot D = c_a \cdot 2 \cdot t_a + c_g \left[2 \cdot \left(\frac{c \cdot f}{a} - t_a \right) + d \right], \tag{3}$$

where c_a - asphalt layer cohesion; t_a - the thickness of the asphalt layer; c_g - cohesion of the gravel layer; f - vehicle clearance; *a, c, d,* - the barrier dimensions in the Fig. 2.

When using the sliding support (5) Fig. 2, the horizontal part of the squeezed subsoil is subjected to normal force. Assuming that half of the vehicle's weight is applied to the barrier, the product $\tau \cdot D$ can be expressed by:

$$\tau \cdot D = c_a \cdot 2 \cdot t_a + c_g \left[2 \cdot \left(\frac{c \cdot f}{a} - t_a \right) + d \right] + d \left(\frac{m \cdot g}{2 \cdot j \cdot i} \cdot \tan \delta_g \right), \tag{4}$$

where δ_g - angle of internal friction of the gravel; j, i - the barrier dimensions in the Fig. 2.

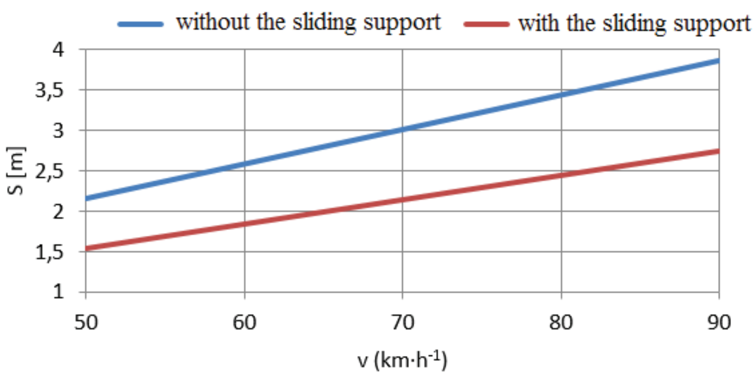

Fig. 4 The stop line $S = f(v)$

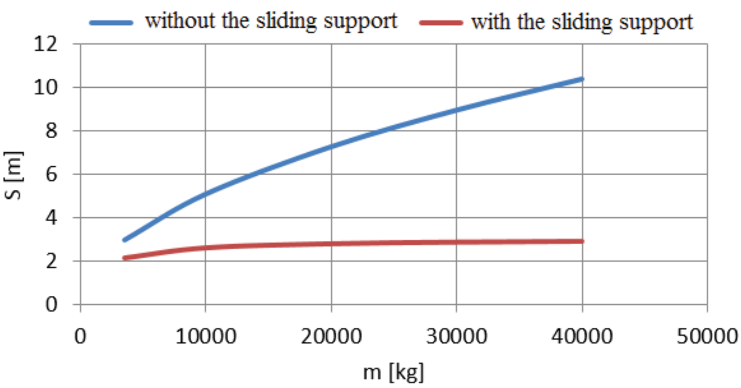

Fig. 5 The stop line $S = f(m)$

Fig. 4 shows the results of the path calculation required for stopping for a 3.5 t vehicle depending on the impact velocity. The thickness of the asphalt layer is 0.05 m; slipping board width 0.2 m, drop depth 0.15 m.

Fig. 5 shows the results of the path calculation required to stop for a vehicle at an impact speed of 70 $km \cdot h^{-1}$ depending on the weight. The other conditions are the same as in the previous case.

The results of the calculation in Fig. 4 and Fig. 5 show that the vehicle can be stopped on a relatively short track. More accurate results can be obtained by simulation.

5. Conclusion

From this paper it is obvious that the barrier can´t be developed like universal obstacle yet has to be develop for specific conditions. This means what vehicles are considered dangerous and can approach the barrier successfully. Its availability can be limited by the width of the road, the radius of curves, etc. The dimensions of the basic part of the barrier and strut are determined from the main parameters of the road.

Shear strength is another factor of road material and subsoil at the site of the barrier installation. This determines the dimensions of the slipping plate.

However, it is not appropriate for the shear strength of the subsoil to be too high. For example, when installing the barrier in the concrete, it is very probable that destruction of the "initiation" strut and overcoming the barrier will occur.

It is also necessary to consider the fact that barriers can´t be installed everywhere. Advantageously, they can be used especially for the permanent protection of pedestrian zones, where they will not interfere with the appropriate external design.

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Utilization of Six Sigma Methodology in Terms of Reducing Train Delays

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Abstract

The Six Sigma is an improvement methodology for achieving productivity and profitability as well as increasing the customer satisfaction rates. A worldwide success of this methodology is based on minimizing of waste and maximizing the value for customers. Many enterprises consistently focus their effort on providing a high standard of services and enlarging their competitive advantages within the global economy. This paper deals with an implementation of Six Sigma toolkit in the field of railway transport processes. Here, it is essential to understand each tool´s pros and cons. The article particularly focuses on analyzing the Pareto principle in order to identify the most important train delay causes.
KEY WORDS: *Six Sigma, train delay, Pareto principle, process*

1. Introduction

In current competitive environment with constantly changing conditions, companies have to change their attitudes, break old paradigm and subsequently keep moving forward with new ideas. The fundamental principle of achieving a success is to accept customer requirements, especially in the processes of providing transport services. Transport enterprises have to stay flexible and offer highly rated services with focus on the passengers' needs.

Managers play an important role in transforming a company culture. They have significant influence on the performance of employees and determine the future business strategy. In terms of achieving better results, it is necessary to have a clear vision how to manage all elements in organization. On the one hand, managers have to choose and implement quality management system correctly, but on the other hand, they have to be able to motivate the staff to work. In order to reach the sustainable growth, companies have to involve each employee into the processes. The customer satisfaction can be increased depending on staff work enthusiasm and achieving desired outcomes. The Six Sigma can be described as a journey of achieving the improvement in processes, costs, qualities and customer satisfaction as well. Applying Six Sigma toolkit to processes in railway sector, we can improve quality of services and create new values for passengers, staff and society. This new approach reaches its full potential only when all processes are analyzed in detail. There is constant opportunity to improve services and achieve higher quality as the process improvement is never-ending and requires great effort.

2. Passenger Rail Transport Description

The infrastructure management and operation in Slovak republic is in responsibility of ŽSR (Železnice Slovenskej republiky) as an infrastructure manager. The passenger railway transportation services are operated by both the state and private railway carriers. Transportation performance within the public passenger transport is based on the orders from the particular public authority [15]. For this purpose in railway sector, ordinary passenger trains usually stop at all the operational stops and stations on particular route serving the area.

Location of Slovak republic is in the middle of Europe. Despite the fact that the railways have a good density of rail network, there are also disadvantages such as bad technical condition of rail infrastructure and low ability of reaction for customer's requirements [3]. This requirements should be evaluated in short reaction time. It is needful to fulfill the customer's requirements and after the services get feedback from customers [6]. If all of this do not happens it leads to failure in meeting defined standards, goals and causes in the extraordinary situations and failure in passenger's expectations [4, 12].

Train delays are caused by reasons that can be divided into the following three categories:

- delays caused by infrastructure manager;
- delays caused by railway operators;
- delays caused by external reasons (landslide, floods, etc.) [2].

In domestic transport, there is a financial compensation when the train is delayed more than 5 minutes or when it is partially or completely cancelled. ZSSK (Železničná spoločnosť Slovensko) as a leading carrier does not take responsibility for delays and cancellations of trains caused by external reasons. When delay is caused by carrier (ZSSK), passenger is even entitled to terminate the ongoing journey and ticket purchase costs will be refunded.

3. Implementation of Six Sigma Toolkit into Issue of Train Delays

The Six Sigma can be applied as a strategic business approach. It consists of many techniques and tools, which can be applicated in railway transport. Service quality in railway transport is currently a frequently discussed problem, especially from the view of competitive environment [10]. There will always be flaws and faults needing to see the light of day and to be amended and corrected [14]. In general, the Six Sigma is a tool for improving productivity, creating internal teamwork, or reducing costs, and an effective approach to a broad-based quality control program [16]. Simultaneously, the Six Sigma is a methodology for minimizing mistakes and maximizing values, and the statistical term for a process that produces fewer than 3.4 defects per million opportunities for defects [5].

Important part of the Six Sigma is a solid, structured and rigorous logical method – called DMAIC (define, measure, analyze, improve and control) [8]. The process is understood as a summary of mutually arranged activities changing inputs into outputs by consumption of certain resources in controlled conditions [9, 11]. Within the Six Sigma methodology, the basic cycle (DMAIC) with five phases is generally used. The aim of this structured problem-solving method is to map and measure the characteristics of processes and sequentially examine and analyze data and information and, finally, to propose a solution [7]. The first phase is about defining the project and to design the project charter. Moreover, it is typical for identifying main problems in processes and determine the few vital factors. The measure phase deals with measurement of the current process performance. This performance can be mapped and evaluated by key performance indicators. In the analyze phases, there is determined the source of variation. The following improving phase should provide improvement in order to eliminate main defects. In the final phase it describes the ability of process control system implementation.

The Pareto chart provides a graphic depiction of the Pareto principle and belongs to the group of basic quality control tools. Pareto charts was named after Alfredo Pareto and are based upon the 80:20 principle which means that 80 % of the quality problems are caused by 20 % of the cases [1]. The main aim of the Pareto chart is to emphasize the most significant factors which influence the business performance at most. The Pareto analysis can be used to identify those critical elements that are most likely to lead to significant improvement in overall project completion time [13].

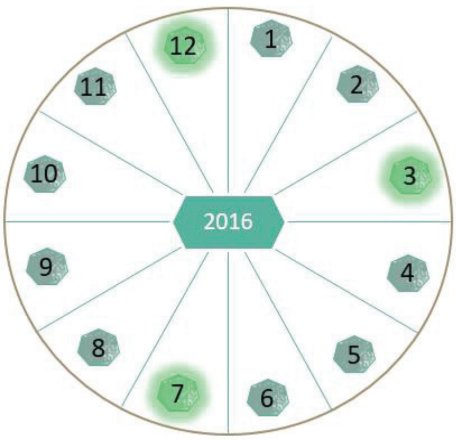

Fig. 1 Selected 3 months for data analysis

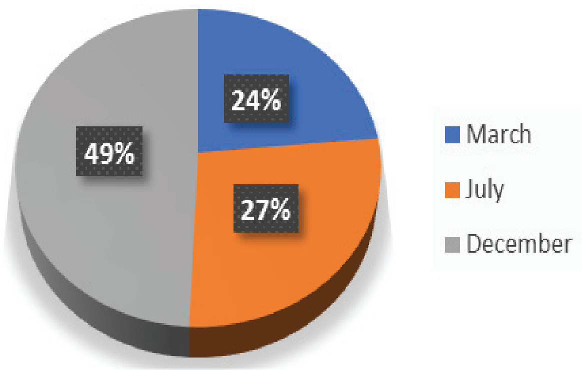

Fig. 2 Division of entire delay among 3 months

Practical application of the Pareto chart in terms of railway transport was described on example of train delays during the three months in 2016 – March, July and December (see Fig. 1). The survey was focused only on delays of passenger trains within one part of the rail network: Žilina – Čadca railway line (operated by ZSSK).

Data showed that the greatest number of train delays occurring in selected three months took place in December (see Fig. 2). Approximately half of delayed trains appeared this month, in comparison to 24% of them in March or 27% of them in July.

In the Figure 3, the analyzed data are categorized by frequency and code of delay (listed on x-axis). Lengths of columns represent frequency of train delays. Each reasons of train delay (see codes of delay) is illustrated by real value in minutes with negative impact to punctuality. The quality criteria are defined by amount of train delays, which are visualized by the Lorenz curve (by minutes per months and cumulative percentage values). The most numerous group of them are delay reasons caused by train succession, increased frequency, rail connection (in the meaning of inter-connection bonds) and weather conditions. These factors represent the most significant reasons (approximately 20 % of all reasons) which cause train the majority of train delays (approximately 80 % of all delays).

Thus, applying Pareto principle in railway transport processes, we can identify most important factors causing train delays. These factors should become an object of following depth analyze with valuable outcomes useful in an effort of reducing real train delays.

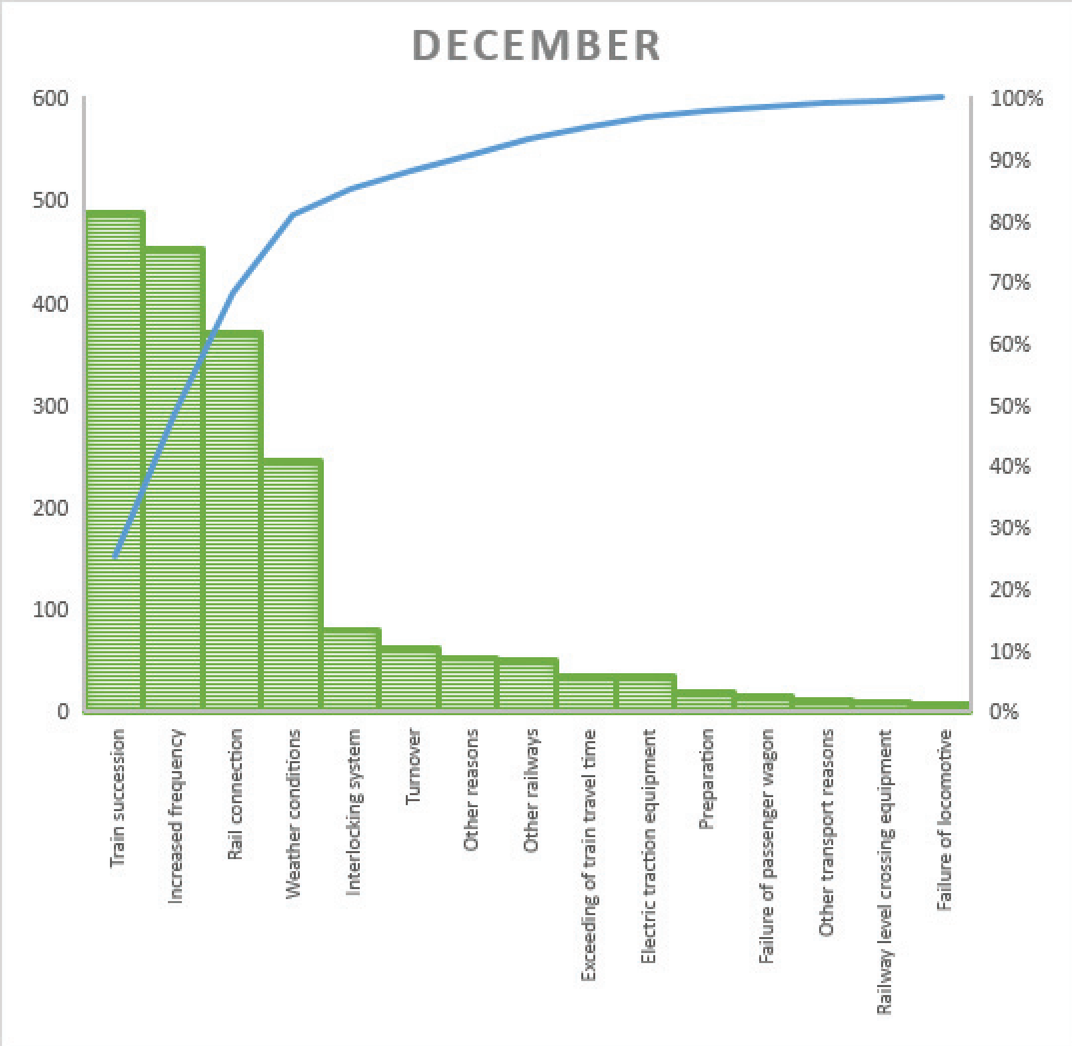

Fig. 3 Train delays in December

4. Conclusion

Principles of the Six Sigma methodology can be efficiently applied not only in manufacturing process but also in transport services. There are still activities in the processes that add no value from the perspective of the customer. The punctuality in passenger railway transport is very desired and related to customer satisfaction. It is essential to provide transport services on time. Goal of the business in transport services is not only to improve service delivery time but also reduce company's service costs. Simultaneously, each company wants to streamline processes, achieve major cost reductions and generally make the processes more effective. The aim of this article was to suggest and explain new possible quality approach which focuses on using of the new important tool – the Pareto chart – in railway sector.

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Fuzzy Modeling of Evaluation Logistic Systems

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Abstract

In the article was presented model of evaluation of logistic systems with use of fuzzy logic. In order to build mentioned model three following areas were included: financial condition of the company, customer service parameters and scope of business profile. Proposed model comprising above mentioned parameters constitutes the foundations of the global evaluation of analysed systems. It will enable most of all companies to analyse its own activity and to detect so called weaknesses.
KEY WORDS: *evaluation, modelling, logistic system, fuzzy logic*

1. Introduction

Transport, forwarding, and logistics (TFL) companies today focus on cutting the costs of logistics while simultaneously improving the quality of their services. They also often extend the range of these services to make them more comprehensive, including the transport of goods in any quantity or size, transport in both directions between various countries, as well as the loading, storing, customs clearing, unloading, completion and distribution of the goods [3, 5].

Logistics operators strive to encourage potential customers to buy as many services as possible. They are always looking for ways to achieve and maintain a competitive advantage. By analysing failures and investigating their causes, as well as through client evaluation, companies are able to respond to changes in the market and to protect themselves from losing market share.

The primary problem when comparing functioning logistics systems is selecting an appropriate methodology for evaluating such systems. The authors of this article undertook to resolve the following research question: what is the best way to analyse and evaluate functioning logistics systems in the TFL industry in order to choose the best solution for the client? To solve this problem, it was proposed to use fuzzy logic to develop a model and then implement it practically with the support of numerical data.

2. Fuzzy Model of Evaluation Logistic Systems

The evaluation of systems is an integral part of any human activity, particularly in the framework of the functioning of systems in industry. The subjects of the evaluation were companies in the TFL industry operating on the Polish market.

Each assessment contained a cognitive component which either added extra information to the profile that the expert has at his or her disposal or which collected information about the system in an orderly manner. The significance of the evaluation demonstrated its usefulness in the decision-making process [1].

In order to evaluate and choose the best logistics operator, a Matlab/Simulink R2016b was used, together with Toolbox Fuzzy Logic. The proposed logistics system evaluation model consisted of four fuzzy Mamdani systems (Fig. 1):

- A – financial condition of the company;
- B – scope of the business profile of the company;
- C – customer service parameters;
- M – evaluation of the logistics system.

Real TFL industry data were used to build the model, where the average values from the last three years were calculated to input into each model, and subsequently divided into sets.

Mamdani-type fuzzy models are often found in fuzzy systems that are based on expert knowledge. The advantages of these models include intuitive design and good adaptation to the perception of human variables. However, Mamdani models also have some disadvantages. The method is useful when the number of input and output variables is small, while for more variables there is a problem with orienting the rule base, as the number of rules grows exponentially with the number of variables in the premise. For this reason, the model has been designed in such a way that the output variables of models A, B, C are at the same time the input variables for model M. This approach allows the analysis of each area, i.e. financial condition, customer service parameters, and scope of the business profile of the company, separately. This greatly simplifies the analysis of their impact on the assessment of the entire system, decreases the number of rules necessary for each model, and makes it easier to understand the relationships between each area [1, 2, 4, 7].

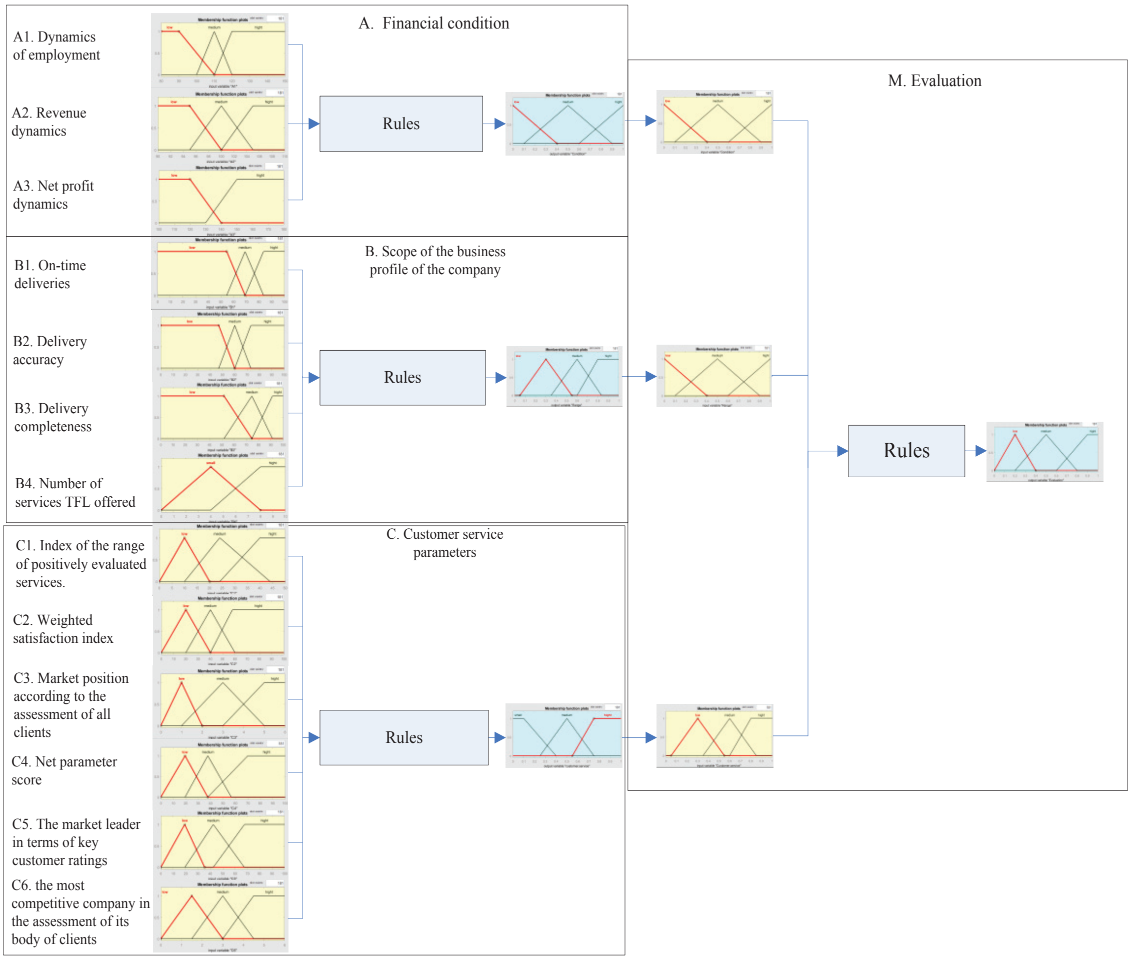

Fig. 1 Fuzzy system diagram

The fuzzy systems consist of the following blocks (Fig. 2) [7]:

- fuzzification,
- reasoning together with the rule base,
- defuzzification.

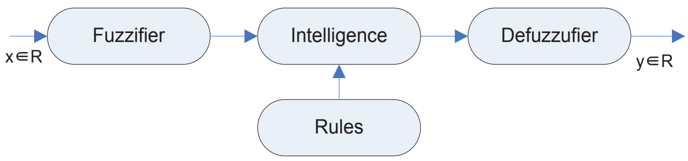

Fig. 2 Simplified fuzzy system diagram

Model A:

To build model A (financial conditions of the company), 18 rules were created. The model consisted of 3 input variables (Fig. 3):

• A1 – dynamics of employment, divided into three sets: 2 trapezoidal: low and high, as well as one triangular: medium in the [80–150] range;

• A2 – revenue dynamics, divided into three sets: 2 trapezoidal and 1 triangular: low, medium, high in the [90–110] range;

• A3 – net profit dynamics, divided into two trapezoidal sets: low, high, in the [100–180] range.

The output of the first model was the financial conditions of the enterprise, which was divided into three triangular sets – low, medium, and high, in the [0–1] range (Fig. 4).

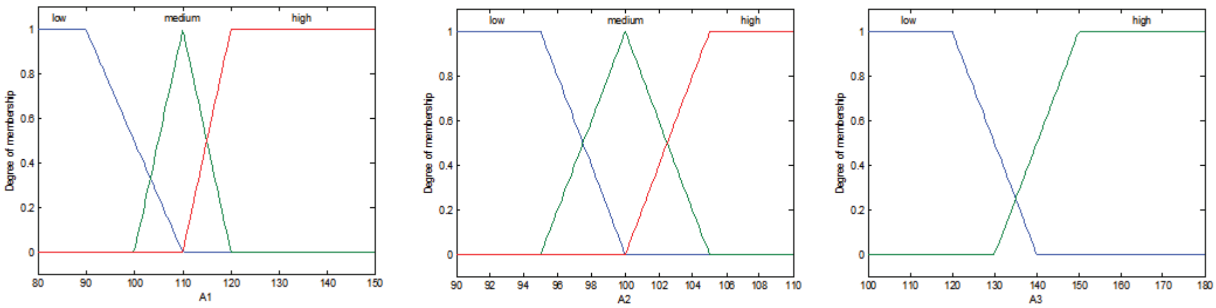

Fig. 3 Input variables for model A: A1, A2, and A3

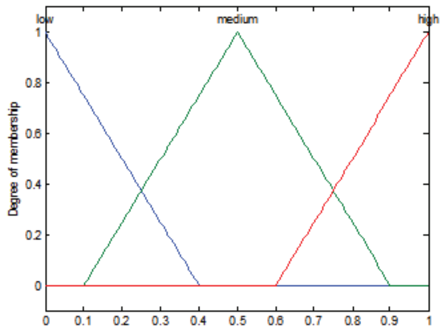

Fig. 4 Fuzzy variable output for model A: *financial condition*

Model B

Model B comprised 54 rules. The model contained 4 input variables (Fig. 5). B1 (on-time deliveries) was understood as the percentage of key clients who evaluated deliveries as executed within the agreed period. B2 (delivery accuracy) was the percentage of key clients who evaluated executed deliveries as being without documentation and labelling deficiencies or damage to goods or packaging. B3 (delivery completeness) was the percentage of key clients who evaluated the deliveries as complete. Variables B1, B2, and B3 were then divided into three sets: 2 trapezoidal and 1 triangular set in the [0–100] range. The last input variable to be taken into account in the model, scope of the business profile of the company, was the number of services TFL offered, divided into two sets: 1 triangular – low , and 1 trapezoidal – high in the [0–10] range.

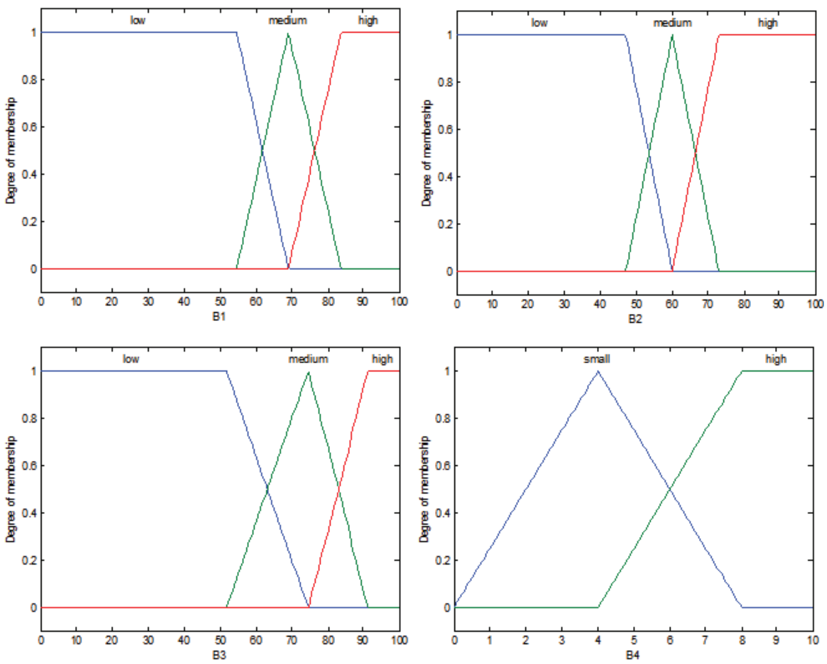

Fig. 5 Input variables for model B: B1, B2, B3, and B4

The output variable of the model was B. The scope of activities of the company (Fig. 6) was divided into 2 triangular sets (low and medium) and 1 trapezoidal set (high) in the [0–1] range.

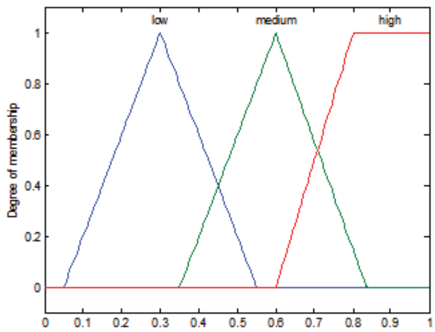

Fig. 6 Fuzzy variable output for model B: *scope of activities*

Model C:

Model 3 consisted of 6 output variables. A rule base consisting of 714 postulates was created for the model.

The input variables were (Fig. 7):

- C1 – index of the range of positively evaluated services. This was the percentage of all clients completely satisfied with the implementation of the most common logistics services. The variable was divided into three sets: 2 triangular (low and medium) as well as 1 trapezoidal (high) in the [0–50] range.
- C2 – weighted satisfaction index. This showed the level of trust in the customer service of a company, which was not replaced by another. The parameter was divided into three sets: 2 triangular (low and medium) as well as 1 trapezoidal (high) in the [0–100] range.
- C3 – market position according to the assessment of all clients. This was a percentage indication of how often a logistics company was indicated by the client as the leader in terms of customer service. The index was divided into three sets: 2 triangular (low and medium) as well as 1 trapezoidal (high) in the [0–6] range.
- C4 – net parameter score. This indicated how often clients unreservedly recommended the company to others, how often they did not recommend its services, and how often they were ambivalent. The index was divided into three sets: 2 triangular (low and medium) as well as 1 trapezoidal (high) in the [0–100] range.
- C5 – the market leader in terms of key customer ratings. This percentage showed how often a given logistics company was indicated by its key customers as the best logistics company on the market. The index was divided into three sets: 2 triangular (low and medium) as well as 1 trapezoidal (high) in the [0–100] range.
- C6 – the most competitive company in the assessment of its body of clients. The market leader position indicator was calculated as the quotient of the number of clients who considered the company to be the best in the market and the number of key clients studied. There are three triangular sets: low, medium, high, in the [0–6] range.

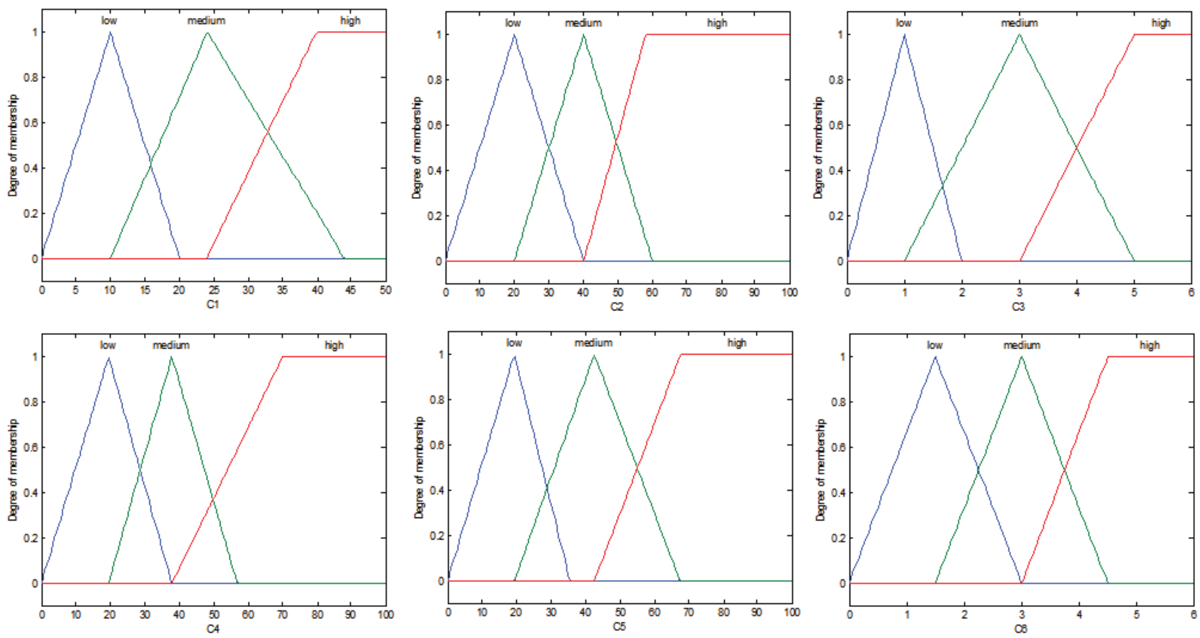

Fig. 7 Input variables for model C: C1, C2, C3, C4, C5, and C6

The output variable was parameter C, customer service (fig. 8), and was divided into three sets: 2 trapezoidal and 1 triangular: low, medium, high, in the [0–1] range.

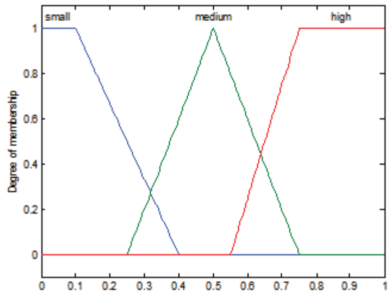

Fig. 8. Fuzzy variable output for model C: customer service

Model M

The summative model was a fuzzy model of the evaluation logistic systems, consisting of 27 rules. The system model integrated all of the previous models into a single fuzzy model, where the Simulink program allowed the simulation of the model as well as the verification of its correctness. The model consisted of 3 input variables (Fig. 9): A – financial condition (3 triangular sets), B – scope of activity (3 triangular sets), C – customer service (2 triangular sets and 1 trapezoidal set) and one output (Fig. 10) – evaluation, divided into 2 triangular sets and 1 trapezoidal set. All parameters were in the [0–1] range.

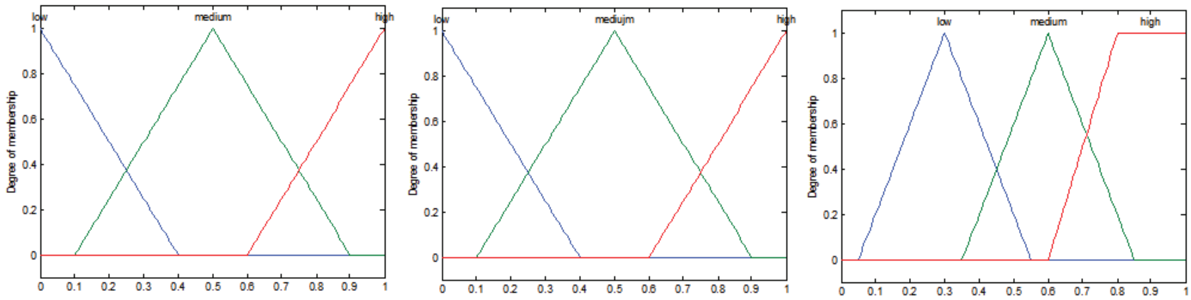

Fig. 9. Fuzzy input variables for model M: *financial condition, scope of activities,* and *customer service*

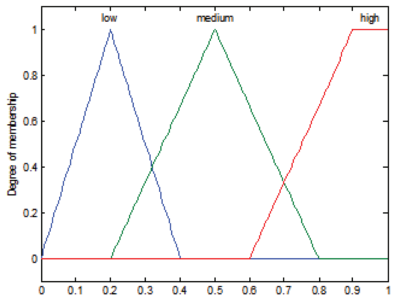

Fig. 10 Fuzzy variable output for model M: *evaluation of logistics systems*

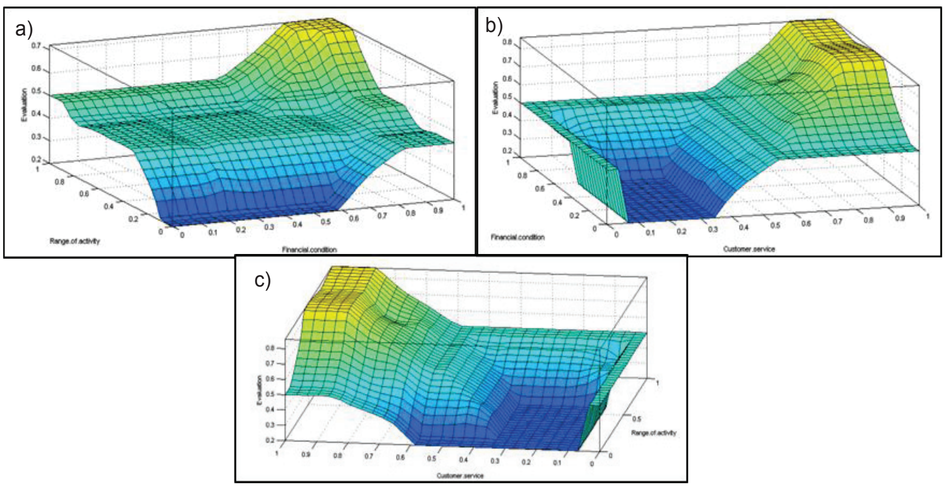

Fig. 11 Graphical interpretation of the fuzzy model surface: a - $y(x_1, x_2)$ where $x_3 = \text{const.}$; b - $y(x_2, x_3)$ where $x_1 = \text{const.}$; c - $y(x_2, x_3)$ $x_1 = \text{const}$

From the above three figures, the logistics system evaluation assumed extreme values for a narrow range of values for the areas in question, i.e. financial condition of the company, customer service parameters and scope of the business profile of the company (Fig. 11). The evaluation of the system reached its maximum values (approx. 0.7–0.83) for those values in the areas in question of approx. 0.8–1.0. It should also be noted that the logistics system evaluation was more strongly conditioned toward the financial condition of the company than the other two areas, as evidenced by the first two figures, due to the fact that it was a factor necessary for the functioning of the company.

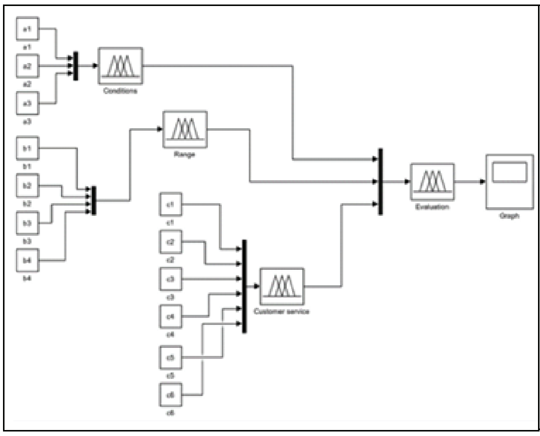

Fig. 12 Model of system created in Matlab/Simulink software

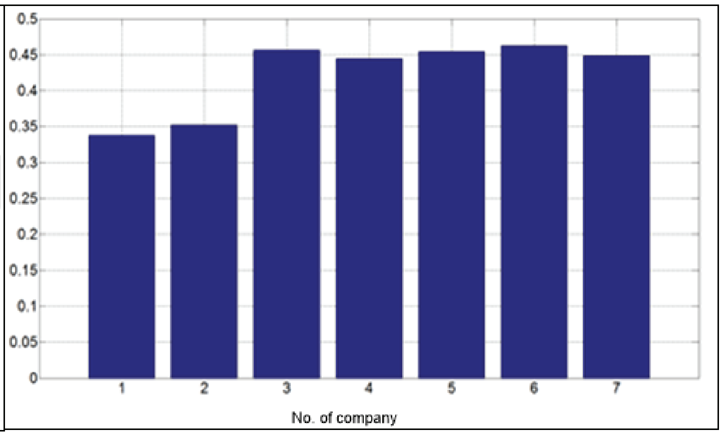

Fig. 13 Total ratings of evaluation logistic systems

On the basis of the model made in the Matlab/Simulink software (Fig. 12), a final assessment of seven logistics companies was made. Based on the results obtained (Fig. 13), it was found that the most prosperous company was no. 3 (Panalpina Polska), however the results achieved by companies no. 3-7 are not very differentiated and testify to the average level of evaluation [6].

3. Conclusions

The use of artificial intelligence for analysing logistics systems determines not only the level of influence of particular elements on their functioning but, above all, the general evaluation of their functioning in the present market. The presented analysis is the basis for making rational decisions and, if necessary, improvement of the critical points (in which the lowest scores are obtained).

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Significant Factors Affecting the Passenger Arrival Rates

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Abstract

The passenger satisfaction in civil aviation plays a crucial role in many ways. The airports are business companies with one primary purpose - to generate a profit. This also applies to airlines, handling agents, or cleaning, catering or parking services at the airport. For this purpose it is necessary to maintain a high level of passenger satisfaction as well as a high level of operational efficiency. Maintaining these factors in the required range is important in the entire terminal process and especially at centralised security control checkpoints. One of the essential assumptions for maintaining adequate quality of service is the knowledge of precise estimates of passenger arrival rates. This article describes the principle of passenger arrival rates modelling and deals with factors affecting expected arrival rates.
KEY WORDS: *passenger flow, arrival rates, airport, security*

1. Introduction

One of the key factors in the effort to ensure high level of passenger satisfaction and the required operational efficiency is the issue of terminal capacity. For both strategic and operational passengers flow control and the determination of the adequate service in all parts of the terminal process, the knowledge of the passengers' arrival rate is important. This knowledge is important at all levels of terminal capacity process planning and controlling (strategic, pre-tactical and tactical) to ensure optimum service throughout the year, week and day (hardware and software equipment, appropriate staff numbers, etc.).

Generally, this article is based on the issues of security controls process and effectiveness analysis. New technologies can have a very positive effect on increasing the number of checked passengers [1]. Similarly, process modelling and complex management systems are important [2, 3]. In the article, we will focus on basic and important topic – passenger arrival rate prediction.

The first part of this article discusses the baseline approach for estimating the arrival intensity of the system requirements (in our case the number of passengers) and the necessary input information. In real situations, it is much more advantageous to use stochastic and simulation tools instead of the basic deterministic model described in this article. However, for the purpose of introducing the issue of estimating passenger arrival rates into operation, the described model is more than adequate.

In the second part of the article there are described various factors that may influence the real numbers of incoming passengers in the terminal process. The third part of the article deals with the consequences of a possible mismatch between the expected (planned) and actual arrival rate of passengers.

2. The Basic Principle of Determining Passenger Arrival Rate

This chapter describes a basic model for estimating daily passenger incoming rates. In the first step, it is necessary to define and describe a particular part of the whole terminal process that the model focuses on. Subsequently, important parameters are defined. Thus allow the model to be created. The final step is to create a mathematical model in the range that matches the expected outputs.

2.1. Specifying the Appropriate Part of the Terminal Process

The physical point or part of the terminal process, to which the model is intended to determine the required operational estimates, will always vary depending on the intended outputs. Even the chosen mathematical models and the necessary parameters for their creation may differ significantly. Operational estimates of input intensities may be relevant, for example, for public transport in order to ensure comfortable connection between the city and the airport, for parking at the airport to ensure sufficient input and output points, including total capacity, for restaurant facilities at the airport to ensure a sufficient number of staff and for shops. It is very important to estimate the arrival intensity for common check-in counters, to ensure fluent security checks, cleaning capacity and many more.

At number of airports, there is a preference for centralized security checks for passengers and cabin luggage as part of a modern concept of the terminal processes and passenger flow. There may be also a combination of security control and passport control processes. All passengers have to pass through these parts of the terminal process and it is not possible (as opposed to all the previous and subsequent parts) to avoid them.

In this article, we will continue to deal with the determination of incoming passengers' rate to a centralized security control (for instance, similarly the model can be used for centralized passport control).

2.2. Determining Important Input Data into the Model

First of all, it is necessary to get information about aircraft movements during the day. This basic information can be obtained from long-term flight schedules, current arrivals and departures, the airport's website or various applications. In relation to the chosen point of interest in the terminal process, information whether passengers will pass over the chosen point need to be determined (e.g. whether it is an arrival or departure, to which destination the flight is heading and from which terminal will the flight depart, depending on parameters for a particular disposition of airport and terminals).

After the assignment of passengers from a particular flight to our model, we need another critical input data. It is the number of passengers on a particular flight. The long-term estimated number of passengers can be obtained, for example, by multiplying the average load factor (average occupancy of flights) and the capacity of the type of airplane with which the flight is operated. The third important input is the scheduled departure time. The following table (Table 1) shows an example of necessary input information in the model.

Table 1

Example of necessary input information for the model

Flight number	Destination	Aircraft	Departure
AA2648	LPPT	319	6:00
KL1342	EDDF	321	6:00
QS2136	EBCI	73H	6:15
LH3350	EHAM	73J	6:30

The next step determines the probability distribution of arriving passengers to the chosen point of the terminal process depending on the departure time. This model will include the distribution of passengers arriving in time before departure to the security control. It is appropriate to get the data directly from the measurement and data evaluation at the airport. It is also possible to use the general values available in publications about this topic as [4-6]. The figure (Fig. 1) shows an example of a possible basic passenger's distribution for the model. For more accurate models, it is advisable to use 5 - 15 minutes time intervals.

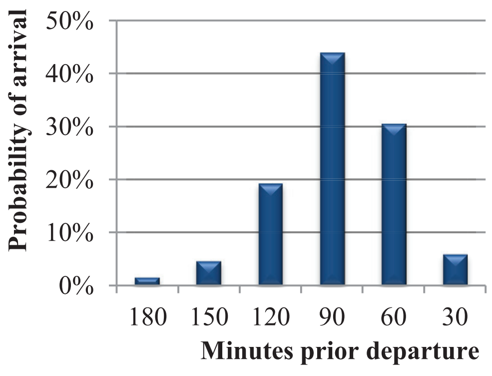

Fig. 1 Passenger arrival distribution

2.3. Mathematical Model

After obtaining important input data, it is possible to create a basic mathematical model that links this information into a desired output. The estimated number of departing passengers is determined by the type of aircraft and load factor for the flight assigned to point of interest in the terminal process. The number of passengers will be multiplied by the passenger arrival distribution. Then the incoming number of passengers for a particular flight will be obtained. The calculation will be made for all assigned flights. The sum of the number of passengers from each flight then determines the total estimated number of incoming passengers to the security control. For example from the table (Table 1), the resulting estimated number of incoming passengers over time is shown in the figure (Fig. 2).

For the example of 4 departing aircraft and data acquisition using the basic model (Fig. 2), a maximum of 45 incoming passengers is reached at the selected five-minute intervals at 04:40.

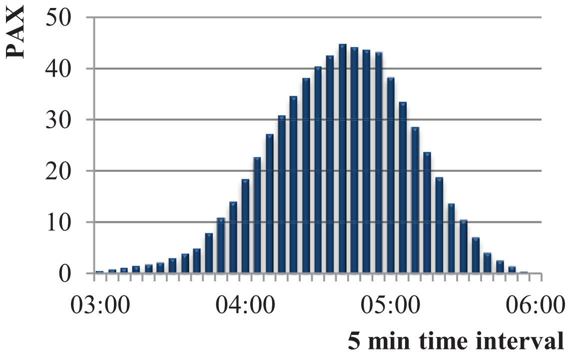

Fig. 2 Example of basic model for PAX arrival estimation

3. Factors Influencing Inconsistency Between Modelled and Real Number of Incoming Passengers

Comparing the measured values to the theoretical modelled values, there are various inconsistencies and deviations throughout the day which may have a negative impact on overall operational efficiency and passenger satisfaction. In the following part of the article, the most important selected factors are described.

3.1. Reliability and Quality of Input Data

A reliable source of input information is very important. Operational problems could be caused by a model based on wrong information. For example, it may include non-existent flights or, on the other hand, not receiving information about planned flight, changing the flow of passengers outside of chosen point, changing the type of aircraft, destination or departure time. These changes may be related to an unreliable source of input data but also to extraordinary ad-hoc operational adjustments that have not been communicated properly.

3.2. Suitability of the Mathematical Model

Appropriately chosen mathematical interconnection of input data and necessary calculations for the resulting number of incoming passengers over time are crucially important. The same issue is about graphical interpretation of the resulting numbers. There is a risk of values time shifts or that the used passenger distribution does not match the real distribution and many others. The figure (Fig. 3) shows the resulting number of incoming passengers assuming a uniform distribution (inappropriately used) of the passengers' arrival probability over time.

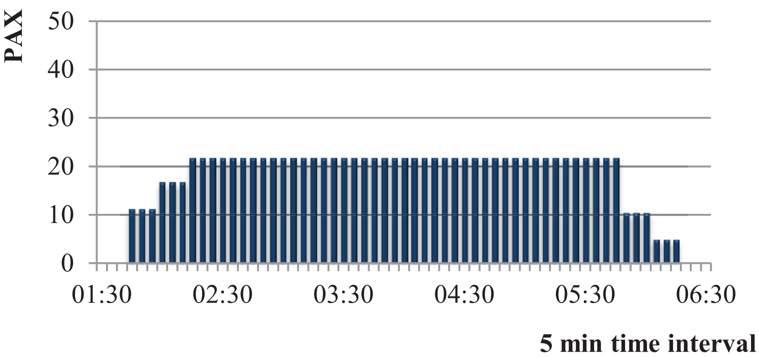

Fig. 3 Inappropriate passenger distribution

Using the inappropriate probability distribution of passengers, the modelled example (Fig. 3) compared to the appropriate model (Fig. 2) significantly reduced the number of incoming passengers at five-minute intervals from 45 PAX to only 22 PAX in maximum. Even though these models are only theoretical, they clearly show that although the input data are correct, the model may not correspond to real arrival rate unless the mathematical model and its characteristics are accurate.

3.3. Loadfactor

The issue associated with the estimation of individual flights occupancy are very complex. Strategic operations models are based on the input data that are required in many cases more than one year in advance. Determining load factors at very short time intervals is also challenging. Usually, it is based primarily on experience and qualified estimates. The figure (Fig. 4) shows an example for the same 4 departing planes (from the previous model) with a difference in loadfactor, 100% and 60%.

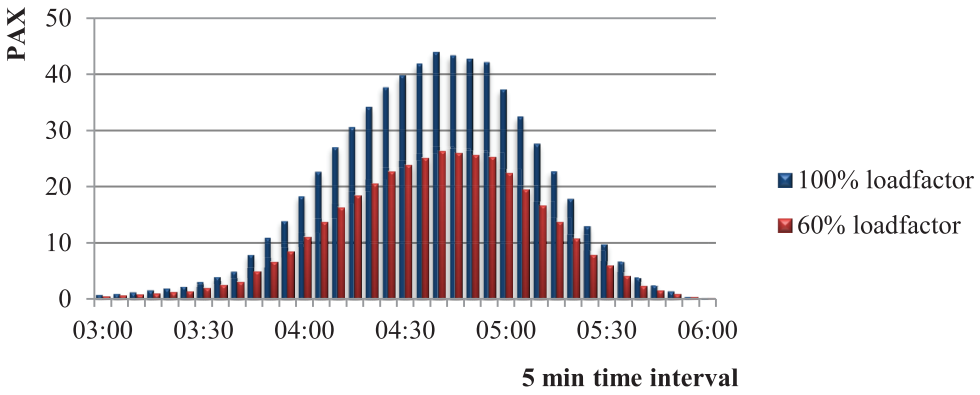

Fig. 4 Two models with different loadfactors

Changing the average load factor from 100% to 60% has greatly influenced the total number of incoming passengers over time (Fig. 4). The original maximum value of 42 PAX in five minutes was decreased in a maximum of 26 PAX in a five-minute interval. Due to different time of the departure of each flight, the total decrease in loadfactor in each flight may not be the same as in total numbers. In real situations, there will not be an average increase or decrease in the load factor, but it will vary individually for each flight.

Uncertainty for estimating the number of arriving passengers has also extremes during the year, such as holidays, extended weekends, great sports or cultural events, and so on. The opposite problem causes an unexpected drop in passengers due to terrorist attacks, incompatible weather conditions with operations, etc.

3.4. Operational, Safety and Security Limitations

Operational, safety and security limitations can cause a very significant and ad-hoc impact on the expected arrival of passengers. Operational constraints may include a drop in check-in systems and significant queues at check-in counters, inadequate staffing of operational needs in previous parts of the terminal process, unexpected short-term closure for construction, traffic accidents and other airport process congestion.

For example, in extreme cases restrictions may cause a short-term terminal closure (due to a fire alarm for instance). In this case, there will be a cumulation of passengers who would arrive in real time without restrictions together with passengers arriving late due to the closure of the terminal. The figure (Fig. 5) shows a fifteen-minute closure model with the change of passenger arrival.

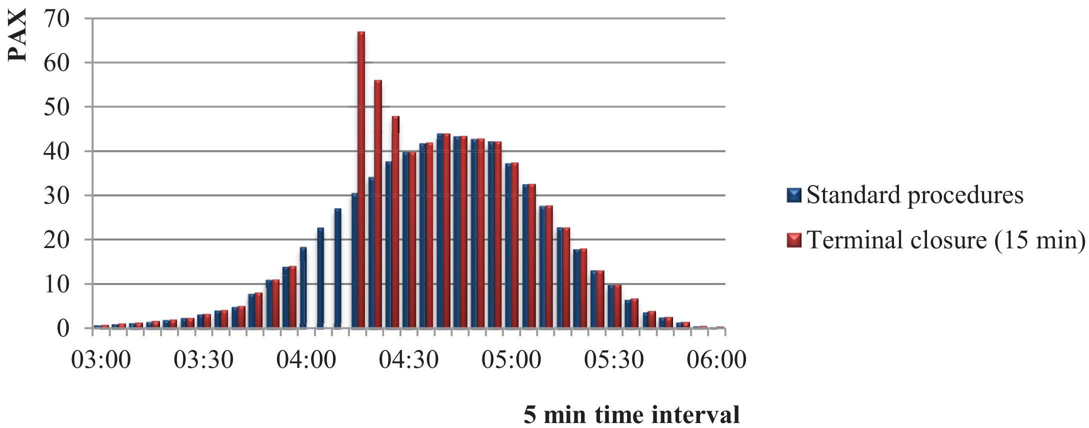

Fig. 5 Terminal closure model

Extraordinary operational situations are usually reflected in a short-term decline in passenger arrival compared to expected values, with a consequent increase over the expected limit.

3.5. Aircraft Departure or Check-in Process Delay

Aircraft delays on departure or delay of check-in process (or early check-in) may be present in two ways. The first interference is the increase in the number of passengers when they were not counted in the model (Fig. 6). Passengers from the delayed flight are out of plan at another time together with the properly expected passengers.

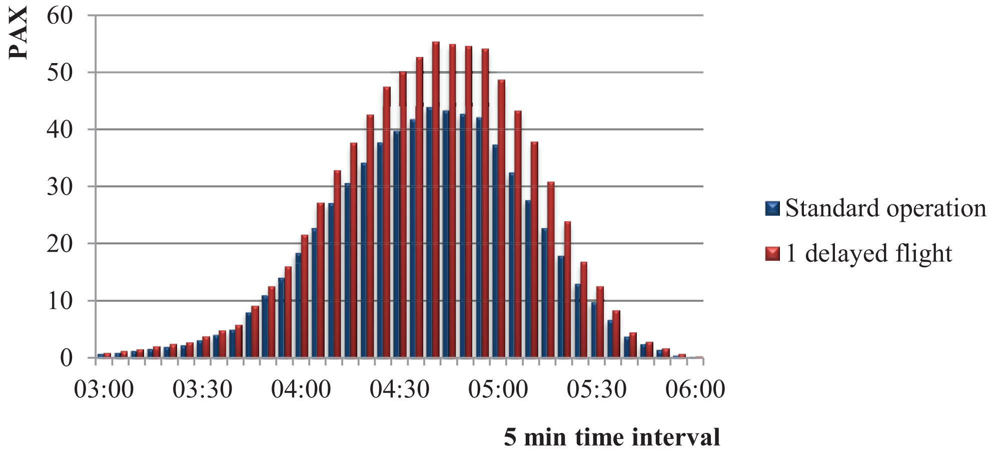

Fig. 6 One delayed flight - counted to the model

The second interference is the decrease in the number of passengers at the time of their expected arrival (Fig. 6). This is a situation when passengers from a delayed flight do not arrive in the expected time, but (usually) later.

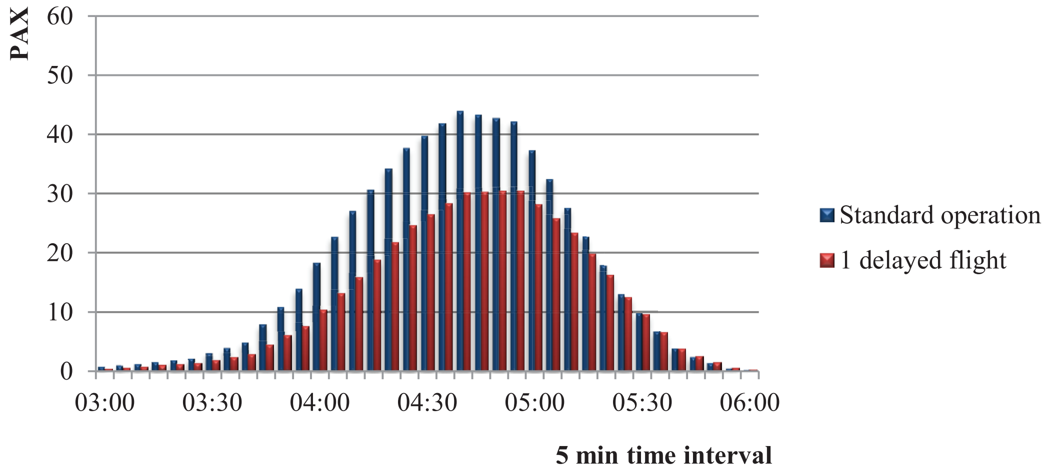

Fig. 7 One delayed flight – not counted in the model

3.6. Other Factors Affecting Passenger Arriving Rate

Other factors that may affect the number of incoming passengers over time include for example the impact of a larger group of passengers. This may be an early common arrival at the airport, waiting for the entire group to be checked-in together and its subsequent arrival to the security check and so on. In such a case, unlike the expected random Poisson distribution, the clustered arrival of passengers will be present to a greater extent.

The influence may have also local time-limited attractions such as an interesting exhibition in the terminal building, opening ceremony of a new restaurant with discounts in the public area of the airport, music concert and many other circumstances.

4. Consequences of Inconsistency Between the Modelled and Real Number of Incoming Passengers

From the effectiveness of strategic and pre-tactical operational needs coverage planning point of view, the impact of different numbers of incoming passengers from expected numbers depends on the overall range of the difference and its distribution over time and duration. The first consequence may be ensuring inefficient operation, when (for example Fig. 7) the service rate is set on higher level than the real passenger arrival rate. The determined service rate corresponds to long-term planning, but it is inefficient at the moment.

On the other hand, different consequence may be the adjustment of service rate by strategic and pre-tactical planning to the lower level than the actual arrival rate is (for example Fig. 6). In this case, the efficiency of the service is very high, but passenger queues arise. Depending on the extent of the mismatch and its duration, passengers' satisfaction may be negatively affected.

5. Conclusion

For strategic and pre-tactical planning of operational needs, knowledge of these needs is important in advance and in sufficient quality and reliability. Inappropriate models or identified processes can negatively affect both overall operational efficiency and passenger satisfaction. These parameters are interlinked and very important for the airport.

As it was described in this paper, there is frequently a mismatch between modelled and real flow of incoming passengers. It is important to correctly identify and describe each influencing factor. Improvement can be in assessing the impact of factors in terms of occurrence frequency and impacts on passenger arrival rate. Determining the degree of factors influence will make it possible to integrate them better into models and operational estimates. In this case, however, the complexity of the models will increase considerably. Consideration can be also given to stochastic models in contrast with a current deterministic approach based on historical experience and measured input data.

Acknowledgement

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Numerical Simulation of Omnidirectional Mobile Platform for Loads Transportation

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Abstract

The article presents kinematics model and concept of eight-wheeled mobile platform with mecanum wheels dedicated for loads transportation. Mobile platform through use of mecanum wheels has 3 degrees of freedom and it can move in any direction with any configuration of platform's frame on level base. Derived kinematics equations were used to perform numerical simulations of inverse kinematics problem. In order to solve inverse kinematics problem trajectory and velocity of platform's selected characteristic point were established.
KEY WORDS: *omnidirectional transport platform, mecanum wheels, mathematical model, kinematics*

1. Introduction

Omnidirectional wheels (Fig. 1) are drive wheels consisting of a hub and a certain number of rollers mounted on the circumference of the hub, which can freely rotate around its own axis of rotation [1, 4, 5].

a b

Fig. 1 Examples of omnidirectional wheels: a - conventional omnidirectional wheels; b - mecanum wheels

These wheels can be characterised by means of the angle ψ present between the axis of rotation of the wheel and the axis of rotation of the roller. If $\psi = 90°$, these are the conventional omnidirectional wheels (Fig. 1, a), whereas if $\psi = 45°$, such a wheel design is referred to as mecanum wheels (Fig. 1, b) [2, 4].

2. Advantages and Disadvantages of Using Mecanum Wheels

Omnidirectional wheels have a wide range of practical applications. They are successfully used in transport, for example in the industry, e.g. in universal mobile platforms manufactured by Kuka [6] and Weiss GmbH [7]. Furthermore, the said wheels are used in medicine, robotics, education, as well as in the military [1].

The wide range of applications stems from many advantages of the systems equipped with omnidirectional wheels, e.g. owing to the use of mecanum wheels, a mobile platform has three degrees of freedom and it can move on a flat surface in any direction with any platform frame configuration. This so-called "omnidirectional movement" is particularly useful if the structure has to move inside industrial plants, e.g. in warehouses, where movement space is significantly reduced. This allows to avoid frequent manoeuvring operations in the event of a change in the direction of movement of a vehicle. In addition, this solution reduces the time required for operation and implementation of warehouse tasks in the discussed case of operation [1, 3].

The platforms equipped with mecanum wheels are most often rectangular in shape, which is frequently related to an even number of drives used, e.g. four, six, eight, etc. This gives the project a very compact configuration, although three drives with mecanum wheels are sufficient for "omnidirectional movement", in this case the platform itself is triangular in shape. Such a solution is most often used in small-wheeled mobile robots. Further advantages of using mecanum wheels include easy control in an open system, which consists in controlling angular velocities of particular wheels. At the same time, this eliminates the necessity of using a conventional steering system. Furthermore, the systems in question are characterised by high load capacity, which is why they are often used to transport large cargo [1].

However, mecanum wheels also have certain disadvantages. In comparison with conventional wheeled vehicles, for which the tyre-surface contact track is a line, mecanum wheels are in pointwise contact with the surface. In this case, this leads to an increased load of the surface on the mecanum wheels. This is an undesired feature, as it leads to faster abrasion of the material which the rollers in contact with the surface are made of. On the other hand, an appropriate number of rollers can minimise the loads of the surface on the mecanum wheels. In addition, the high sensitivity of the discussed solution to the irregularity of the shape of the surface and the discontinuity of wheel contact with the surface during movement are further disadvantages of the solution [1, 3].

3. Kinematics of an Omnidirectional Mobile Platform

The proposed solution is an omnidirectional mobile platform used for in-house transport of loads, consisting of eight direct-current motors and the same number of mecanum wheels located in the platform (Fig. 2). Mecanum wheels

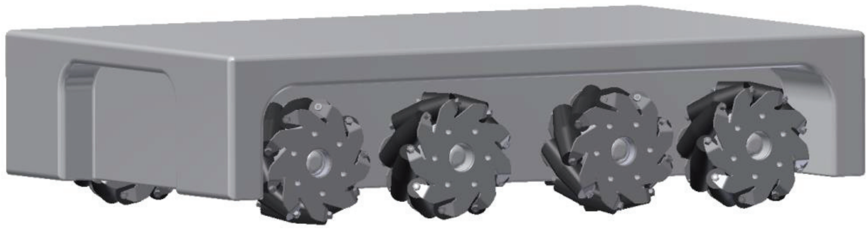

Fig. 2 A virtual model of an omnidirectional mobile load transport platform

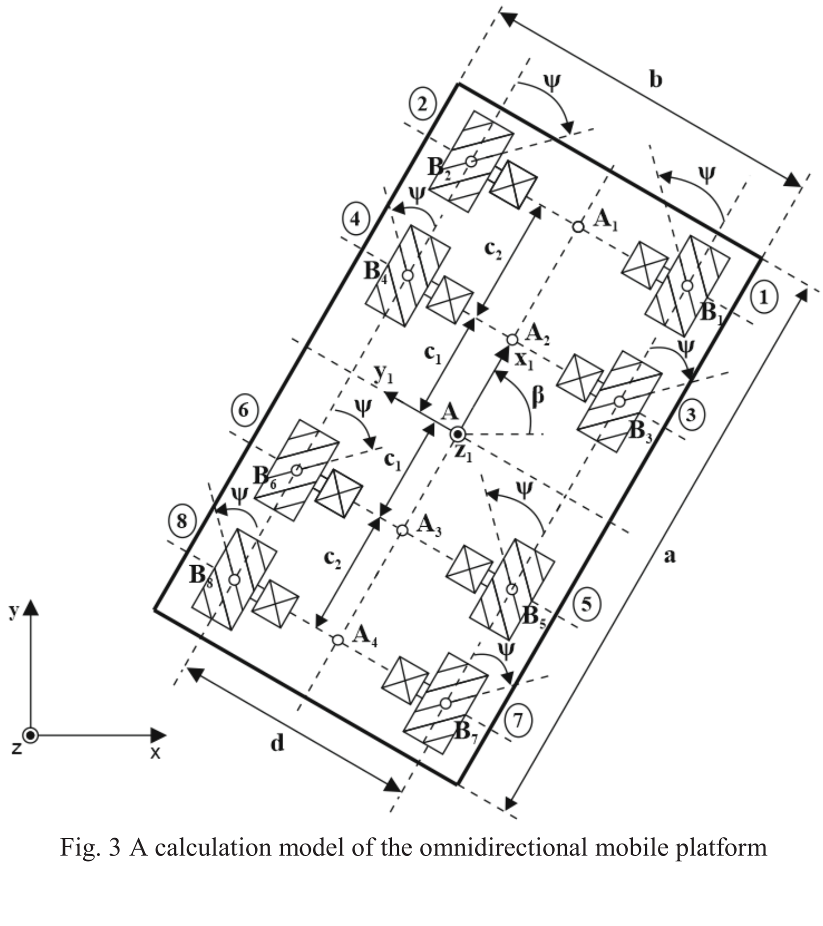

Fig. 3 A calculation model of the omnidirectional mobile platform

are mounted in a rigid manner on motor shafts, which ensure the option of flexible control of angular velocity of particular wheels. The current analysis adopts the configuration of mecanum wheels shown schematically in Fig. 3. During movement of the platform, the mecanum wheels rotate with angular velocity $\dot{\varphi}_i$, where i denotes the number of the wheel (i = 1, 2, 3, 4, 5, 6, 7, 8). In addition, it is assumed that the radiuses of mecanum wheels R_w and rollers R_r are constant values that are equal for each of the eight wheels. It is also assumed that the platform rotates around the geometric centre of the frame, i.e. point A (selected tracking point in the system) by angle β. The length of the platform of the described object is equal to a, whereas the width is equal to b. The shape of the designed platform (Fig. 2) allows for the extension of the vehicle with additional equipment, e.g. ultrasound detectors or laser scanners, often used for the purpose of detecting obstacles during movement of the vehicle, therefore preventing potential damage to the object.

The analysis of kinematics of the system is presented on the basis of wheel no. 1 (Fig. 4).

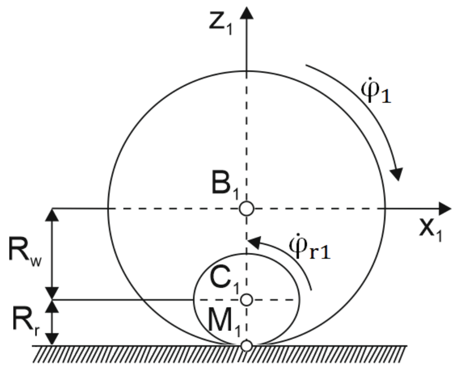

Fig. 4 Kinematics of wheel no. 1

Assuming that the roller in contact with the surface rolls without skidding with angular velocity $\dot{\varphi}_{r1}$, the following relation must be satisfied:

$$\bar{v}_{M_1} = \bar{0}. \tag{1}$$

The mecanum wheel moves in a resultant motion, therefore, when relation (1) is written out, the following is obtained:

$$\bar{v}_{B_1} + \bar{v}_{C_1B_1} + \bar{v}_{M_1C_1} = \bar{0}. \tag{2}$$

When equation (2) is projected on the axes of a flat coordinate system x, y, and the position of wheel no. 1 in the platform is taken into account, the following equations are obtained:

$$\dot{x}_A + \frac{d}{2}\dot{\beta}cos\beta - (c_1 + c_2)\dot{\beta}sin\beta - R_w\dot{\varphi}_1cos\beta - R_r\dot{\varphi}_1cos\beta + R_r\dot{\varphi}_{r1}sin(\beta + \psi) = 0; \tag{3}$$

$$\dot{y}_A + \frac{d}{2}\dot{\beta}sin\beta + (c_1 + c_2)\dot{\beta}cos\beta - R_w\dot{\varphi}_1sin\beta - R_r\dot{\varphi}_1sin\beta - R_r\dot{\varphi}_{r1}cos(\beta + \psi) = 0. \tag{4}$$

Rollers are passive elements in the analysed system, which means that if lack of skidding is assumed when the mentioned element rolls on the surface, they do not influence the kinematics of the system [4]. This makes it possible to omit them in the kinematic analysis and, therefore, by means of using relations (3), (4), the following can ultimately be stated:

$$\dot{\varphi}_1(R_w + R_r)cos(\psi) = \dot{x}_A\,cos(\beta + \psi) + \dot{y}_A\,sin(\beta + \psi) + \dot{\beta}\left[\frac{d}{2}cos(\psi) + (c_1 + c_2)sin(\psi)\right]. \tag{5}$$

Next, kinematic equations of the discussed object were derived analogically in reference to the other seven wheels, written in the following matrix form:

$$\dot{\varphi} = JV_p, \tag{6}$$

where $\dot{\varphi} = [\dot{\varphi}_1, \dot{\varphi}_2, \dot{\varphi}_3, \dot{\varphi}_4, \dot{\varphi}_5, \dot{\varphi}_6, \dot{\varphi}_7, \dot{\varphi}_8]^T$; $V_p = \left[\dot{x}_A, \dot{y}_A, \dot{\beta}\right]^T$.

In turn, the Jacobian J element appearing in relation (6) can be written in the form of the following matrix:

$$J = \frac{1}{[R_C cos(\psi)]} \begin{bmatrix} cos(\beta+\psi) & sin(\beta+\psi) & \frac{d}{2}cos(\psi)+(c_1+c_2)sin(\psi) \\ cos(\beta-\psi) & sin(\beta-\psi) & -\frac{d}{2}cos(\psi)-(c_1+c_2)sin(\psi) \\ cos(\beta-\psi) & sin(\beta-\psi) & \frac{d}{2}cos(\psi)+c_1 sin(\psi) \\ cos(\beta+\psi) & sin(\beta+\psi) & -\frac{d}{2}cos(\psi)-c_1 sin(\psi) \\ cos(\beta+\psi) & sin(\beta+\psi) & \frac{d}{2}cos(\psi)+c_1 sin(\psi) \\ cos(\beta-\psi) & sin(\beta-\psi) & -\frac{d}{2}cos(\psi)-c_1 sin(\psi) \\ cos(\beta-\psi) & sin(\beta-\psi) & \frac{d}{2}cos(\psi)+(c_1+c_2)sin(\psi) \\ cos(\beta+\psi) & sin(\beta+\psi) & -\frac{d}{2}cos(\psi)-(c_1+c_2)sin(\psi) \end{bmatrix}. \quad (7)$$

where $R_c = R_w + R_r$ – total radius of a mecanum wheel.

4. Numerical Simulations

The analysis of kinematics of the omnidirectional platform presented in section 3 was used to run a numerical simulation depicting a solution of an inverse kinematics problem of the platform in question in the case of movement of point A of the analysed object on a trajectory in the form of a geometrical figure, i.e. a square with constant configuration of the platform in the course of the simulation. The following geometric dimensions of the platform have been adopted in the simulation: $\psi = \frac{\pi}{4}$[rad], $R_C = 0.4$[m], $d = 1$[m], $c_1 = c_2 = 0.66$[m] and the following initial conditions: $[x_A(0), y_A(0)] = [0,0]$, $\beta(0) = 0$.

In order to take consider in the simulation the transitional stages of movement, i.e. acceleration and breaking, approximation was conducted for the assumed profile of velocity of point A in the form of the following relation:

$$v_A = v_{set}\left(\frac{1}{1+e^{-g(t-t_{ac})}} - \frac{1}{1+e^{-g(t-t_{br})}}\right), \quad (8)$$

where v_{set} [m/s] is the velocity of point A in stationary state, g [1/s] is the coefficient of acceleration and breaking, whereas t_{ac} [s] and t_{br} [s] are parameters describing the average time of acceleration and breaking [4, 5].

The trajectory of motion of point A of the platform is a square, as presented in Fig. 5. Apart from the mentioned trajectory (the arrow designates the direction of movement), the configuration of the platform is designated at characteristic stages of the simulation, i.e. when the direction of movement of the discussed point changes.

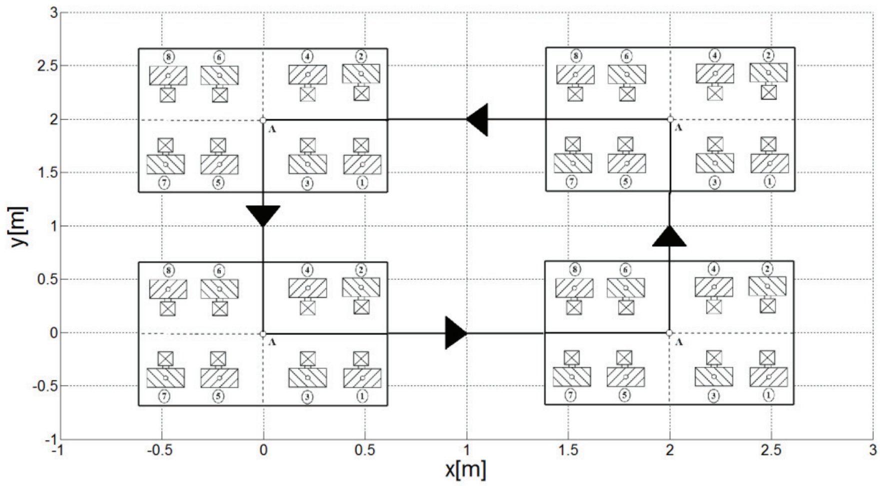

Fig. 5 The trajectory of movement of point A of the platform with graphic representation of framework configuration

The conducted numerical calculations assume the value of the angle of rotation of the frame that is constant and invariable in the course of simulation β (Fig. 6), which implicates zero value of angular velocity of the mentioned frame of the mobile platform (Fig. 7).

The solutions of the inverse kinematics problem of the object are two courses presented in Figs. 8 and 9. The first of the listed Figures presents the course of angular velocity for mecanum wheels no. 1, 4, 5, 8, whereas the second one for wheels no. 2, 3, 6, 7. The discussed angular velocities are necessary for implementation of the set trajectory of motion of the described point of the omnidirectional mobile platform.

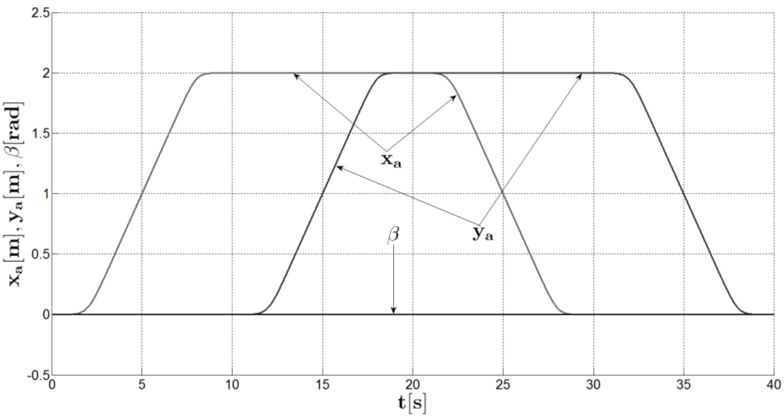

Fig. 6 Courses of the coordinates of point A of the platform and the angle of rotation of the frame

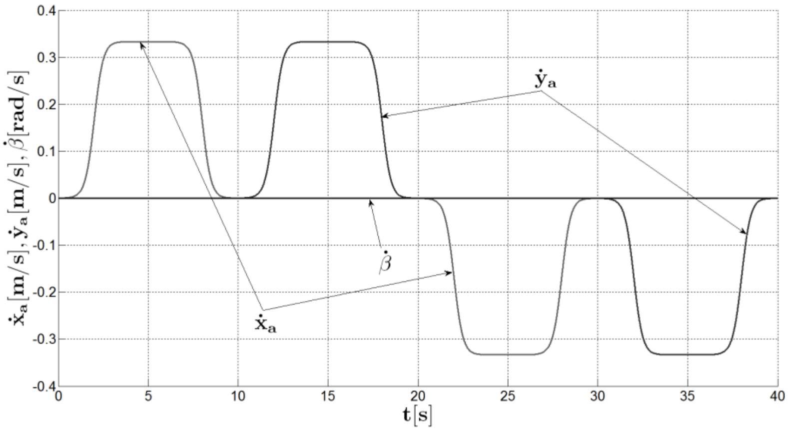

Fig. 7 Courses of projections of velocity of point A of the platform and angular velocity of the frame

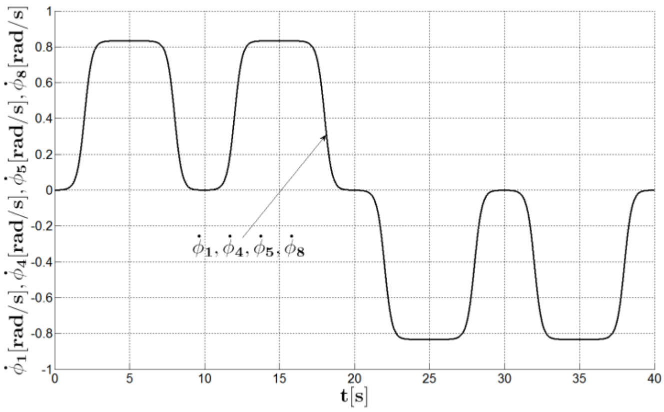

Fig. 8 Course of angular velocities of wheels no. 1, 4, 5, 8

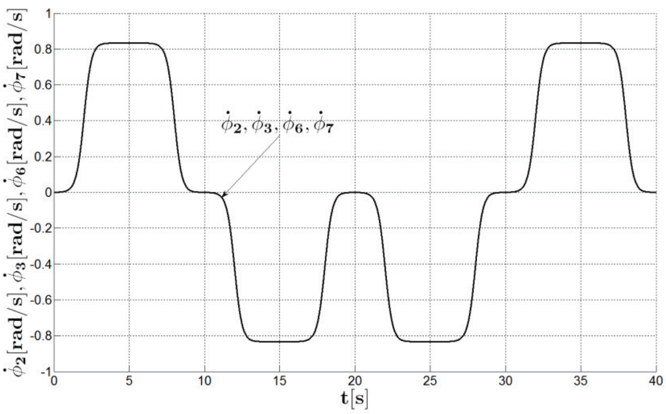

Fig. 9 Course of angular velocities of wheels no. 2, 3, 6, 7

All the numerical simulation tests presented in the work were conducted in Matlab/Simulink software.

5. Conclusions

The work introduces the kinematics of an eight-wheel omnidirectional mobile platform with mecanum wheels and conducts a numerical simulation of its movement on a square-shaped trajectory, therefore presenting the fundamental advantage of possible use of the object in load transport, i.e. freedom of movement in every direction. The application of the designed platform, dedicated to in-house transport operation allows to save the time necessary to transport a load to a selected location and enables further development of the object, i.a. with additional detectors allowing fully autonomic operation, without the need to control the object by an operator.

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Optimization of the Specific Transport Connections Using Mathematical Methods

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Abstract

Purpose of this paper is to assess the current offer of connections in public passenger transport between specific cities in the given country based on appropriate selection of criteria and mathematical methods to verify the suitability of the current situation and propose improvements. On the basis of obtained information from the traffic survey and particular data, several options to improve and enhance the transport connections of these cities are proposed. In the paper, Weighted Sum Approach (WSA) is specified as suitable method to assess individual variants. Moreover, the paper confirms that mathematical methods for solving transport issues are not purely academic matter, however, they can bring a new perspective on certain situation. When transport planning, their effective use in the practice can prevent traffic problems in operational and economic aspects.
KEY WORDS: *commute, transport connection, public passenger transport, Weighted Sum Approach, Gravity model*

1. Introduction

Transport is a basic factor of today's modern economy and it is necessary to place a sufficient and special emphasis on its effective optimization and organization of existing transport systems in order to meet the requirements of sustainable development and increasing demand for transportation. Thus, it is inevitable to streamline transport and transportation processes by ensuring the consistency of transport capacity and changing market requirements [1-4].

When designing individual strategies, it is important to identify the most advantageous (the best possible) strategy while decision-making process and implement it in real life. The exact tool or technique for solving decision-making problems can be to apply mathematical methods of operational analysis. Using these methods, it is possible to achieve certain results which are not burdened by human error during the process of proper and correct utilization of input data. The success of implementing these methods in practice is also conditioned by management members skills which solve current transport (traffic) problems [2, 5-7].

The aim of this paper is to objectively evaluate the current state of transport connections between Český Krumlov and České Budějovice. To select the most appropriate solution, specific mathematical methods are utilized, particularly the Weighted Sum Approach (WSA) method and the Gravity model. On the basis of calculations and individual outcomes assessment, a modification of a current state of transport connections is proposed in order to better meet passengers' requirements.

2. Railway Passenger Transport Connections

Regarding the data about connections in railway passenger transport between cities of Český Krumlov and České Budějovice and back, departure and arrival details, days of connections and travel time were monitored (see Table 1, 2).

Table 1

Railway connections between cities of Český Krumlov and České Budějovice

Český Krumlov - České Budějovice						
Departure	**Arrival**	**Working days**	**Weekend**	**Holiday**	**Operator (carrier)**	**Travel time**
4:36	5:19	Yes	x	x	ČD	0:43
6:14	6:57	Yes	Yes	x	ČD	0:43
7:14	7:57	x	Yes	Yes	ČD	0:43
8:10	8:54	Yes	x	x	ČD	0:44
8:59	9:43	x	Yes	Yes	ČD	0:44
10:49	11:33	Yes	Yes	Yes	ČD	0:44
12:49	13:33	Yes	Yes	Yes	ČD	0:44
14:49	15:33	Yes	Yes	Yes	ČD	0:44
16:55	17:39	Yes	Yes	Yes	ČD	0:44
18:52	19:39	Yes	Yes	Yes	ČD	0:47
21:13	21:56	Yes	Yes	Yes	ČD	0:43

Source: Authors

Table 2

Railway connections between cities of České Budějovice and Český Krumlov

České Budějovice - Český Krumlov						
Departure	**Arrival**	**Working days**	**Weekend**	**Holiday**	**Operator (carrier)**	**Travel time**
6:07	6:55	Yes	Yes	Yes	ČD	0:48
8:08	8:52	Yes	Yes	Yes	ČD	0:44
10:19	11:04	Yes	Yes	Yes	ČD	0:45
12:19	13:04	Yes	Yes	Yes	ČD	0:45
14:19	15:04	Yes	Yes	Yes	ČD	0:45
15:13	16:03	Yes	x	x	ČD	0:50
16:08	16:53	Yes	Yes	Yes	ČD	0:45
18:21	19:06	Yes	Yes	Yes	ČD	0:45
20:07	20:52	Yes	x	x	ČD	0:45
22:45	23:28	Yes	Yes	Yes	ČD	0:43

Source: Authors

If we focus particularly on arrivals to jobs, schools and doctors during working days, the analysis confirmed that nine connections exist in the direction to České Budějovice and 10 connections are operated in the opposite direction to Český Krumlov. Passengers transportation is provided only by one operator, České dráhy, a.s. (ČD = Czech Railways), that has set the basic fare price (ticket price) to CZK 51/38/26 (adult/student/pensioner), however, this enterprise also offer a wide range of benefits. The driving time ranges from 43 to 47 minutes which is, due to surrounding traffic conditions, a very acceptable driving time.

3. Bus Transport Connections

Following Table 3 summarizes bus transport connections details between cities of Český Krumlov and České Budějovice. As far as individual connections are concerned, days of connections, carrier ensuring the specific connection, type of a commitment and travel time were monitored. From the table below, it is clear that the number of bus connections is wider compared to train (railway) connections.

During the traffic survey of bus connections between cities of Český Krumlov and České Budějovice, it was found that connections are provided by four carriers, where ČSAD, a.s. is the carrier in a public commitment and offers two bus lines. Three other carriers operate public transport without subsidies.

And again, if we focus particularly on bus connections during working days, from the table below, it is clear that the most of transport connections are offered by the carrier ČSAD, a.s. in a public commitment, and the private carrier Student agency, k.s. is next.

Travel time on road network is calculated by internet route-planner on 29 minutes, however, in practice, it is not real due to very significant traffic collisions in the municipality of Planá. In a case the travel is performed in the morning or afternoon, when most people arrive or depart from their jobs, the actual travel time between cities is about 50 minutes and sometimes longer.

Table 3

Carriers sorted according to a number of bus connections on working days

Bus line	Carrier	Number of connections from Český Krumlov to České Budějovice	Number of connections from České Budějovice to Český Krumlov
Bus line 320 020	ČSAD	29	28
Bus line 133 109	Student agency	13	15
Bus line 330 111	ČSAD	2	2
Bus line 330 810	RAIL Bus	2	2
Bus line 133 110	M express	1	1

Source: Authors

4. Data and Methods

The overall review of commute to jobs and schools within the municipality of Český Krumlov is passive, due to the prevailing number of outgoing passengers (departures) above incoming passengers (arrivals). On the total balance, commuters to schools represent about one-third of the share. The total balance of the city of České Budějovice is the only positive one within the whole South Bohemian Region. The number of arrivals to jobs and schools exceeds the number of outgoing passengers (departures). The table below (Table 4) contains an overview of number of outgoing passengers, incoming passengers and balance of commuters within the cities of Český Krumlov and České Budějovice.

Table 4

Number of outgoing and incoming passengers and balance of commuters. Source: CSO-office

	Outgoing passengers (departures)			Incoming passengers (arrivals)			Incoming passengers (arrivals)		
	Jobs	Schools	Total	Jobs	Schools	Total	Jobs	Schools	Total
České Budějovice	21401	8337	29738	24864	13267	38131	3463	4930	8393
Český Krumlov	8790	3436	12226	6060	1709	7769	-2730	-1727	-4457

Gravity Model. The Gravity model is mostly used when planning transport relations, and in this case, it is applied only to detect the suitability of commute interval between cities of Český Krumlov and České Budějovice. The relationship for calculating the commute interval through the Gravity model is expressed by Equation 1 [9, 10].

$$v_{ij} = \frac{\sqrt{Z_i C_j}}{t_{ij}^2}, \text{ (min)} \qquad (1)$$

where v_{ij} - commute interval (min); Z_{ij} - population of the source point (Český Krumlov - 13000 inhabitants); C_{ij} - population of the destination point (České Budějovice - 93 000 inhabitants); t_{ij} - transport resistance (time in minutes spent on a road by a vehicle = 29 min).

Calculation of the commute interval through the Gravity model:

$$v_{ij} = \sqrt{}(13\,000*93000/29^2) = 34770/841 = 41.34 \text{ min}$$

Based on the resulting stronger transport relation, it can be proposed that at least one hour interval of public transport would be appropriate for the given area.

Application of the Weighted Sum Approach - Method of Multi-criteria Evaluation of Variants. As far as this method is concerned, firstly, it is necessary to create a criteria matrix. In this matrix, individual transport connections between cities of Český Krumlov and České Budějovice are indicated, particularly one train line and five bus lines including carriers.

This matrix (see Table 5) consists of individual evaluation criteria: (1) transport distance - it is indicated in minutes; (2) fare price - the ticket price is indicated in CZK and specified for the adult; (3) number of connections - it is detected on the basis of traffic survey and specified for working days; (4) distance to stop - it is indicated in meters and for the distance from one particular housing estate - Špičák; (5) comfort - criterion regarding comfort is assessed on the basis of a scale of 1 to 6 where grade 1 being the worst and grade 6 being the best [11-17].

Table 5

Criteria matrix

Transport connection		Criteria				
train/bus (line)	Carrier	Criterion 1 Transport distance (min)	Criterion 2 Fare price (CZK)	Criterion 3 Number of connections	Criterion 4 Distance to stop (m)	Criterion 5 Comfort
Train	ČD	44	51	9	1300	5
Bus line 320 020	ČSAD	45	32	29	200	2
Bus line 133 109	ČSAD	35	36	2	200	3
Bus line 330 111	Student agency	40	40	13	200	6
Bus line 330 810	RAIL Bus	30	37	2	200	1
Bus line 133 110	M express	30	37	1	200	4
MIN/MAX	-	MIN	MIN	MAX	MIN	MAX

Source: Authors

5. Obtained Results

The WSA method is based on the construction of the linear function of utility on a scale from 0 to 1. The worst variant, according to the given criterion, will have the utility of 0 and the best variant will have the utility of 1. Other variants will have utilities between both extremes (marginal values). This method requires major information, the criteria matrix and the criteria weight vector. It allows for overall evaluation for each variant, and thus, it can be used for both searching for the most advantageous variant as well as organizing variants from best to worst.

The WSA method is considered the special case of the “Utility Function method”. If the variant a_i according to the criterion j reaches the certain value of y_j, it brings to a user the utility that can be expressed by the linear function of utility. The total utility of a variant is expressed by the weighted sum of values of partial utility functions where u_j are the partial utility functions of individual criteria and v_j are weights of criteria. This can be calculated according to the Eq. 2 [12, 18, 19].

$$u(a_i) = \sum_{i=1}^{m} v_j u_j(y_{ij}). \tag{2}$$

The WSA method procedure is specified by following steps:

1. We determine the ideal variant H with a valuation of (h_1, ..., h_n) and basal variant D with a valuation of (d_1, ..., d_n).

2. We create a normalized criteria matrix R. Its elements are obtained by the Eq. 3.

$$r_{ij} = \frac{y_{ij} - d_j}{h_j - d_j}. \tag{3}$$

3. The matrix R already represents the value matrix of utility functions of the i-th variant according to the j-th criterion, since the elements of this matrix are linearly transformed by the criteria values so that $r_{ij} \in$ <1;0>. Then, the basal variant corresponds to the value of 0 and the ideal variant corresponds to the value of 1.

4. For each variant, we calculate the aggregate utility function using the Eq. 4.

$$u(a_i) = \sum_{i=1}^{n} v_j r_{ij}. \tag{2}$$

Variants are aligned in descending order according to the value (a_i) and necessary number of variants with the highest utility values is considered the solution of the problem.

The resulting normalized matrix, including the resulting order according to maximization and minimization criteria, with a calculation of each variant utility, is summarized in Table 6.

Table 6

Normalized criteria matrix

Transport connection		Criteria					$u(a_i)$
train/bus (line)	Carrier	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	
Train	ČD	0.0667	0	0.2857	0	0.8	0.12762
Bus line 320 020	ČSAD	0	1	1	1	0.2	0.8
Bus line 133 109	ČSAD	0.0667	0.7895	0.0357	1	0.4	0.36447
Bus line 330 111	Student agency	0.3333	0.5789	0.4286	1	1	0.51174
Bus line 330 810	RAIL Bus	1	0.7368	0.0357	1	0	0.53532
Bus line 133 110	M express	1	0.7368	0	1	0.6	0.52104
MIN/MAX	-	MIN	MIN	MAX	MIN	MAX	x
Weight	Scoring method	0.2	0.2	0.4	0.1	0.1	x

Source: Authors

6. Discussion

Thus, according to the WSA method, the best possible variant seems to be the bus line 320 020 (České Budějovice - Český Krumlov - Větřní), which is provided by the ČSAD, offering the largest number of connections, the lowest fare price and the optimum transport distance on a route Český Krumlov - České Budějovice.

According to the WSA method, the order on the second and third place is almost identical. This is caused by the same fare, the transport distance and the low number of offered connections. The fourth place by the Student agency is caused by a higher fare price. The fifth place is represented by an irregular line provided by the ČSAD, and the train line provided by the ČD is at the last place. The problematic location of the railway carrier is caused due to a considerable distance needed to get to the train station and the highest fare.

Order of variants according to the WSA method:

1. bus line 320 020 (České Budějovice - Č. Krumlov - Větřní) – ČSAD;
2. bus line 330 810 (Frymburk - Lipno nad Vltavou - Český Krumlov - Lhenice - Písek - Prague) - RAIL Bus;
3. bus line 133 110 (Prague - Tábor - České Budějovice - Český Krumlov) - M express;
4. bus line 133 109 (Prague - České Budějovice - Český Krumlov) - Student agency;
5. bus line 330 111 (Český Krumlov - České Budějovice - Písek - Prague) – ČSAD;
6. train line (České Budějovice - Český Krumlov) – ČD.

7. Conclusions

On the basis of the information provided by the traffic survey and calculations, it can be stated that the number of traffic connections between Český Krumlov and České Budějovice is sufficient, yet it would be advisable to think about the better timetables of given transport connections in order to avoid a duplicity of bus connections as well as acceleration of railway connection between these two cities and better access to the railway station.

The analysis also confirmed that, among the most significant criteria influencing the public transport connection between cities of Český Krumlov and České Budějovice, the number of individual transport connections is at the first place, followed by the transport time, the fare price and also the distance to the railway/bus station.

Thus, in general, it can be concluded that passengers prefer bus transport than railway (train) transport. This preference is caused especially due to the higher number of connections, the lower fare price, and, in the case of Český Krumlov, a really long distance to the train station. For further streamlining traffic on the transport line between both cities, it would be appropriate to speed up transportation services by implementing a so-called express connections that would create backbone (main) transport connections throughout the day. In addition, it would be advisable to organize traffic by establishing a slow regional line which will stop at all stopovers.

Mathematical methods do not only bring new insights into the given situation, however, can prevent traffic problems while their real application, and it is also possible to achieve higher economic efficiency when optimizing regional transport lines.

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Crisis Solution of Accidents During Floods and Fires

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Abstract

The floods result in a need to deploy special equipment to dispose and drain excessive water. It includes mobile equipment transportable or conveyable on various communications and in different, often not easily accessible terrain. The paper deals with an approach to designing and construction of such mobile assets with a possible water transportation. Focus is laid on reliability of such equipment.
KEY WORDS: *crisis situation and accident, water pumps, reliability of means, mobility of assets*

1. Introduction

Crisis situations are defined as situations exceeding common, standard behavior or course of events. Floods and fire events are situations that are not planned by a time limit, however it does not mean, that we are not trained or ready for them. The responsibility of crisis management and units dealing with such situations and being deployed into, is to provide all possible solutions with equipment. In this notion, special equipment is considered as machinery and means that are able to meet tasks in non-standard conditions sustaining technical quality, operational capability and functionality.

The paper provides a current notion of special equipment, its classification and possible tends of development from a point of view of a scientific and professional activity. Starting points stem from orientation and heading of needs of crisis management and armed departments within alliance groupings assigned for defense needs, to solve non-standard situations, where there is a presumption that special equipment will be developed, operated or deployed. Special attention is paid to a mobility of special equipment. The container program being solved is understood not only from a view of its operation, but also from a view of its handling and stability. Such equipment requires a thermal, radiation, ballistic protection and ballistic reinforcement, resistance to moisty environs, anticorrosion resistance. The problem is being used through material and machinery technologies aimed at their hardening. The paper also deals with provision of electrical energy and water for working places with special equipment in containers.

The paper details particular examples of new equipment designed by the Faculty of Special Technology in cooperation with particular organizations and institutions in Slovakia. [4]

2. Crisis Situations from a View of Providing them with Special Equipment

Crisis situations occur in non-traditional, non-standard situations, on a road and in a field, in air, in water. From a view of needs of crisis management with special equipment, we have been solving the following issues:

- Access and availability, cross ability through water, sloughy, mountain and forest terrains, on road and by air.
- Mobility and transportation of equipment and systems.
- Hardening of mobile working places in form of thermal, radiation, ballistic protection, and resistance to moisty environs, anticorrosion resistance.
- Provision with electric energy.
- Provision with potable and utility water.
- Sanitary and medical support. [2]

For purpose of this paper we submit possible solutions in provision with electric energy, potable and utility water and a container system for transportation of equipment and systems.

Forms of hardening are to be solved in line with heading of special equipment development as well as for needs of state protection. Trends in defense capabilities can be applied as starting points. [4]:

- Development and application of new technologies.
- Increased efficiency and a fatal capacity of asymmetrical threats, mainly by active terrorist groups.
- Solution of post-conflict situations.
- An increasing part of battles led in urban terrain and in cities.
- Application of highly accurate and efficient weapons on targets in environs with civil population.
- Saving of human resources as a priority in operation planning.
- Gradual roboting of operation.

3. Reliability of Special Machines and Equipment

Reliability is a general notion, which underwent a complex historical evolution, nowadays it is used in different contexts and with different interpretations. Rise of a responsibility notion comes from 1940s with relation to development, production and commissioning of complex weapon systems e.g. aircraft carriers (USA), missiles (Germany) and others. For an efficient deployment it was necessary to ensure that a weapon complex meets requested functions and conventional procedures did not ensure this aim. At present time reliability is defined by standards as a comprehensive term being used to describe readiness and factors that has an influence over: no-failure operation, maintainability and sustainability of maintenance. This definition considers a fact, that an ability to meet required functions is not assigned only by features of the object itself, but this ability is significantly influenced by external factors, as e.g. maintenance organization and technology, its logistic support, human reliability etc. Global assessment of reliability includes so called complex indicators of reliability e.g. a coefficient of readiness that is defined by a relation [6]:

$$K_p = \frac{\sum_{i=1}^{n} t_{pi}}{\sum_{i=1}^{n} t_{pi} + \sum_{j=1}^{m} t_{oj}}, \tag{1}$$

where $\sum t_{pi}$ - total of time periods of failure less operations; $\sum t_{oj}$ - total of repair time during a time period being assessed.

Sometimes a coefficient of technical usage is applied that is defined by a relation [6]:

$$K_{TV} = \frac{\sum_{i=1}^{n} t_{pi}}{\sum_{i=1}^{n} t_{pi} + \sum_{j=1}^{m} t_{oj} + \sum_{k-1}^{p} t_{up}}, \tag{2}$$

where $\sum t_{up}$ - total of periods of preventive maintenance.

Arrangement of elements and blocks of machines and equipment is a way how to solve e.g. a no-failure operation.

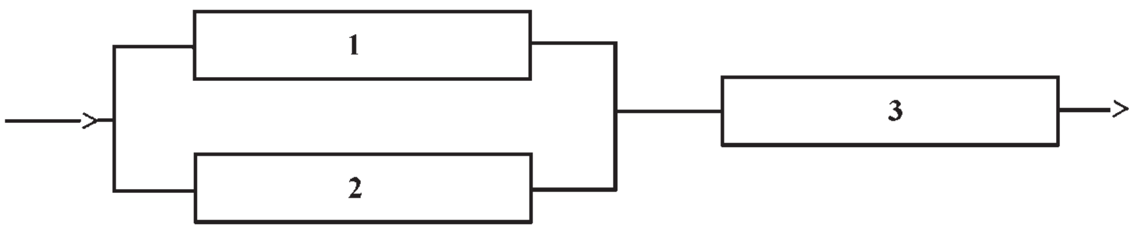

Fig. 1 Series and parallel arrangement of machine blocks

In case that elements are arranged in series and parallels in line with a chart in Fig. 1 then the above mentioned rules can be used as well as for a computation of parallel arrangement of elements as follows [1], [4]:

$$\begin{aligned} F_{1,2}(t) &= F_1(t)F_2(t) \\ R_{1,2}(t) &= 1-\{F_1(t)F_2(t)\} \end{aligned} \tag{3}$$

and a computation of a series configuration composed of elements (1,2) and 3 will be:

$$\left.\begin{aligned} R_{1,2,3}(t) &= R_{1,2}(t)R_c(t) \\ R_{1,2,3}(t) &= \{1-[F_1(t)F_2(t)]\}F_3(t) \end{aligned}\right\}, \tag{4}$$

4. Specification of Climate Conditions for Needs of Assessment of Quality and Operation Reliability of Some Special Equipment

As extreme climate conditions are considered all conditions that are beside values typical for Central European mild climate zone. This environs has been defined by values shown in Table 1.

Table 1

Features of a mild climate zone [4], [5]

The lowest air temperature	-40°C
The highest air temperature	+40°C
The highest relative humidity	95%
The highest absolute humidity	60 $g.m^{-3}$
The highest intensity of solar radiation	1120 $W.m^{-2}$
The highest intensity of thermal radiation	600 $W.m^{-2}$
The highest air speed	20 $m.s^{-1}$

Area, where selected machines and equipment were monitored, is characterized as environs with an increased corrosive aggressiveness, dusty environs with a non-flammable dust, however that deteriorates relative dielectric permittivity and electric disruptive resistance due to its conductivity, environs with quakes and environs with biological pests.

Such characterized environs as a consequence of extreme climatic conditions, influences mainly corrosion resistance of materials. In addition it significantly influences also parameters of electric parts and components that are sensitive to electrostatic charge, to conductivity of environs, which form a part of machines and equipment. I t is also necessary to consider an influence of a corrosion spreading more quickly on electric contacts, interface and juncture fields, unless they are especially adopted to this environs. Formation of non-conductive layers occurs resulting in sparkling and creation of electric arcs (transition actions). Similarly it is at corrosive attack on commutators, where sparkling occurs as well as abrasion on non-conductive corrosion layers and clogging of winding with ground particles through a ventilation.

Aiming to assess the quality and operational reliability of selected special equipment as a variable dependent on climatic conditions, it is suitable to choose measurable parameters or quantifiable in monitoring.

Several types of simulation chambers are used to simulate effects by environs on parts and devices. There is an environment created inside the chambers to imitate the environs where usage of products is expected, e.g.:

- Testing with moist heat– a cyclic mode;
- testing with moist heat – a non-cyclic mode;
- testing with mildew;
- testing for tightness;
- testing with solar radiation;
- testing with atmospheric pressure;
- testing with temperature alteration;
- freeze testing;
- dry heat testing and salt steam testing;
- low pressure testing;
- dust testing.

In case that the equipment would be deployed in environs with increased exhaust concentrations and in littoral areas, we recommended the following tests:

- corrosion test in a condensation chamber – to verify a resistance of materials and surface protection, when it relates an influence of an increased humidity, respectively and increased concentration of SO_2 with no effect by additional factors;
- corrosion testing in salt mist – to verify a resistance of materials and surface protection in a littoral atmosphere with a sea water aerosol as a threatening factor;
- solar radiation testing – to verify a resistance of a product to effects of light and heat effects of solar radiation;
- dust and sand testing – simulation of desert conditions;
- testing with dry and wet heat;
- testing with mildew – simulation of a biological attack on material;
- vibration testing.

The above listed tests have proved in practice with relation to a later operation of equipment and material e.g. in areas of equatorial Africa and on Cyprus Island.

5. Intention to Provide an Affected Area with Potable and Utility Water

Sufficient water supplies require a huge funds, investments into infrastructure as a needed network, filling stations and water treatment facilities. Especially it is important to handle the supplies of utility and potable water in crisis situations. In order to solve these tasks, the attention is to be paid to:

- Reconnaissance of water sources and diagnostics of its quality.
- Water transportation and shipment.
- Water treatment.
- Processing, treatment and transportation of sludge as a residual material after water purification.

Container program was developed for needs of crisis program. Technological procedures of water treatment and a treated water itself must comply with different requirements:

- Water must be of consistent quality;
- It must be delivered in sufficient quantities ;
- Total manufacturing costs must be minimal.

The quality of treated water must comply with relevant standards or regulations. The SR Regulation Nr. 354/2006 Reg. on requirements for water assigned for human consumption and quality control of such water is valid for potable water.

An example of a treatment of contaminated water for application is shown in the Fig. 2.

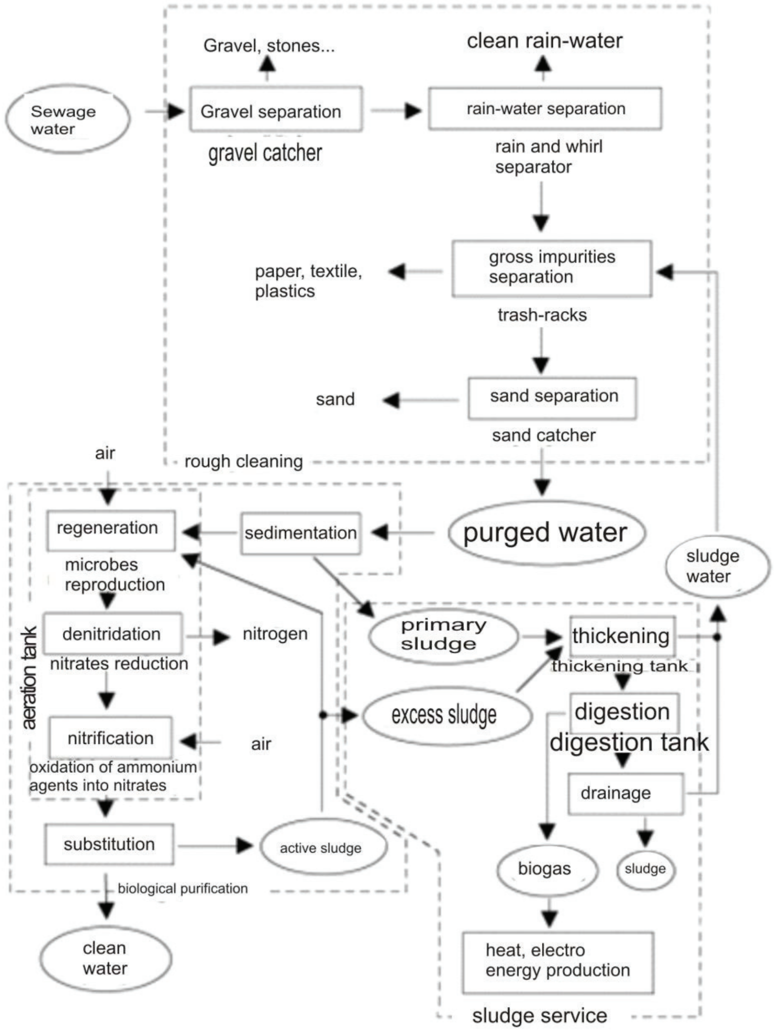

Fig. 2 Flow chart of a water treatment facility [5]

The water treatment facility needs to be transported and a best way is to locate it into a container (Fig. 3), as it can be transported in all transportation modes.

Fig. 3 Transportation of a container water treatment facility [5]

Container sewage water treating facilities serve to purify sewage water from small isolated sources of contamination as. satellite small towns, hotels and lodging houses, camps, filling stations, small industrial works. The container water treatment facilities play a non-substitutable role in crisis management. The water treatment facilities are designed as rectangular, cantilever tanks, in which a technological construction is installed. Such completed water treatment facilities can be easily transported. The advantages of container water treatment facilities comparing with a standard construction of a water treatment facilities are as follows:

- low price;
- easy service;
- reliable, safe and quiet operation, withstanding easily an impulse load;
- high cleaning effect (up to 95% at a temperature of a sewage water about 14°C);
- they are inodorous;
- variability and a possible increased capacity in phases;
- a simple structural preparation (basic concrete panel only);
- a total production in a manufacturing works;
- a swift commissioning into service (only a calendar week).

6. Current Electric Energy Sources Used for Mobile Logistic Assets in ISO 1C Containers

Electric source units in ISO 1C containers are assigned for a production and distribution of electric energy as a backup source to provide operation of electric facilities in field conditions. They include a drive unit, a plant producing electric energy, transformer station and distribution wiring net. The power block is installed in the ISO 1C container, it is sound and thermal proof, tempering and airing is provided with embedded exhaust blowers and through orifices with closing blinds for airing. The container floor is designed as a leak-proof tub assigned to catch possible leakage of operating liquids. The container includes a sales stock for distribution wiring and power block accessories. ISO 1C container is equipped with large door with a visor and detachable panels for an easy access for a quotidian maintenance. [1].

One of the most important requirements to electric sources for mobile assets is applicability in a micro climate area with an N14 (STN 03 8206) climate:

- Temperature ranging from -35°C to +55°C;
- Relative humidity of air up to 30% at temperature of +25°C;
- Velocity of air flow up to 20 $m.s^{-1}$ from all directions.

Atmospheric precipitations in form of rain with intensity of 3 $mm.min^{-1}$ falling 30° angle wise in all directions [2].

They need to be produced so that can be connected to several kinds of distribution systems:

- TN – C, 3 + PEN, 400/231 V – the most common four-line wire distribution system;
- TN – S, 3 + PE + N, 400/231 V – distribution system used in the world;
- TT, 3 + PE + N, 400/231V – distribution system, which is not much used, however it exists in electric wiring of special equipment;
- IT, 3 + PE + N, 400/231 V – an isolated system being used mainly in special or medical equipment and in power equipment for insular power facilities. [4]

Containers are adjusted to their assignment and their electric parameters comply with their function as shown in Table 2.

Table 2

Electric installation parameters of some logistic container working places

Designation and marking of a logistic container	Voltage system	Maximum power input, kW	Output of a source itself, kW
ISO 1C container – social	TN.S 3+N+PE 400/230V AC 50Hz	18,2	0
ISO 1C container – water tank	TN.S 1+N+PE 1x 230V, 50Hz	1,25	0
ISO 1C container – accommodation 2-bed	TN.S 3+N+PE 400/230V AC 50Hz	5,5	0
ISO 1C container – accommodation 4 bed	TN.S 3+N+PE 400/230V AC 50Hz	5,5	0
ISO 1C container – briefing folding 3-wall	TN.S 3+N+PE 400/230V AC 50Hz	7,5	0
ISO 1C container - office	TN.S 3+N+PE 400/230V AC 50Hz	6	0
ISO 1C container – refrigerator for deceased	TN.S 3+N+PE 400/230V AC 50Hz	5,1	0
ISO 1C container – refrigerator, two chamber	TN.S 3+N+PE 3x 400V, 50Hz	4,8	Combustion engine
ISO 1C container – surgery ward	TN.S 3+N+PE 400/230V AC 50Hz	9,5	
ISO 1C container – mobile workshop asset of „A", "B" and "C" types	TN.S 3+N+PE 400/230V AC 50Hz	15	5,1

One of the most ecological kinds of energies is electric energy obtained through a direct transformation of solar radiation, (as shown in Fig. 4) which has been known since the 19th century. There is a large excess of solar energy impinging the Earth´s surface, however with a low density, and it is featured by a seasonal and daily variability influenced by weather as well. However majority of PV systems do not need a direct solar radiation.

Recently the wind power engineering has marked a huge development with a yearly increase of output more than 30 %. Nowadays the wind power stations are routinely built with output of 1,5 - 2,5 MW. The wind turbines are used with a diameter from 0,4 m to 80 m and with output from 0,25 kW up to MW order.

Fig. 4 Examples of using photovoltaic systems on mobile equipment [3]

7. Conclusion

Need for science, research and education in special equipment is apparent. We can prevent from effort to rename special equipment through its complex definition corresponding with current needs of science, research and practice. Consequently through a development and publishing a relevant publication of a monograph type, this would fully characterize a special equipment issue. Cooperation of Trencin University called by Alexander Dubcek in Trencin with schools and institutions in Slovakia and abroad is a presumption for a development of special equipment in a complex term. An issue relating materials and technologies for special equipment has historical roots in abroad as well as in Slovakia and in the past also a successful history of cooperation. It is a base to start solving other, new projects being solved on an international level.

Preconditions of work in areas related to special equipment are rather wide and it is obvious, that authors as well as the Faculty they have been working for, will find a place of their materialization.

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Model of Artificial Neutral Network to Approximation of Injection Rate in Conditions of Supply of Divided Dose

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Abstract

In the paper is presented a methodology serving to evaluation of fuel outflow rate from atomizer of compression ignition engine. Based on the data from a measurements performed with use of injection dose indicator, courses of fuel injection have been obtained. The measurements were performed for divided fuel dose, at constant fuel pressure in the rail and changing values of preset times of dwell between portions of the dose. The artificial neutral networks were used for interpolation of injection courses for values of the dwell between values preset in the measurements. A modification of artificial neutral network, which more accurately maps courses of the injection occurring in conditions of divided dose supply, was proposed. Two criteria: criterion of integration and Pearson correlation coefficient, were used to assessment of mapping of calculated courses.

KEY WORDS: *Diesel engine, fuel injection rate, divided fuel dose, artificial neural network*

1. Introduction

Contemporary combustion engines with compression ignition should be characterized by high efficiency, low emissions of harmful components of exhaust gases and acceptable level of generated noise. Increasing operational requirements for traction power units can only be met owing to knowledge of time distribution of the fuel dose supplied to the engine and course of combustion process. These processes, despite many performed research studies, are not sufficiently known. This is due to overlapping and interdependencies of a phenomena occurring during processes of: fuel supply and combustion. Design development of high-pressure injection systems, their manufacturing technology, and in particular development of electronic control systems, have made it possible that often contradictory requirements put on the engines can be met, and resulted in significant increase in knowledge on injection and combustion of fuel.

Development of combustion engines with compression ignition is associated with development of injection systems. Modern compression ignition engines are mostly fueled with use of electronically controlled Common Rail systems, with electromagnetic or piezoelectric injectors. They allow accomplishment of multiphase injection, and owing to it, shaping over a wide range of heat release course, and course of pressure in cylinder of the engine. This occurs under conditions of precise dosing and very good atomization of the fuel, at high injection pressures. Course of the injection, i.e. fuel outflow rate from injector‘s atomizer, is one of those elements, which greatly influences broadly understood parameters of engine operation. How-ever, it is necessary to know the factors influencing course of the injection and to have ability to measure fuel outflow rate from the atomizer.

2. Aim, Objective and Methodology of the Research

In the field of combustion engines the artificial neural networks are widely implemented. In a brief due to necessity review of the bibliography, covering only the studies on fuel supply systems of internal combustion engines, the study of P. Czech should be presented. The author consistently introduces the artificial neural networks to testing and diagnosis of a machines and combustion engines. One of the latest studies [3, 4] concerns the method of diagnosing elements of fuel supply systems. The study [6] is devoted to problems of detecting a damage of injectors in big compression ignition engines. Five types of the neutral net-works have been used for analysis of changes in the operating parameters, resulting from damages and wear. In turn, the study [2] discusses usage of the neural networks in analysis of the values measured on engine dynamometer, especially fuel consumption. The implemented network consisted of six inputs and one output.

The aim of the study was to evaluate a possibility of interpolation of courses of fuel outflow rate from atomizer of compression ignition engine. These courses, being the basis to calculations were determined experimentally, depending on preset time of the dwell between portions of the dose at constant fuel pressure in the rail. It was proposed to solve this task with use of artificial neural networks.

The authors have previously undertaken an analysis of a similar issue. In study [1], they had been considered possible to determination fuel outflow rates from atomizer for intermediate values of fuel pressure, between measured courses. However, this study involved an injector from automotive engine used in passenger car and lower number of measurement cases, lower doses and fuel flow rates, lower values of supplied doses and fuel outflow rates. Constant values of preset injection times, at changing pressure of fuel in the rail, were considered. The number of learning data was relatively small. Defined task was solved using a unidirectional, multilayer neural network.

In this paper are presented results of the measurements and calculations of fuel outflow rate from atomizer of a truck. Measurements of injection course were performed at the test stand with use of indicator of injection dose. The stand contained a chamber with increased volume. Fuel pressure growth was measured in the chamber to which the injection occurred. Measurement of the pressure was based on registration of digital signal from the AVL GU21D piezo sensor with use of the Tektronix TDS-3014 digital oscilloscope, and then approximation of the recorded courses with polynomials, to obtain smooth functional forms suitable for differentiation. Detailed method of the proceedings is presented in [5].

Fuel outflow rate from the atomizer and total doses were calculated of the base of the dependency (1):

$$\frac{dB}{dt} = \frac{V}{E}\frac{dp}{dt} \quad \left[m^3/s \right], \tag{1}$$

here B – fuel dose per single injection; t – time; V – volume of indicator's chamber; E – elasticity modulus of fuel; p – pressure in indicator's chamber.

Changes in the modulus of elasticity for variable parameters of the fuel (temperature and pressure) contained within the limits determined by conditions of the measurement were taken into account in each calculation step of a given course. Integrating each time the course of injection dB/dt, which was obtained from successive transformations and calculations, calculated volume of the fuel per a single injection was obtained.

3. Measurement Results and their Analysis

Performed measurements were aimed at assessment of an impact of: fuel pressure in the rail, method of dose division and time of dwell between injections, on course of the injection. The study included measurements of injection courses of divided dose at constant fuel pressure in the rail and variable preset times of dwell between portions of the dose. Preset values of time of the first portion of dose pilot and the second portion of the dose main amounted to 400 µs. In the table 1 are summarized values of time of the dwell as preset during the measurements.

Table 1

Preset dwell time taken during the measurements

i	1	2	3	4	5	6	7	8	9	10
Injection dwell time t_i^b, µs	1	100	200	300	400	500	600	700	850	1120

Fig. 1 shows courses of fuel outflow rate from the atomizer, determined according to the methodology presented in the Chapter 2. There is a noticeable differentiation in forms and times of the injection. The biggest differences between measured courses of pressure in the indicator and the approximated ones are seen in the final phase of the first part of injection. In turn, the biggest relative errors occur at initial period of the injection and are about 2%.

In the Fig. 2, with use of a surface stretched over measured courses of the injection, it was presented investigated range of changes in parameters of the injection process. The subject-matter of the consideration is method of determination of fuel outflow rate from the atomizer in areas where such rates had not been determined on the test stand.

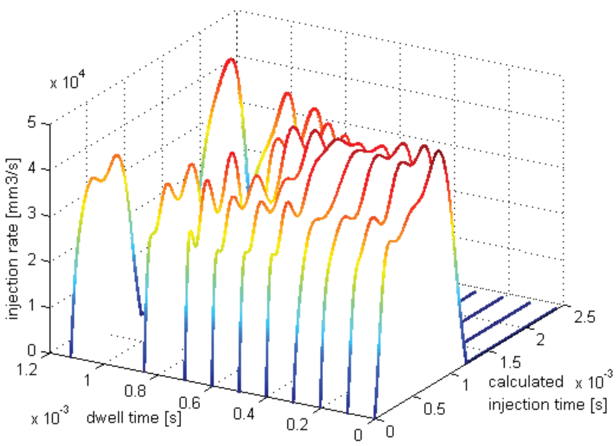

Fig. 1 Measured courses of the injections for constant values of the pressure, divided dose, and changing values of preset times of dwell

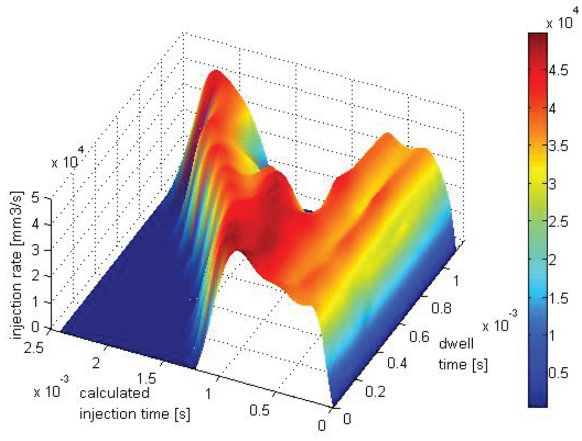

Fig. 2 Change in fuel outflow rate from the atomizer in function of time of dwell, for divided dose at constant values of fuel pressure

4. Calculation of Injection Courses with use of Artificial Neutral Networks

Based on experience learn from the work performed earlier [1], it have been performed calculations of the fuel outflow rate for the data presented in Fig. 1. An artificial neural network with two inputs and one output and with three hidden layers was used. In the first succession, the calculations were made with use of the learning data, that is, the data obtained from measurements. Results of the measurements and calculations, for all analyzed cases, are summarized in Fig. 3. The presented results are referred to the network in which the number of neurons in successive hidden layers amounts to 2 × 7 × 25 × 7 × 1 respectively. We can see very good compatibility of the compared courses.

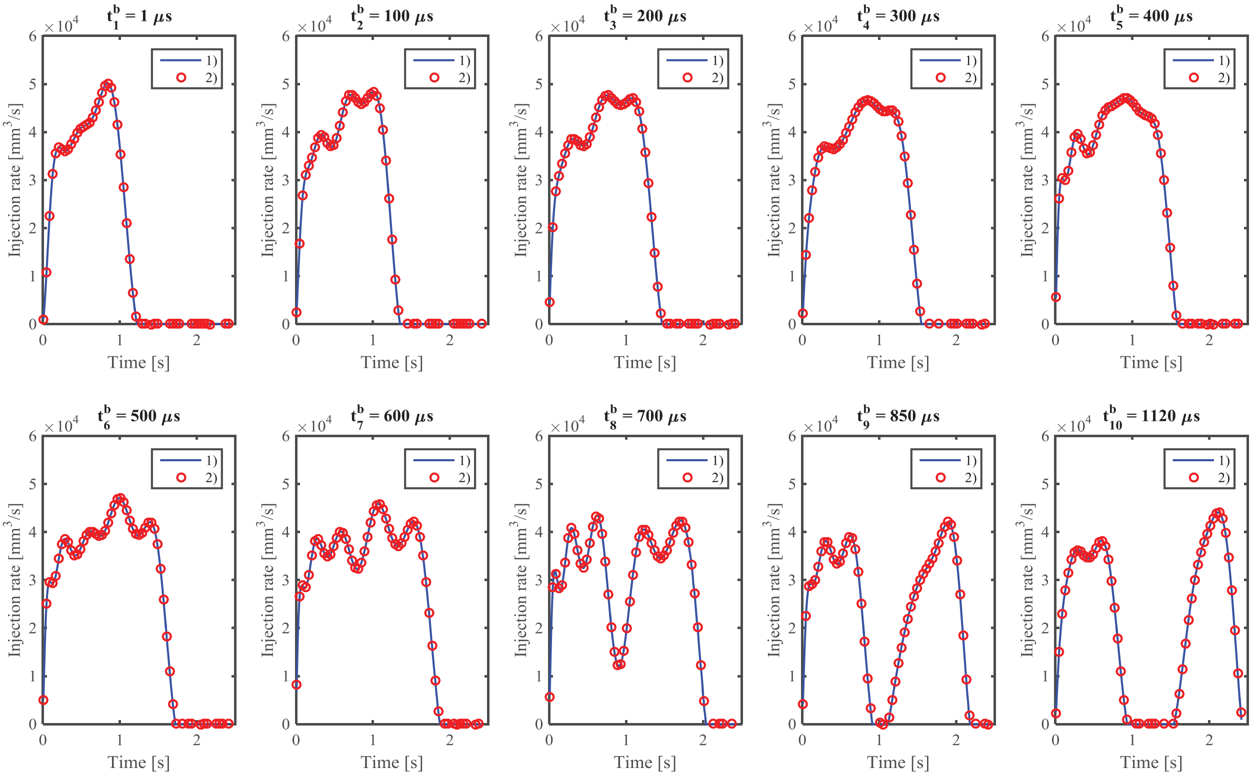

Fig. 3 Comparison of measured 1) and calculated 2) fuel outflow rates from the atomizer based on dwell time, divided dose and constant values of fuel pressure

Next, calculations of injection courses were performed for times of the dwell between portions of the dose, different from those used in the measurements. The injection dwell time taken for the simulations was calculated according the formula (2):

$$t_i^s = \frac{t_i^b + t_{i+1}^b}{2}, \; 1 \le i < 9 . \tag{2}$$

Selected calculated courses, referenced to the values obtained for the learning data, are shown in Fig. 4.

Accuracy of the mapping of all calculated injection courses was evaluated on the basis of two criteria. The first criterion was the integral from injection course (fuel dose) and the second one was the Pearson correlation coefficient.

Integral of the injection rate calculated for the injection dwell time t_i^b (3):

$$I_i^b = \int_0^{t_e} q_i^b(t)\,dt , \tag{3}$$

here $q_i^b(t)$ is course of the injection rate determined for the injection dwell time t_i^b. Similar integrals can be calculated for the injection rate courses $q_i^s(t)$ obtained for the times t_i^s taken in simulation of the neural network (4):

$$I_i^s = \int_0^{t_e} q_i^s(t)\,dt . \tag{4}$$

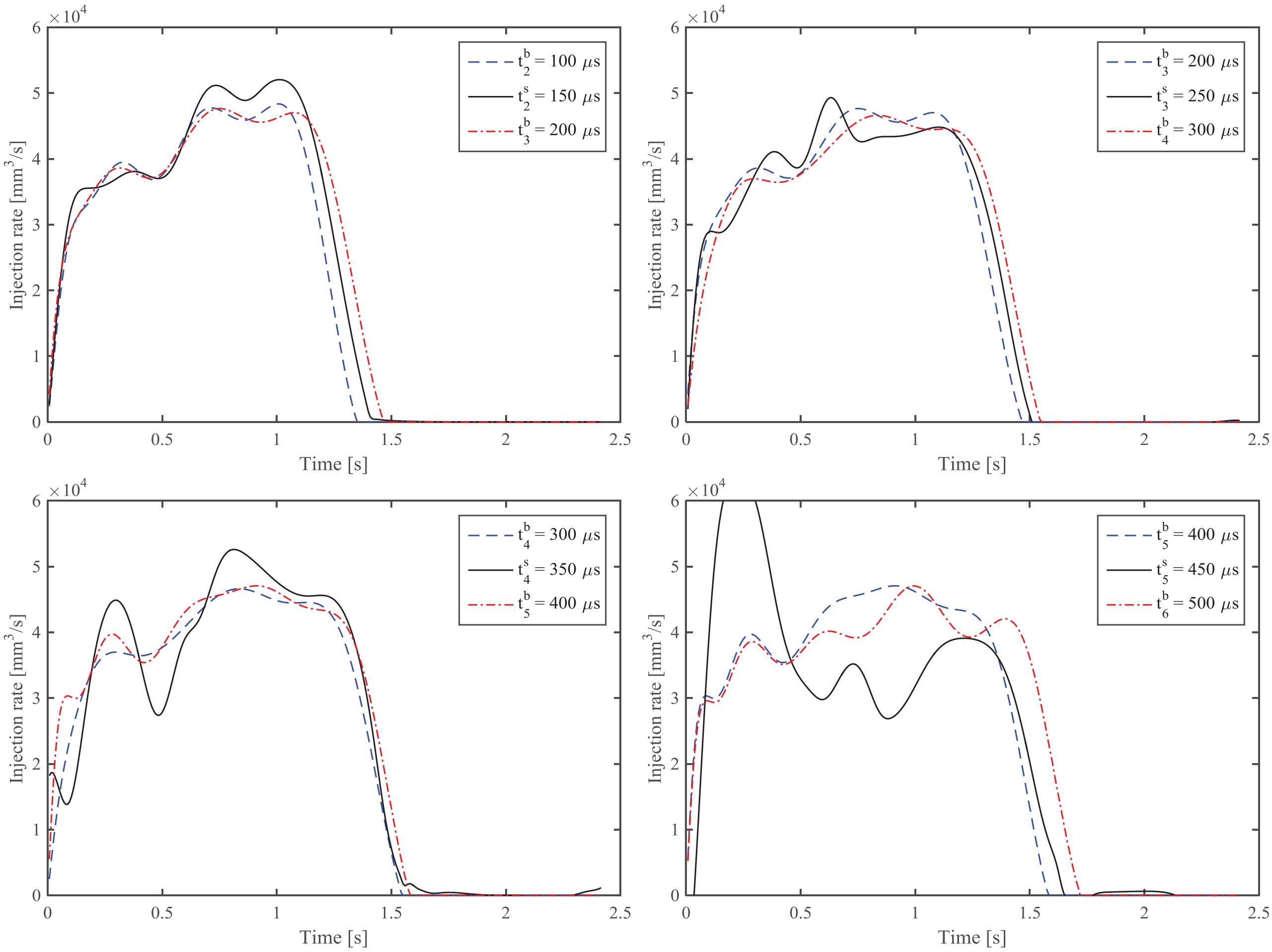

Fig. 4 Comparison of calculated injection courses for the learning data (blue and red lines) with the courses determined for intermediate values from the dwell time

Pearson correlation coefficients can be calculated as follows:

$$r_i = \frac{\sum_{j=1}^{n}\left(q_i^b\left(t_j\right)-\bar{q}_i^b\right)\left(q_i^s\left(t_j\right)-\bar{q}_i^s\right)}{\sqrt{\sum_{j=1}^{n}\left(q_i^b\left(t_j\right)-\bar{q}_i^b\right)^2 \sum_{j=1}^{n}\left(q_i^s\left(t_j\right)-\bar{q}_i^s\right)^2}}, \tag{5}$$

where n is the number of time steps, $\bar{q}_i^b$, $\bar{q}_i^s$ are means of all discrete values of $q_i^b(t_j)$ and $q_i^s(t_j)$.

Obviously, the integrals were calculated only for those parts of the graphs that lie above the OX axis. For the sectors where course of the fuel outflow rate is negative, the integral equal to zero was taken.

Values of criteria parameters are summarized in the Tables 2 and 3. In the Table 2 are shown values of the integrals for the individual courses. As can be seen, the values shown in the fourth column for a longer dwell times significantly differ from the expected. It is why the second indicator – the Pearson correlation coefficient – was introduced (Table 3). Its values evaluated for the analyzed part of the courses are significantly different from the value of unity.

Table 2

Integrals of injection rate obtained from single MLP network for different simulations

i	t_i^s, μs	I_i^b	I_i^s	I_{i+1}^b
1	50,5	4.21E+04	4.37E+04	4.91E+04
2	150	4.91E+04	5.36E+04	5.36E+04
3	250	5.36E+04	5.45E+04	5.52E+04
4	350	5.52E+04	5.75E+04	5.86E+04
5	450	5.86E+04	5.68E+04	6.16E+04
6	550	**6.16E+04**	**6.65E+04**	**6.52E+04**
7	650	**6.52E+04**	**5.24E+04**	**6.47E+04**
8	775	**6.47E+04**	**9.87E+04**	**5.45E+04**
9	985	**5.45E+04**	**3.68E+04**	**5.06E+04**

Table 3

The Pearson correlation coefficients obtained from single MLP network

i	t_i^s, μs	r_i	r_{i+1}
1	50,5	0.9817	0.9709
2	150	0.9898	0.9896
3	250	0.9890	0.9874
4	350	0.9816	0.9766
5	450	**0.8435**	**0.8339**
6	550	**0.7811**	**0.7833**
7	650	**0.5682**	**0.5882**
8	775	**0.4585**	**0.1152**
9	985	**0.2314**	**0.2030**

In view of the very good mapping accuracy of the learning data, based on experiences from the work [A], the authors expected that increase in number of the measurement cases would have effect on increase of accuracy of the approximation calculations. However, analysis of the obtained results has shown that the selected artificial neural network well approximates the injection courses for the dwell times from the middle of the analyzed interval, while the results for the boundary values are subject to significant errors.

Therefore, after many additional attempts, a modification of the artificial neural network was proposed, which would be used to calculation of the injection courses. The proposal consists in introducing of two networks. Each of these networks will address another set of learning data. The learning data has been split into two sets, depending on the preset dwell time. It has been found, however, that in this part of the investigated area where significant changes in form of the injection are occurring, change in the parameters is better reflected by another type of the network (2 × 7 × 7 × 4 × 1). Scheme of the network after the modification is shown in Fig. 5.

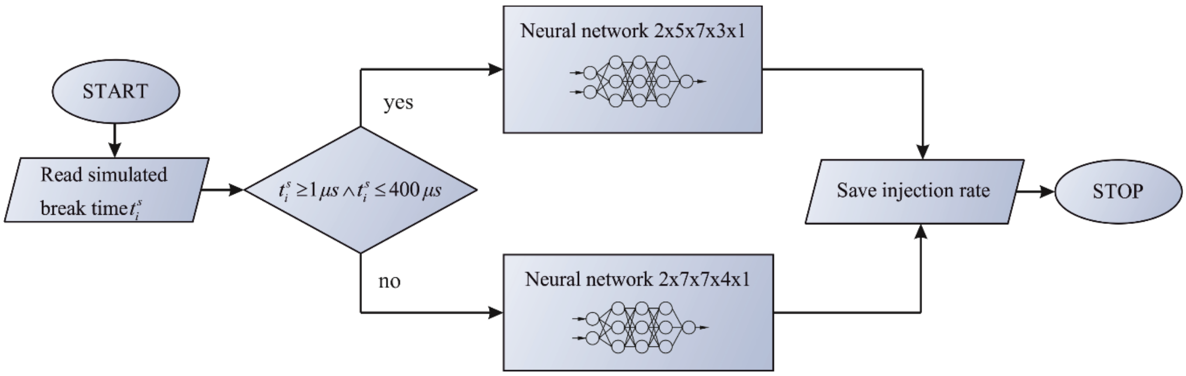

Fig. 5 Scheme of modified artificial neutral network to calculations of injection course

Results of the calculation of the fuel outflow rate from the atomizer obtained with use of the modified system of neutral networks are shown in Fig. 6.

It can be seen that the results of the calculations of injection courses for intermediate injection times are well mapped. However, it should be needed to perform their quantitative assessment, based on previously utilized criteria. Results of the repeated assessments of the mapping of the calculated fuel outflow rates from the atomizer are summarized in Tables 4 and 5. It can be seen that proper relations between integrals of injection courses (fuel doses) are maintained. Also values of correlation coefficients of the analyzed curves significantly increased, what proves a very good mapping of the analyzed values.

Table 4

Integrals of injection rate obtained from the proposed model of the neural network

i	t_i^s, μs	I_i^b	I_i^s	I_{i+1}^b
1	50.5	4,213E+04	4,624E+04	4,911E+04
2	150	4,911E+04	5,156E+04	5,360E+04
3	250	5,360E+04	5,472E+04	5,517E+04
4	350	5,517E+04	5,654E+04	5,859E+04
5	450	5,859E+04	5,989E+04	6,161E+04
6	550	6,161E+04	6,347E+04	6,521E+04
7	650	6,521E+04	6,556E+04	6,475E+04
8	775	6,475E+04	5,996E+04	5,455E+04
9	985	5,455E+04	5,252E+04	5,061E+04

Table 5

The Pearson correlation coefficients obtained from the proposed model of the neural network

i	t_i^s, μs	r_i	r_{i+1}
1	50.5	0,9767	0,9841
2	150	0,9897	0,9928
3	250	0,9938	0,9943
4	350	0,9970	0,9977
5	450	0,9816	0,9818
6	550	0,9807	0,9716
7	650	0,9417	0,9013
8	775	0,8295	0,9235
9	985	0,8516	0,7957

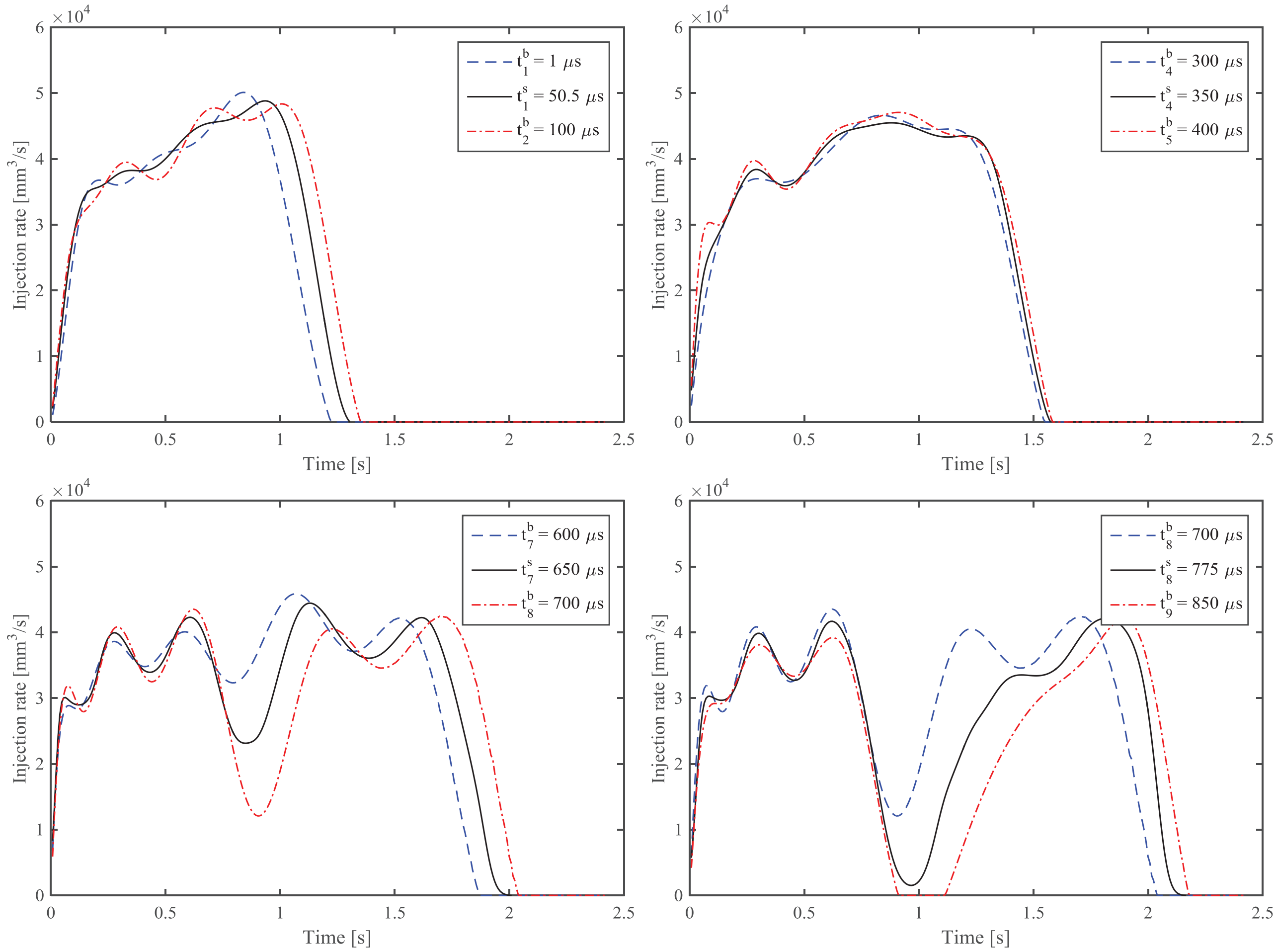

Fig. 6 Results of calculations of fuel outflow rates from the atomizer obtained with use of modified system of the networks

5. Conclusions

Use of the artificial neural networks significantly reduces time required to obtain injection courses of divided fuel dose. Proposed interpolation method of the fuel outflow rate from atomizer of a compression ignition engine allows evaluation of practically any number of the courses depending on time of the dwell, and lying between measured courses. Proposed modification of the artificial neural network, consisting in introduction of two networks, using different sets of learning data, greatly improves the mapping accuracy of the calculated courses. This is a significant observation, useful particularly in presence of variable forms of the injection. Adopted criteria for evaluation of accuracy of the fuel injection courses are accurate and simple tools for quantitative assessment of analyzed quantities.

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Applying the Techniques of Vehicle Routing Problem on the Particular Transport Section and their Comparison

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Abstract

Currently, when the transport development has an increasing tendency, there is still greater demand for reduction of transport costs. In practice, we meet them very often, particularly in cases, which are related to collection (pick-up) and distribution (deliveries) of material. If the distribution is performed from a single supplier to multiple customers (delivery points), this represents the issue of the Vehicle Routing Problem. If this problem is solved as a whole, the overall transport costs compared to individual vehicle journeys will be reduced. In the processed case study within this paper, the comparison of outcomes of several methods application, which are focused precisely on the vehicle routing problem on the particular transport section, is carried out.
KEY WORDS: *vehicle routing problem, transport costs, optimization, delivery points, collection, distribution, Clark-Wright method, Mayer method*

1. Introduction

Although, logistics is often neglected by the unqualified public in connection with enterprise success, logistics is one of most important elements of an enterprise. No enterprise can exist successfully without a well-developed logistics plan. Particularly, this is the case in current globalization when it is necessary to transport goods, people as well as information for a long distance.

By optimizing logistics processes, a great competitive advantage by two ways can be achieved. The first, optimization reduces overall costs, and lower costs mean more efficient production and lower pricing. The second effect is represented by improving the customer service. Customer requirements for punctuality, speed of delivery and quality are a further force in enterprise management. Therefore, keys are to master logistics processes [1-3].

2. Solution of Vehicle Routing Problems Using Different Methods

To implement individual methods in this research study, random routing problem for transported goods by three vehicles with a payload of 3,500 kg is selected. Thus, the capacity is limited by the cargo weight. In calculations, the load is reduced to 3,000 kg, since vehicles have a special hydraulic front. In total, there was transported 7,403 kg of cargo [4, 5].

Following table (Table 1) shows the current course of deliveries, where q_i is a loading weight, time t_{ij} is a driving time, time t_m is the time of unloading and time T is a sum of these times. These routes are 502 km long in total. Transport costs per 1 kilometer are fixed and their value is CZK 10.70.

In this study, the Clark-Wright Method and Mayer Method are applied. The Closest Neighbor Method is used to determine the order of serving each delivery point.

Table 1

The course of the current traffic problem

Routs	Load weight q_i	Route length	Time t_{ij}	Time t_m	Total time T
V_0-V_1-V_2-V_3-V_4-V_5-V_0	1,686 kg	111 km	1.9 hr	2.5 hr	4.4 hr
V_0-V_{14}-V_{15}-V_{11}-V_{12}-V_{13}-V_1-V_0	3,180 kg	217 km	3.6 hr	3.0 hr	6.1 hr
V_0-V_7-V_9-V_8-V_{10}-V_6-V_0	2,537 kg	174 km	2.9 hr	2.5 hr	5.9 hr
Sum	7,403 kg	502 km	8.4 hr	8.0 hr	16.4 hr

Source: authors

Table 2 identifies the locations and service requirements. There is shown the determination of individual delivery points on the basis of which the distance matrix is created. In addition, the table summarizes the requirements of transported kilograms related to individual delivery points.

Table 2

Indicated locations and requirements

Location number	Location	Requirements q_i	Location number	Location	Requirements q_i
0	České Budějovice	-	8	Písek	1,163 kg
1	Č.B. Jednota	1,893 kg	9	Čížová	100 kg
2	Netolice	860 kg	10	Čimelice	306 kg
3	Husinec	120 kg	11	Kamenice nad Lipou	820 kg
4	Prachatice	144 kg	12	Žirovnice	680 kg
5	Dub U Prachatic	300 kg	13	Počátky	413 kg
6	Vodňany	164 kg	14	Popelín	140 kg
7	Protivín	140 kg	15	Jindřichův Hradec	160 kg

Source: authors

3. Solution of Vehicle Routing Problem Using Clark-Wright Method

Clark-Wright method is one of the many operational research methods primarily focused on vehicle routing problem solution. This method is one of the most commonly used methods for this purpose. Using this method for the calculation of the practical example is more demanding than calculation using other similar methods, however, the result is more accurate and complex in terms of the whole issue optimization. The method procedure consists in the selection of two possible routes (V_0-V_i-V_0) and (V_0-V_j-V_0) according to certain criteria. Then, these selected routes are connected to the combined route (V_0-V_i-V_j-V_0). If the assigned route is eligible for the permissible solution, the routes can be combined. It means the sum of the combined routes does not exceed the capacity of the vehicle K [4, 6].

In the process, other conditions such as driving time, route distance, number of nodes or maximum route distance are easier to check and meet. The advantage or disadvantage of an assigned route is determined by the savings which are generated by the assignment. This savings are measured by the advantageous coefficient $z_{ij,}$ which is derived from the relation $z_{ij} = (d_{0i} + d_{0j} - d_{ij})$, where d_{0i}, d_{0j} and d_{ij} are edge lengths (V_0, V_i), (V_0, V_j) and (V_i, V_j). The value z_{ij} is the difference between the sum of the route distances (V_0-V_i-V_0) and (V_0-V_j-V_0) and the combined route distance (V_0-V_i-V_j-V_0). In the each iteration of process, the method is related to two nodes that have a higher z_{ij} coefficient. The main advantage of this procedure is that the coefficient *zij* depends only on the distances between the nodes V_i, V_j and V_0, and if there is an option to join these nodes, the coefficient is unalterable [4, 6-8].

Using the Clark-Wright Method, the solution of optimizing task begins by creating the distances matrix D, as it is outlined in Table 3. The individual elements of this matrix indicate the distances between individual locations which were found using Google Maps. The number of individual delivery points is in accordance with the locations (cities) which require service, according to Table 2.

Table 3

The distance matrix D

i/j	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
0	0	5	26	42	44	46	32	37	50	60	73	75	74	78	71	53
1	5	0	21	37	39	41	27	32	45	62	75	79	79	82	75	57
2	26	21	0	17	19	21	13	21	33	44	57	100	99	103	97	76
3	42	37	17	0	6	10	22	30	43	48	57	117	115	119	113	92
4	44	39	19	6	0	16	25	33	46	57	64	119	118	122	115	95
5	46	41	21	10	16	0	17	26	38	49	54	96	107	110	104	89
6	32	27	13	22	25	17	0	8	21	32	44	79	89	93	87	72
7	37	32	21	30	33	26	8	0	13	24	36	75	86	90	84	68
8	50	45	33	43	46	38	21	13	0	12	25	84	95	99	93	78
9	60	62	44	48	57	49	32	24	12	0	19	94	105	109	103	87
10	73	75	57	57	64	54	44	36	25	19	0	88	100	104	104	87
11	75	79	100	117	119	96	79	75	84	94	88	0	12	16	16	24
12	74	79	99	115	118	107	89	86	95	105	100	12	0	4	5	21
13	78	82	103	119	122	110	93	90	99	109	104	16	4	0	7	25
14	71	75	97	113	115	104	87	84	93	103	104	16	5	7	0	19
15	53	57	76	92	95	89	72	68	78	87	87	24	21	25	19	0

Source: authors

The next step is to create the advantageous matrix *Z* from the distance matrix *D* [4, 9]. The calculation of the advantageous matrix *Z* is based on the following Eq. (1).The advantageous matrix is depicted in Table 4.

$$z_{ij} = d_{0i} + d_{0j} - d_{ij} \, . \tag{1}$$

Table 4

The advantageous matrix *Z*

i/j	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1	0	10	10	10	10	10	10	10	3	3	1	0	1	1	1
2		0	51	51	51	45	42	43	42	42	1	1	1	0	3
3			0	80	78	52	49	49	54	58	0	1	1	0	3
4				0	74	51	48	48	47	53	0	0	0	0	2
5					0	61	57	58	57	65	25	13	14	13	10
6						0	61	61	60	61	28	17	17	16	13
7							0	74	73	74	37	25	25	24	22
8								0	98	98	41	29	29	28	25
9									0	114	41	29	29	28	26
10										0	60	47	47	40	39
11											0	137	137	130	104
12												0	148	140	106
13													0	142	106
14														0	105
15															0

Source: authors

Now, after compilation of limiting conditions, partial calculations can be performed. The VRT is designed for three vehicles with a capacity of 3,000 kg and a speed of 60 km/h. The unloading time is specified to 30 minutes and the total time is up to 9 hours (540 minutes). Subsequently, when the matrix is created, the first iteration should be calculated (see Table 5).

Table 5

1. Iteration $z_{ij} = z_{1312}$=148

Route	q_i	**Route distance**	**Time t_{ij}**	**Time t_m**	**Total time *T***
V_0-V_{13}-V_{12}-V_0	1,093 kg	156 km	2.6 hr	1 hr	3.6 hr

Source: authors

In the matrix *Z*, the largest element, which is z_{1213} = 148, is found, so we determine the routes V_0-V_{12}-V_0 and V_0-V_{13}-V_0. Amount of cargo is 1,093 kg, route distance is 156 km, driving time is 2.6 hours, unloading time is 1 hour and total time is 3.6 hours. None of the parameters exceeds the limitations. For updating the table of routes, we determine z_{1213} = 0 and we continue to look for the next largest element. By the same method, we continue until all the delivery points are depleted. Using the Clark-Wright Method, the resulting effect consists in routes which are summarized in Table 6.

Table 6

Routes optimization using Clark-Wright methods

Routes	q_i	**Route distance**	**Time t_{ij}**	**Time t_m**	**Total time *T***
V_0-V_1-V_2-V_0	2,753 kg	52 km	1.0 hr	1 hr	2.0 hr
V_0-V_3-V_4-V_5V_6-V_7-V_{10}-V_9-V_8-V_0	2,437 kg	206 km	3.4 hr	4 hr	7.4 hr
V_0-V_{13}-V_{12}-V_{14}-V_{11}-V_{15}-V_0	2,213 kg	180 km	3.0 hr	2.5 hr	5.5 hr
Sum	7,403 kg	438 km	7.5 hr	7.5 hr	15.0 hr

Source: authors

4. Solution of Vehicle Routing Problem Using Mayer Method

The Mayer method is another applied method, where the first step is to construct the distance matrix *D*, how it is in the previous method. The beginning of the solution is at node V_0 and the farthest point V_i from the V_0 needs to be found. If it satisfies the capacity of the transport vehicle, it can be assigned to the route (V_0-V_i-V_0). The selected field is indicated in the table and this field excludes the column containing field V_i. Then, the column V_0 is also deleted. We continue from node V_j and look for the shortest distance to the next node V_j. In the matrix, the selected field is again indicated and the entire column containing the field is deleted. The whole procedure is repeated until all nodes are served or until the limiting conditions of the acceptable solution are exceeded. Mayer Method is very simple, however, it does not solve the whole problem, but only part of it. This method only classifies individual routes, but does not address the order in which the nodes are to be served [9-11].

The default matrix D was shown in Table 3. Limiting values remain the same as in the previous method. The second step is to find the longest distance, i.e. the highest value from the initial delivery point V_0. In this case, this value is $V_{13} = 78$. This value will be indicated and the entire column 13 and 0 will be deleted. The new assigned route is V_0-V_{13}-V_0. This route is shown in Table 7. The next step is to find the lowest value in line 13. In other words, we find the nearest location from the location Počátky. This value is $V_{12} = 4$. Finding this value is shown in Table 8. Again, this value is indicated and the entire column 12 is deleted. During Mayer Method application, it must be checked if the limiting conditions are not exceeded [10, 12-14].

Table 7

Sample from the distance matrix D - line 0

i/j	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
0	0	5	26	42	44	46	32	37	50	60	73	75	74	78	71	53

Source: authors

The nearest location from the location Počátky is shown in Table 8. Its value V_{12} is 4.

Table 8

Sample from the distance matrix D - line 13

i/j	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
13	78	82	103	119	122	110	93	90	99	109	104	16	4	0	7	25

Source: authors

Subsequently, this value is indicated and the entire column 12 is deleted. Since no limit value has been exceeded, the route V_0-V_{13}-V_{12}-V_0 can be created and the next step can continue (Table 9).

Table 9

1. and 2. Iteration = V_0-V_{13}-V_{12}-V_0

Route	q_i	**Route distance**	**Time t_{ij}**	**Time t_m**	**Total time T**
V_0-V_{13}-V_{12}-V_0	1,093 kg	156 km	2.6 hr	1 hr	3.6 hr

Source: authors

The routes shown in Table 10, which are not optimized for the operator's order, are the final outcome of the Mayer matrix calculation. Therefore, we have to adjust these routes further in this regard. The adjustment is done using the Closest Neighbor Method. The Closest Neighbor Method is explained on the middle route, specifically on the route V_0-V_{11}-V_{12}-V_{13}-V_{14}-V_{15}-V_0.

The Closest Neighbor Method is one of the simple heuristic methods of route optimization. The method uses the "Greedy" algorithm principles (it selects the best option for a given node) and is sequentially progressive. The procedure consists in selecting the default node and the edge with the shortest distance heading to another node which is not yet reached. In this way, we proceed for each node until we get all of them. At the end, we join the last node with the first node by the lowest edge and add up the rates of all used edges to obtain the searched route distance [4, 14, 15].

Table 10

Overview of basic routes according to the Mayer Method

Elementary routes
V_0-V_2-V_3-V_4-V_6-V_7-V_8-V_9-V_{10}-V_0
V_0-V_{11}-V_{12}-V_{13}-V_{14}-V_{15}-V_0
V_0-V_1-V_5-V_0
Sum

Source: authors

First, we create the V_0-V_{11}-V_{12}-V_{13}-V_{14}-V_{15}-V_0 matrix and select the lowest number (see Table 11). This is represented by number 4 in our case. We join the delivery point V_{13} and V_{12}. Limiting parameters does not have to be searched any longer, because it is only a matter of determining the order of journeys.

Table 11
Distance matrix for route V_0-V_{11}-V_{12}-V_{13}-V_{14}-V_{15}-V_0

	V13	V12	V11	V14	V15
V13	0	4	7	16	25
V12	**4**	0	5	12	21
V11	7	5	0	16	19
V14	16	12	16	0	24
V15	25	21	19	24	0

Source: authors

Number 5 is next and serves the delivery point V_{11}. Like this, procedures need to continue until all the points are served. This creates the order in which the individual points are to be served. The route is in the order according to the Table 12.

Table 12
The course of the optimized problem using the Mayer method

Elementary routes	q_i	Route distance	Time t_{ij}	Time t_m	Total time T
V_0-V_2-V_3-V_4-V_6-V_7-V_8-V_9-V_{10}-V_0	2,213 kg	199 km	3.3 hr	4 hr	7.3 hr
V_0-V_{13}-V_{12}-V_{11}-V_{14}-V_{15}-V_0	2,997 kg	171 km	2.9 hr	2.5 hr	5.4 hr
V_0-V_1-V_5-V_0	2,193 kg	92 km	1.5 hr	1.5 hr	3.0 hr
Sum	7,403 kg	462 km	7.7 hr	8.0 hr	15.7 hr

Source: authors

The following table (Table 13) provides an overview of the current state data and status data after using the Mayer Method and the Clark-Write Method. The calculation using Clark-Wright Method is the optimal solution. Solution using this method provides the shortest traveled distance and the total traveled time. It also includes the lowest costs share of this transport. It should be noted that this method is the most time consuming in terms of calculations [4, 16, 17].

Table 13
Results overview - the current state and application of each method

Methods	Sum of cargo weight	Route distance	Time t_{ij}	Time t_m	Total time T	Cargo for a day
Current state	7,403 kg	502 km	8.4 hr	8 hr	16.4 hr	CZK 5,371.40
Mayer Method	7,403 kg	462 km	7.7 hr	8.0 hr	15.7 hr	CZK 4,943.40
Clark-Write Method	7,403 kg	438 km	7.5 hr	7.5 hr	15 hr	CZK 4,686.60

Source: authors

5. Conclusions

In this study, Clark-Wright Method and Mayer Methods were applied to the same vehicle routing problem. The application of operational research methods performed to a simple vehicle routing problem with which the enterprises encounter in common traffic. Transport enterprises use software applications, but smaller enterprises cannot afford these applications or deliberately ignore this issue.

In the above research study, there was confirmed a reduction in kilometers traveled using the application of both methods. Of course, this also leads to a reduction in the logistics and transport costs which enterprises are forced to deal with in order to meet customer needs.

The transport costs were specified at CZK 10.70/km. Based on this value, it was possible, at the end of the study, to find out how the transport costs would be reduced. Using the Clark-Wright Method, the traveled distance would be reduced about 64 kilometers, and using the Mayer Method, it would be reduced about 40 kilometers. The difference between these methods is 24 kilometers. Based on these calculations, it would be good to decide for applying the Clark - Wright Method.

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Selected Methods of Operational Analysis Usable in Evacuation of People

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Abstract

Evacuation belongs to basic types of collective protection of the population. By the form of effective organized displacement of people from the endangered territory enable to save their lives and health.
Nowadays it is becoming more important, especially in connection with the more frequent occurrences of natural disasters, which are related to rising extreme weather fluctuations. In order to be evacuation done efficiently, the displacement of people must be well planned and organized.
Using the methods of operational analysis, the evacuation can be effectively planned and executed, if it is necessary. In the contribution is described a simple example in which way can be the operational analysis used in the evacuation process, namely by utilizing the transport task and assignment of means of transport. The aim of the contribution is to show the benefits of specific methods of operational analysis in the practice of protecting the population.
KEY WORDS: *evacuation, transport task, evacuees*

1. Introduction

The extraordinary events have become a daily part of our lives in recent years. Evidence of this is also the fact, that the media, the press, and other mass media are full of reports of various extraordinary events. The need to protect life, health, human property and the environment is becoming increasingly important. All of this involves the issue of civil protection of the population. The term "civil protection" has its basis in the Latin "civitas" = "the population". If we are talking about civil protection, we are talking about the protection of people, protection of life, health and property before and during emergencies, natural disasters, accidents or catastrophes. In addition to this, the mission of the civil protection is to create the conditions for the survival during extraordinary events and emergency situations. Often are consequences of an incident in such proportions that require the evacuation of residents from the affected and threatened territories. Planning, provision and implementation of evacuation is a very complex process that requires the linking of knowledge from a variety of disciplines. Through the using of methods of operational analysis, it is possible to simplify and streamline this process.

2. Process of evacuation

The process of evacuation as well as its implementation in the legal system of the Slovak republic defined in the Act no. 42/1994 Coll., which was later supplemented and modified and its current version is under Act no. 444/2006 Coll. of The National Council of the Slovak republic about civilian protection of the population. Another legal norm, regulating the details of the evacuation, is the Decree of the Ministry of interior of the Slovak republic no. 328/2012 Coll. In addition to the legal system, the process of the evacuation of the deal with on campus, where there are several publications dealing with the discussed issue. Under the term evacuation we understand the displacement of threatened persons, animals, or things from a certain territory, which was declared an extraordinary situation on [1]. A certain territory is meant in particular the surroundings of the nuclear facility; also the territory of the endangered by contamination during leakage of the dangerous substance at the technological accident; the territory endangered to possible by a natural disaster; accident on the water work and the additional territory allocated to ensure the tasks of the defence of the state in time of war and the war state [2]. The evacuation is declared by mass information means and it is revoked if the reason for which was declared is over. [1]. The evacuation is subdivided according to different criteria, which is possible to see also on the following Table 1.

Table 1

Types of evacuation processed by the author according to [3]

Evacuation		
According to place	a) b)	object (point) spatial (areal)
According to the method of security	a) b)	planned unplaned
According to the declaration method	a) b)	quied unquied
According to the time duration	a) b)	short-term long-term
According to the method of solution	a) b)	voluntary violent

3. The Evacuation as a Traffic Task

As was said in the introduction, transfer of evacuated persons is traffic task. For traffic solution it is necessary to briefly elucidate its tasks.

Distribution problems are making up a special problem category of linear programming. Here belongs such tasks as: traffic problem, which solves optimal delivery plan, assignment system, which solves optimal object assignment to their destinations, a task of business traveler and a task of optimal resource allocation etc.

Traffic task is used to build optimal delivery plan of goods (material) from distributors to subscribers. Distributors are defined by their capacities and subscribers by their requests. Process of distribution is described by costs (charges, kilometer distances) for transport of unit quantity of goods from defined distributor to subscriber:

Needed input data:

- Number of distributors m
- Capacity of distributors $a_1, a_{2 \ldots} a_m$ (capacity vector)
- Number of subscribers n,
- Subscribers requests $b_{1,}, b_{2 \ldots} b_n$ (vector of requests)
- Unit charges c_{ij} $i = 1, 2, \ldots m$ a $j = 1, 2, \ldots n$ (matrix of rates)

In solving traffic tasks there is a request for equality between distributors and subscribers capacities. The equality is expressed by this equation: $\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$.

Solution goal of traffic task is to define transported amounts x_{ij} from all distributors to all subscribers, so all subscribers requests must be fulfilled. To make use of distributor capacities a cost value spent on whole transport must be minimal or maximal.. Basement for traffic task solution is the mathematical expression of the problem:

- Specific function $z = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} \cdot x_{ij} \longrightarrow$ MINIMIZE
- Limiting conditions
  1. $\sum_{j=1}^{n} x_{ij} = a_i \qquad i = 1, 2 \ldots m$
  2. $\sum_{i=1}^{m} x_{ij} = b_j \qquad j = 1, 2 \ldots n$
  3. $\sum_{i=1}^{m} \sum_{j=1}^{n} x_{ij} \geq 0$

With use of this knowledge was created simple example with use of MS Excel extension. Transport of evacuated persons to specified places is part of evacuation and exactly this part of evacuation process has traffic task form, as described in solved simple example.

Example

In the Žilina self-governing region is due to the agitation of the dam necessary to evacuate persons from the five villages (O1, O2, O3, O4, O5) with a known population size (ai) (Table 2). In these villages it is estimated the extent of the threat 100 %. Is dedicated 8 places (E1, E2, E3, E4, E5, E6, E7, E8), whose capacities we know (b_j). There are available the buses for evacuation with an evacuation capacity of up to 70 people (seated and standing) and the estimated transportation costs are 0,40 € for 1 km driving. It is necessary to ensure the evacuation so that the costs were minimal and that was done in the minimum time.

Table 2

Input data

Input data									
	EM1	EM2	EM3	EM4	EM5	EM6	EM7	EM8	a_i
O1	15	25	32	12	18	15	28	18	381
O2	27	35	33	27	12	25	30	20	455
O3	15	33	35	30	18	12	18	15	560
O4	17	29	25	32	20	15	28	25	775
O5	20	28	18	32	15	32	18	35	2644
b_j	300	390	560	665	840	1000	780	280	

The Solution to the Example of the Evacuation of the Population

The previous problem shows that it is a solution of the classical transport task. Cap rates represent the distance between the evacuated municipalities and evacuation points in kilometres. The number of inhabitants of municipalities represents the capacity of resources and the numbers at the evacuation places represent the capacity for emergency accommodation to the residents.

To address evacuation is required conversion of the input data:

- need to take into account the empty drive and make the conversion rate of km to the €:
  - $c_{ij} = c_{ij} \cdot 2 \cdot 0{,}40$ pre $i \in \{1,2,3,4,5\}$ a $j \in \{1,2,3,4,5,6,7,8\}$

- conversion of the number of inhabitants and the capacity of the places of evacuation:
  - $a_i' = \frac{a_j}{70}$ pre $i \in \{1,2,3,4,5\}$
  - $b_j' = \frac{a_j}{70}$ pre $j \in \{1,2,3,4,5,6,7,8\}$
- equalization of task: $\sum_{i=1}^{5} a_i = \sum_{j=1}^{8} b_j$.

In our case, is the task equalized, since the capacity of the evacuation sites are identical with the number of persons that it is necessary to evacuate from endangered areas (4 815 = 4 815). After the initial conversion, it is necessary to compile a Table 3), which will serve for the solution of a defined problem. The table was created in MS Excel, because this program is available to the wide society. To solve the transport task was used Solver, which is an add-on for MS Excel. On the Fig. 1 is possible to see the solution in MS Excel.

Table 3

Work table

Work table									
	EM1	EM2	EM3	EM4	EM5	EM6	EM7	EM8	a_i
O1	12	20	25,6	9,6	14,4	12	22,4	14,4	5
O2	21,6	28	26,4	21,6	9,6	20	24	16	7
O3	12	26,4	28	24	14,4	9,6	14,4	12	8
O4	13,6	23,2	20	25,6	16	12	22,4	20	11
O5	16	22,4	14,4	25,6	12	25,6	14,4	28	38
b_j	4	6	8	10	12	14	11	4	

= $a_i/70$

= $b_j/70$

= *area B11:I15*2*0,40*

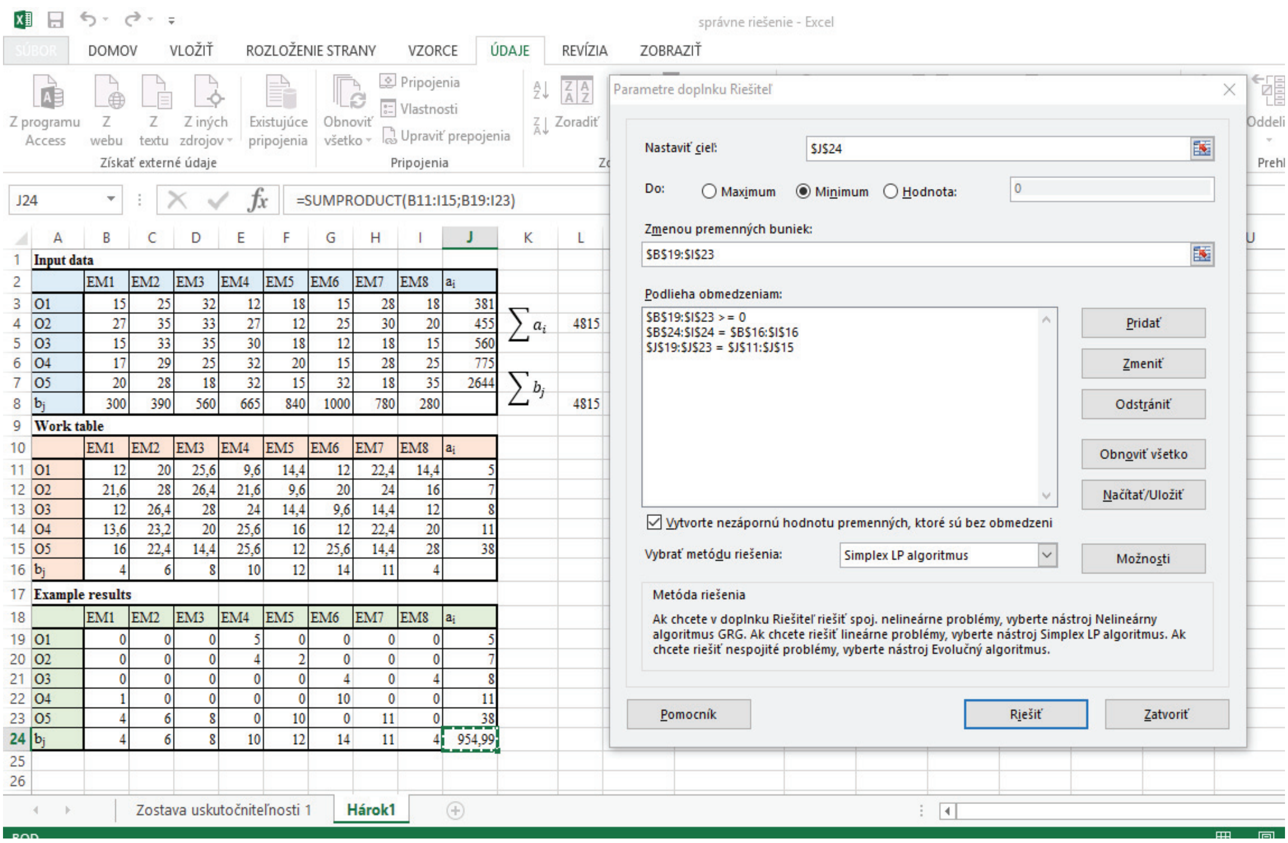

Fig. 1 Solution of classical transport task in MS Excel

The results of the solutions are shown in the Table 4.In the results of the solutions are in the area of the matrix the values representing the number of fully occupied buses with a capacity of 70 persons. The resulting value of the specific features 954,99 € represents the cost of transportation, including realized empty trips to the municipalities, that it is necessary to evacuate.

Table 4

Example results

Example results									
	EM1	EM2	EM3	EM4	EM5	EM6	EM7	EM8	a_i
O1	0	0	0	5	0	0	0	0	5
O2	0	0	0	4	2	0	0	0	7
O3	0	0	0	0	0	4	0	4	8
O4	1	0	0	0	0	10	0	0	11
O5	4	6	8	0	10	0	11	0	38
b_j	4	6	8	10	12	14	11	4	954,99

sum in the row

sum in the column

= SUMPRODUCT(B11:I15;B19:I23)

4. Placing Evacuees into Evacuation Municipalities

The evacuation process does not end up with transportation of evacuees into evacuation places, vice versa. After the transport of the endangered population a number of tasks and responsibilities are necessary to perform, which must be ensured by a particular community, where evacuees are set, a so:

a) after the declaration of an extraordinary event, the relevant municipality will receive information about the declaration of this extraordinary event with an order for accepting evacuees;

b) subsequently mayor of relevant municipality submit information to other members of evacuation commission of municipality (composition of the evacuation commission of municipality are 3-7 members as needed);

c) necessity to bring the evacuation commission into emergency within 2 hours from the declaration of an extraordinary event;

d) awareness of citizens about the obligation to receive evacuated persons into the relevant community;

e) the evacuation commission of the municipality must bring an evacuation facility into emergency and that: exit station for evacuated (within four hours), regulatory station (within 4 hours), place of accommodation (within 4 hours);

f) establishing facilities for servicing evacuation facilities, and that:

- exit stations for evacuated;
- regulatory stations;
- checkpoints;
- place of accommodation for evacuated.

Other tasks resulting from accepting the evacuees to the community:

a) transfer of evacuees from regulatory station;

b) creating of squads:

- squad for performing rescue work in the community, from which evacuated persons are displaced;
- squad which will provide help in supply activities – agreement with suppliers and its efficient distribution;
- squad which will ensure cooking, expenditure of food and other activities in kitchen, in different cooking places;
- squads operating in individual regulating stations;
- squad whose main tasks will be to take care for children and to secure their full-day program;
- squad for ensuring peace, security and order;

c) securing the way of life in the municipality during reception of evacuees:

- the need to create a daily schedule for individual accommodation and catering facilities;

d) providing emergency supply and catering:

- organization of the system of distribution of basic types of food, meat and meat products, diary products and other goods of relevant store chain in community;
- creating a schedule of catering in individual catering facilities [5].

In the context with acceptation of evacuees into community, there are a number of risks that threaten the tasks related to evacuation and operation of relevant municipality as such. Therefore the risks stemming from ensuring of acceptation of evacuated persons for relevant municipality were identified and that:

- the risk connected with the organization of evacuees and the appropriate division of evacuees;
- the risk of tearing of family and following dissatisfaction of evacuees;
- the disturbance of peace resulting from the dissatisfaction of the evacuees placed on individual

accommodation facilities;
- the risk resulting from supplying individual kitchens serving food for evacuated persons;
- the risk resulting from the increase in thefts, disputes, riots and other criminal activities within relevant community;
- the risks resulting from the introduction of a regime of life in the municipality during the acceptation of evacuated persons;
- the risks of reluctance of citizens of relevant municipality to provide emergency accommodation and necessary help to evacuees;
- the risk resulting from transporting connection [6];
- the risk resulting from ability to meet basic needs of evacuated persons (for example providing health care);
- the risk of infectious diseases and illnesses related to poor hygiene;
- the risk resulting from the disturbance of industrial activity located in the municipality [7];
- other risks resulting from specific situations.

The results of the statistical survey related to the placement of evacuees into evacuation places

Except for accommodation facilities, where more evacuated persons can be accommodated, family houses increase the overall capacity of the accommodation of evacuated persons. Within a statistical project has been developed, which dealt with the problem of detecting the knowledge of citizens of a relevant municipality about accepting of evacuated persons. This statistical survey can also be taken into account in other types of municipalities as was the original chosen evacuation community. The effort of the statistical survey was that each interviewed respondent would come from another household of chosen community. The reason was to cover as many households as possible and to make the date as accurate as possible, concerning the given numbers of homes in the community. In the statistical survey questions occurred such as the characteristic of the age of the interviewed citizens, the average age of the interviewed citizens, the lowest age limit of the interviewed citizens, and others. Within the statistical file, it was possible to find out the age layout of the interviewed citizens and also the most represented age categories of citizens. Within the statistical survey the citizen's knowledge of the fact that they have to accept evacuees into their homes has been identified. Further the knowledge of the claim for compensation for accommodating the evacuee has been identified and also identifying the number of social facilities in individual households. Another statistical question was to find out the number of citizens willing to provide accommodation to the evacuee for 3 or more days. Among other things was identified the existence of dependence on the willingness to provide accommodation for evacuees and the knowledge of citizens of the entitlement to reimbursement of accommodation costs. Through the association table, it was found that such dependence did not exist. Through CORREL function, the dependence of the number of social facilities on the number of evacuee that individual households are willing to accept. It was also been surveyed whether the number of evacuees willing to accept is determined by the age of citizens. The data was surveyed by correlation and regression analysis. Using the CORREL function the correlation coefficient was calculated r = - 0,06355. According to its absolute value, we can conclude that there is no dependence between the age of the citizen and the number of evacuees he is willing to accept. The negative value of the correlation coefficient indicates that the dependence is negative – negative, indirect. It was finally surveyed whether the willingness to provide the food for the evacuees depends on the knowledge that they are entitled to reimbursement of expenses associated with the evacuee stay. The association coefficient is -0,295 because the association coefficient is close to zero, it means that the statistical characteristics of the willingness to provide food and the knowledge of the claim for compensation are mutually independent[4]. For illustrative example, one graph is presented, which expresses the number of citizens divided by how many days they are willing to provide accommodation (74 citizens are willing to provide accommodation for one day).

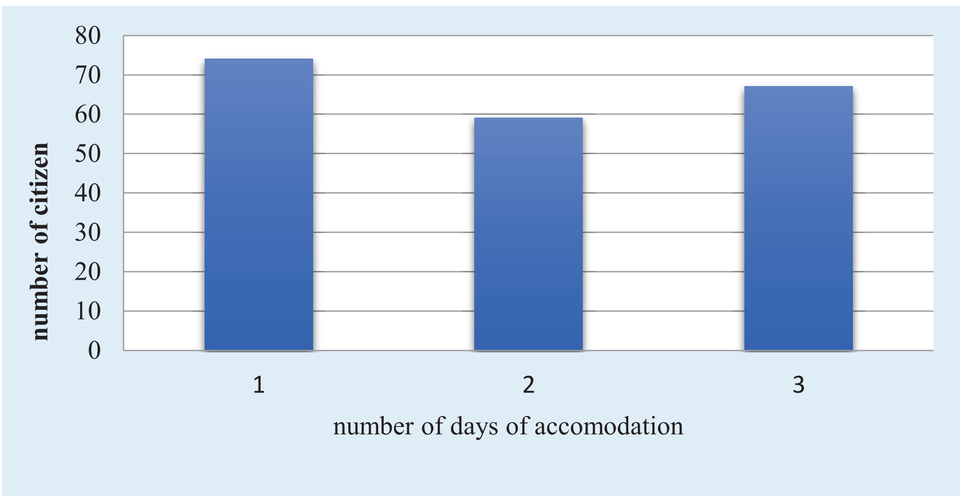

Fig. 2 Willingness to provide housing to evacuees

5. Conclusion

Evacuation is a complex process that should be carried out in the most effective way and must be carefully planned and organized. Methods of operational analysis offer opportunities to simplify and streamline the process transferring the evacuees from threatened territory. Whether we use MS Excel which is available to wide range of users, or we can use other more appropriate programs. Evacuation as a process does not end with the displacement of the population, but also the acceptation of evacuees into the designated municipality is associated with a number of tasks that need to be solved. Even here are the possibilities of using the operational analysis methods during the planning individual tasks. Raising awareness about evacuation can simplify the whole process of evacuation. The statistical survey has shown that it is necessary to know how the population would behave, if necessary, to accommodate the evacuees in their households.

The proper organization and planning of individual tasks and activities are important in solving the evacuation process. The acceptation of evacuees is not a simple matter, but is immensely important for the protection of the most valuable, namely life and health of man. Indeed, thanks to the timely displacement of people from territory threatened by an extraordinary event, human lives are saved.

Acknowledgement

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Analysis of Combined Transport in the Czech Republic in Relation with CSR

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Abstract

Article deals with the problematic of combined transport in the Czech Republic in relation with corporate social responsibility (CSR). Article describes theoretical background of combined transport and CSR. CSR concept represents voluntary integration of social and environmental aspects to strategic and everyday routine processes and operations of companies. CSR consists of three pillars – an economic pillar, a social pillar and an environmental pillar. This article is focused on environmental pillar which is directly connected with the need of emission reduction and transport generally is the largest producer of emissions. Article analyses development of combined transport in the Czech Republic between 2005 and 2015 and basic parameters of combined transport terminals in the Czech Republic.
KEY WORDS: *combined transport, corporate social responsibility, combined transport terminal*

1. Introduction

The quality of life improvement, economic development and environmental protection for the existing and the future generations are the fundamental principles of the existing sustainable development concept. Sustainable development concept includes three areas: the economic area, the environmental area and the social area. Sustainable development must be equitable (interaction between the economic and the social dimension) liveable (the link between the environment and social needs) and viable (economic development must be in accord with ecosystems capacities).

The sustainable development concept is closely related to the concept of corporate social responsibility (CSR). Standard ISO 26000 defines social responsibility as the responsibility for decisions' impacts and activities' impacts on society and on the environment; this responsibility is closely linked to transparent and ethical behavior [1]. This represents the maximum contribution to sustainable development since all three key sustainable development areas are integrated into corporate activities.

Transport has significant economic, social and environmental impacts and represents a significant factor of sustainability [2]. Sustainable transport is characteristic by the fact that it does not represent any threat to public health or to ecosystems, but at the same time it provides for transport needs in such manner that competitiveness and regional development are supported [3]. Greenhouse gases emissions belong among significant environmental aspects; transport systems' sustainability must be thus evaluated also with regard to this indicator [4-6].

Growing performance of road transport has negative impacts on the environment, on public health and on transport safety and it contributes to greenhouse gases emissions and it is energy consumption demanding. Some authors stated that road transport and freight transport in general have great importance for the world economy; but this sector is not social and environmental friendly [7]. This is the reason why corporations' approach to logistics planning must change. In the framework of such logistic planning attention must be given to environmental aspects of transport and to implementation of corporate activities in agreement with CSR principles. In order to meet the objectives in the area of sustainable transport it is essential to focus attention also on larger utilization of multimodal transport, combined transport respectively. Combined transport is concerned with the shipment of commodities from their origin to destination using combinations of transport modes [8].

This article analyses development of combined transport in the Czech Republic between 2005 and 2015 and basic parameters of combined transport terminals in the Czech Republic.

2. Materials and Methods

Experience from abroad show that, in order to achieve more significant share of combined transport in the total freight transport, one condition must be met. This condition is a suitable design of the framework (legal framework) and of the system of incentives. This represents investment and operations incentives. However, it is essential to define the system in such way that it really provides incentives and motivations and that the provided funding is effectively utilized. To make the combined transport more attractive it is essential to define suitable framework conditions (toll fee in road transport taking into account externalities, increased parameters and capacity of railway infrastructure) and at the same time to provide for a tool for direct support of investment into multimodal transport.

In the Czech Republic in some regions there exists a quite dense network of terminals. Majority of these terminals are operated directly by combined transport train operators. These terminals are not usually located on public transport infrastructure. Transfer of railway carriages between public transport infrastructure and terminals located on trailers represents another cost item. This reduces the competitiveness of the newly introduced combined transport lines. This situation has emerged due to setting aside and privatizing terminals that used to be in the national railways ownership. For further development of in particular continental transports it seems to be favorable to define conditions in such way that also terminals with neutral access are created as a concept of open transport network "terminal to terminal".

This article analyses development of combined transport in the Czech Republic between 2005 and 2015. Analysis of combined transport in the Czech Republic is divided into three areas according to [9]:

1. Transport of large containers by rail – analyzed parameter: total number of loaded containers transported.
2. Transport of swap bodies by rail – analyzed parameter: total number of loaded swap bodies transported.
3. Unaccompanied transport of trailers and semi-trailers by rail – analyzed parameter: total number of loaded trailers and semi-trailers transported.

Container is large standardized shipping transport unit, designed and built for intermodal freight transport, meaning these containers can be used across different modes of transport – from ship to rail to truck – without unloading and reloading their cargo [10]. Swap bodies are one of the standard freight containers for road and rail transport. These containers type may also be called "exchangeable container" or "interchangeable unit" [11]. Unaccompanied combined transport means that only the load unit is transported, without the motor vehicle or driver [12]. Other definition describes unaccompanied combined transport as a situation when are boarded only semi-trailers onto the vessels, which are loaded/unloaded at the port with special vehicles; semi-trailers are then coupled with the tractor units located at either end, and moved onto their final destinations as complete units [13].

Analysis is focused on presumed development of combined transport in the Czech Republic in years 2018-2022. We assume based on linear regression (relations 1-3) that the total number of loaded containers, trailers and semi-trailers transported in the Czech Republic will have increasing character. Future values *Y* will be predicted using linear regression (relation 1), where *a* and *b* are parameters or coefficients of approximate line:

$$Y = a + bx . \quad (1)$$

Parameter *a* was expressed by the relation 2, where $\bar{y}$ and $\bar{x}$ are arithmetic means of analyzed values:

$$a = \bar{y} - b\bar{x} . \quad (2)$$

Parameter *b* was expressed by the relation 3, where $\bar{y}$ and $\bar{x}$ are arithmetic means of analyzed values:

$$b = \frac{\sum\left(x-\bar{x}\right)\left(y-\bar{y}\right)}{\sum\left(x-\bar{x}\right)^2} . \quad (3)$$

3. Results and Discussion

In Fig. 1 is presented comparison of total number of loaded containers transported between 2005 and 2015 in the Czech Republic. The curve has a growing character except year 2009, when there was a significant decline. This decline was caused by world economic crisis and reduced demand for this type of transportation. Between years 2005 and 2015 increase the total number of transportation of loaded containers from 300 527 in 2005 to 706 697 in 2015, it is increase between years 2005 and 2015 of 135.15%. The largest increase was observed between years 2006 and 2007, when there was an increase of 80 227 loaded transported containers. The average increase of loaded transported containers between years 2009 and 2015 is 48 255 of loaded transported containers per year.

In Fig. 2 is presented comparison of total number of loaded swap bodies transported between 2005 and 2015 in the Czech Republic. The total number of loaded swap bodies transported between 2005 and 2015 in the Czech Republic has undergone turbulent development, because between years 2005 and 2009 number of transported loaded swap bodies had decreasing character. In 2005 was transported 13 024 these transport units, but in 2008 it was only 8 968 loaded swap bodies. The growing character can be observed between years 2008 and 2012, when was the increase about 11 759 loaded swap bodies, but from 2012 to 2015 the number of transported loaded swap bodies decreases from 20 727 in 2012 to 5 963 in 2015; it is the relative decline of 71.23%.

In Fig. 3 is presented comparison of total number of loaded trailers and semi-trailers transported between 2005 and 2015 in the Czech Republic. In 2005 was transported only 65 laded trailers and semi-trailers, but in 2015 was the total number of transported loaded trailers and semi-trailers 31 955; from 2008 to 2015 this value increases. The largest increase was observed between 2012 and 2013, where was the difference of 8 619 trailers and semi-trailers.

We assume based on linear regression (relations 1-3) that the total number of loaded containers, trailers and semi-trailers transported in the Czech Republic will have increasing character, especially in years 2018-2022. We presume that the total number will oscillate in predicted period (2018-2022) in the Czech Republic between 801 342 and 951 292 for loaded containers and between 40 238 and 54 465 for loaded trailers and semi-trailers.

In the Czech Republic there are sixteen terminals for combined transport (Fig. 4), six of them are located in Ústí nad Labem region.

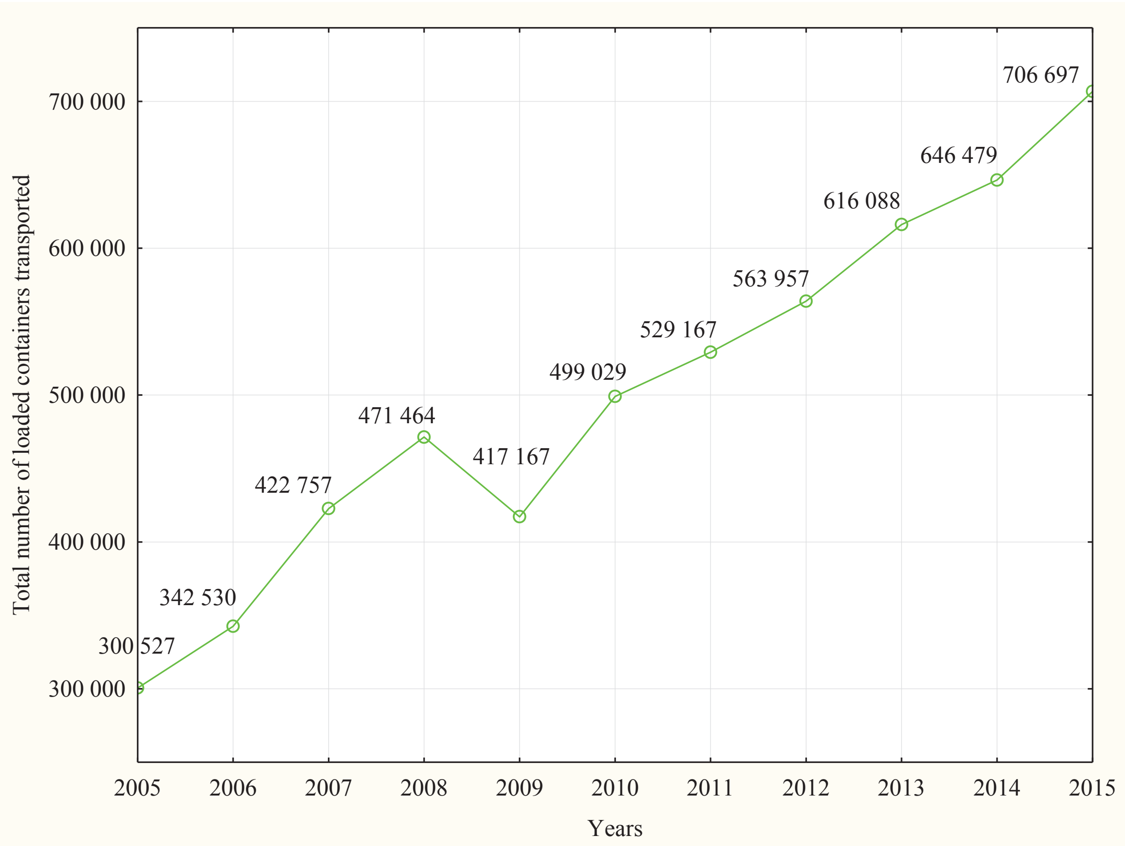

Fig. 1 Total number of loaded containers transported between 2005 and 2015 in the CR (authors based on [9])

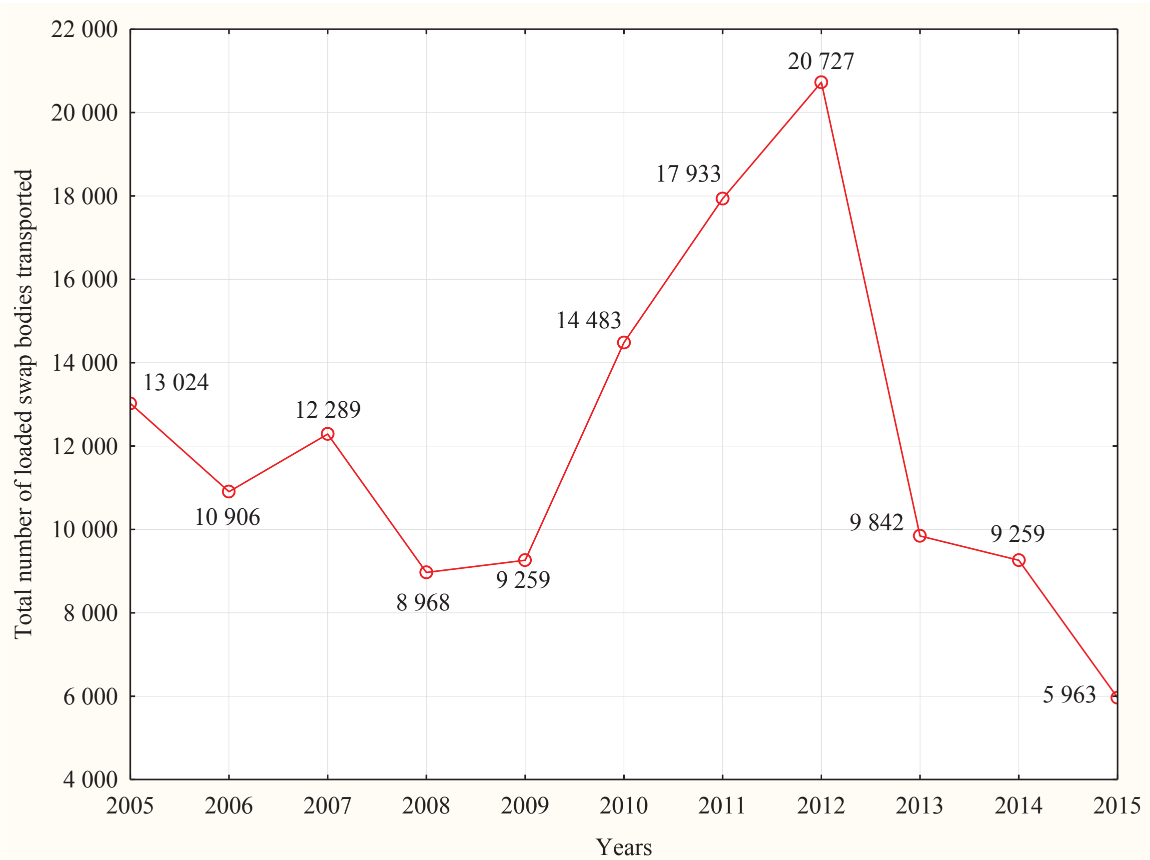

Fig. 2 Total number of loaded swap bodies transported between 2005 and 2015 in the CR (authors based on [9])

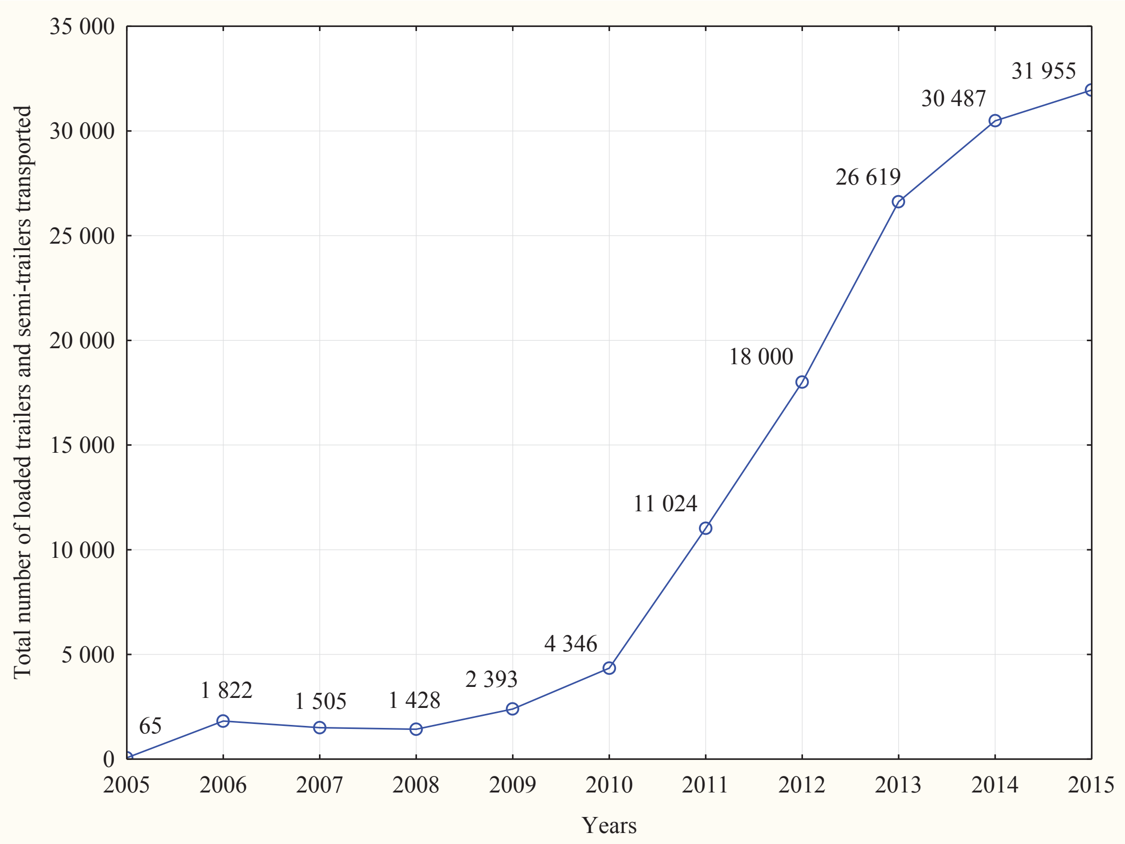

Fig. 3 Total number of loaded trailers and semi-trailers transported between 2005 and 2015 in the CR (authors based on [9])

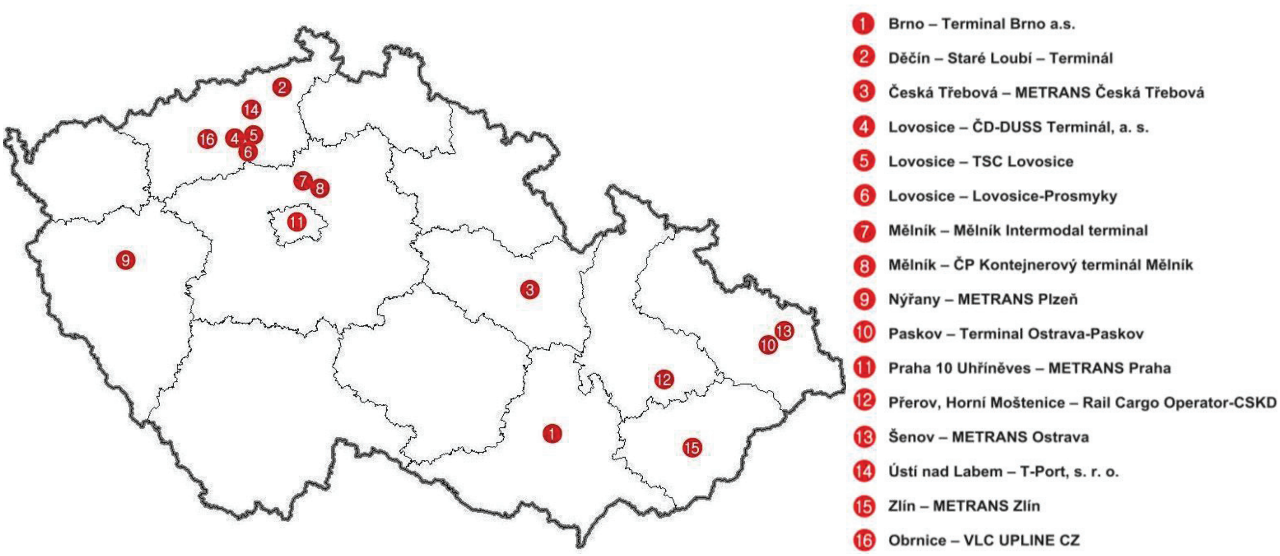

Fig. 4 Map of combined transport terminals in the Czech Republic (authors based on [9])

The overview of terminals in the Czech Republic with some parameters is presented in Table 1. Four terminals are trimodal terminals (no. 2 in Děčín, no. 6 in Lovosice, no. 8 in Mělník and no. 14 in Ústí n/L), which are operated by three transport modes (road, railway and inland waterway transport). Other terminals are bimodal, because these terminals are operated only by two transport modes, which are in most cases road and rail transport. The largest inner area has terminal in Praha 10 (450 000 m^2), which has fifteen railway tracks for transshipments of length between 309 – 695 meters. This terminal has the largest theoretical and actual volumes of transshipments, because standard volume of transshipments is 1 013 200 TEU per year (it is 84.43 % of maximum capacity of transshipments).

Only three terminals (no. 3 – Česká Třebová, no. 7 – Mělník 1 and no. 11 – Praha 10) are operated in 24/7 mode. Terminals use most often container handlers. Road gantry cranes are not preferred, because these types of handling equipment use only two terminals: no. 5 – Lovosice and no. 13 – Šenov.

In the Czech Republic there are dense network of combined transport terminals, which are equipped with adequate technology, handling equipment, trained staff etc. Terminals currently have free capacity for transshipments.

Table 1

Parameters of terminals in the Czech Republic (authors based on [14])

Parameters / Terminals	1	2	3	4	5	6	7	8
Location	Brno	Děčín	Česká Třebová	Lovosice no. 1	Lovosice no. 2	Lovosice no. 3	Mělník no. 1	Mělník no. 2
Transport modes	Ro/Ra	**Ro/Ra/In**	Ro/Ra	Ro/Ra	Ro/Ra	**Ro/Ra/In**	Ro/Ra	**Ro/Ra/In**
Inner area (m^2)	40 000	15 000	130 000	15 000	24 000	2 000	49 000	19 000
Number of tracks	3	3	6	4	2	1	2	1
Length of tracks (m)	350	503 – 800	825 – 885	250 – 600	198	800	613	600
Theoretical / actual volume of transshipments (TEU or ITU)	30 000 / 15 000 TEU	7 200 / 10 TEU	850 000 TEU	53 000 / 22 000 ITU	60 000 / 45 000 ITU	2 000 / 6 TEU	150 000 / 80 000 ITU	30 000 / 20 000 ITU
Number of rail gantry cranes	0	1	3	0	0	2	0	0
Number of road gantry cranes	0	0	0	0	**3**	0	0	0
Number of container handlers	2	0	3	2	1	0	4	1
Operating days	Mo – Sa	Mo – Fr	**24/7**	Mo – Su	Mo – Su	Mo – Fr	**24/7**	Mo – Fr
Parameters / Terminals	9	10	11	12	13	14	15	16
Location	Nýřany	Paskov	Praha 10	Přerov	Šenov	Ústí n/L	Zlín	Obrnice
Transport modes	Ro/Ra	Ro/Ra	Ro/Ra	Ro/Ra	Ro/Ra	**Ro/Ra/In**	Ro/Ra	Ro/Ra
Inner area (m^2)	35 000	32 000	**450 000**	12 000	40 000	18 000	6 000	120 000
Number of tracks	3	3	**15**	2	4	3	9	9
Length of tracks (m)	445 – 568	300 – 310	309 – 695	280 – 360	221 – 918	196 – 599	89 – 620	220 – 700
Theoretical / actual volume of transshipments (TEU or ITU)	200 000 / 130 000 TEU	80 000 / 54 000 TEU	**1 200 000 / 1 013 200 TEU**	30 000 / 18 000 TEU	180 000 / 90 000 TEU	11 000 / 60 ITU	290 000 / 250 000 TEU	30 000 TEU
Number of rail gantry cranes	2	0	**5**	0	0	1	0	0
Number of road gantry cranes	0	0	0	0	1	0	0	0
Number of container handlers	4	4	**10**	2	6	0	**10**	1
Operating days	Mo – Fr	Mo – Sa	**24/7**	Mo – Fr	Mo – Fr	Mo – Fr	Mo – Su	Mo – Fr

Notes: Ro – road transport, Ra – rail transport, In – inland waterway transport; TEU – twenty-foot equivalent unit; ITU – intermodal transport unit; 24/7 – service is available any time and every day; Mo – Monday, Fr – Friday, Sa – Saturday, Su – Sunday.

4. Conclusions

It is essential to utilize suitable transport units in order to increase continental combined transport. The condition for the shifting of further transport from the road to the railway transport is in particular that road transport companies are equipped by needed technology. Road transport companies currently realize transports that could be potentially, based on mutually advantageous conditions and shifted to combined transport trains. Thus it is essential that such companies are equipped with suitable transport units.

For further development of combined transport it is essential to focus attention on projects related, in particular, to the support of the following areas:

1. Combined transport infrastructure area (terminals etc.), transportation means area respectively.
2. Acquisition of intermodal transport unit's area.
3. Transfer of road freight transport into railway transport area.
4. Technical and technological equipment of terminals area.

Combined transport disadvantage is, in majority of cases, higher price compared to direct road transport. Thus it is essential to introduce more advanced technologies that shall make these systems more effective (e.g. increase of cargo parameters of interchangeable additions, reducing transshipment costs). In this relation it is useful to mention, for instance, introduction of horizontal transshipment technologies. Under the Czech Republic conditions it cannot be expected that the first impulse for utilization in combined transport shall be born in the Czech Republic since these technologies are used in particular for transports with transport distance over 300 kilometers. The first impulse thus must be provided by a state that is a natural center and a crossroad of the European freight transport, such as is in particular Germany. Depending on the development of such a system abroad it is possible to develop such a system also in the Czech Republic and that in the form of developing relevant network of terminals.

Larger utilization of combined transport does not depend solely on the supporting measures (such as transport infrastructure, international interoperability, number of quality routes for freight railway trains, harmonization of fees), but also on the ability to react to the existing situation where the most important part of freight transport uses logistical and warehousing centers connected to road network. Combined transport will have to offer services to road transport companies for mid and longer distances. Freight transport logistics will continue to be operated, in particular, by means of the existing private logistic and warehousing spaces while at the same time it shall be essential to create links to combined transport terminals. These terminals must have both sufficient parameters and capacities. Thus the existing spaces will not have to be relocated or amended by building additional railway trailers to these spaces.

Acknowledgement

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Simulation-Based Investigations of Automated Lane Change Process

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Abstract

The lane change automation is a fundamental problem of autonomous cars. In our paper we report some fragments of the works concentrated on sensitivity investigations of the automatic controller. This controller is elaborated with using the optimal control theory referred to simple reference mathematical model of vehicle's lateral dynamics in lane change process (simplified "bicycle model" with a few parameters and variables). For validation of controller's algorithms extensive simulation investigations have been used. In such studies a controller's model steers a virtual object – very detail (and experimentally verified !) model of the medium lorry STAR 1142 treated as a 3D multi-body nonlinear dynamical system. Sensitivity studies have realized by comparative simulations with using „nominal" and changed models. Special sensitivity indexes computed with using error signals support this analysis. Simulation-based sensitivity analysis provides more reliable conclusions on the controller's performance and show us: what parameters should be identified on-line, and what accuracy of measured signals is sufficient. The paper presents information on the models, the method used, as well as example results of studies. Presented in the paper results of simulations demonstrate effects of disturbances and errors (noise, zero's offset) of measured angular signals for different vehicle's parameters.

KEY WORDS: *active safety, automation of lane change process, vehicle motion dynamics, simulation, sensitivity analysis*

1. Introduction

Many research centers work on systems that automate road maneuvers at high speeds (obstacle avoidance, overtaking). Such maneuvers are difficult to automate, because they require steering of a mobile object with dynamics that is unstable and sensitive to changes of parameters. These maneuvers are usually a sequence of elementary lane change maneuvers. Automatic lane change process appears to be a fundamental problem of automation of the car steering.

Steering wheel control is a subject of numerous scientific papers (e.g. [6-7]). (Quite detailed literature review has been presented in [5]). They are usually based on a control concept that includes the designation of the path and the execution of the trajectory in the tracking process using the appropriate sensors and regulators. Trajectory planning is then considered as a parametric optimization task for the assumed geometric form of a path shape function. Controllers proposed in these works are based on well known regulation structures and algorithms.

Within the framework of authors' projects (e.g. [3-5]), extensive scientific research has been done on the subject of automatic steering in emergency situations due to sudden impediments. The authors' conception is based on the optimal control theory implemented to the simplest version of the "bicycle model" describing the vehicle lateral dynamics (more details in p.2). The very simple motion model enables analytical forms of reference signals, as well as analytical forms of regulators' algorithms to be used to correct a steering signal with using real trajectory measurements. Thanks to analytical forms of reference signals and regulators, the automatic lane change control process can be computerized in real time.

This conception requires a lot of simulation investigations for sensitivity analysis of the control system. Fragmentary unpublished results of the studies are presented in this paper. They concern the sensitivity of the controller to inaccuracy in measuring of angular position of the car. As a control object occurred a medium size lorry STAR 1142 modeled with many details. Of course, the simulations have been repeated for various vehicle's operating parameters. A similar paper but related to the inaccuracy of lateral displacement measurements was recently presented at the SAE Congress [5]. In the conclusion we could notice that at the low noise levels and a small offset of lateral displacement signal, despite wide range changes of operating conditions of the vehicle, that automatically operated vehicle was able to avoid the obstacle without losing directional stability. Therefore it can be stated that the proposed control concept and developed regulators have proven not to be especially sensitive to measurement errors of lateral position. Now, such problems will be discussed for measured signals of vehicle's angular position.

2. Conception of Lane Change Automated Control System

Imagine a car traveling on a straight road. Suddenly, an obstacle appears and the vehicle is braked. To dodge a crash, the steering wheel rotation angle is activated automatically and carried so as to avoid the obstacle with a constant velocity of motion. The control of the vehicle goes from the "braking process" to the "lane change process".

The lane change process refers to two variables – the displacement of the centre of mass and the angular position of the car body in relation to the trajectory of the centre of mass. According to experiences of drivers as well as the control theory the steering system signal (steering wheel angle signal) should base on the "bang-bang" - type form and the control process can be divided into two phases – transposition and stabilisation, (Fig. 1).

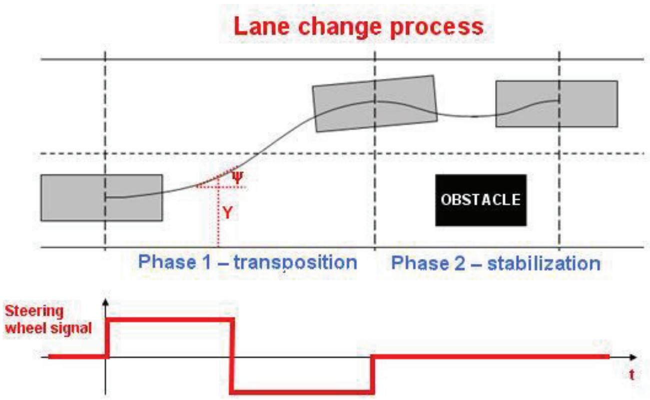


Fig. 1 The concept of time decomposition of lane change control

The lane change process controller (Fig. 2) consists of a generator of three reference signals (steering wheel angle signal, lateral displacement signal and yaw angle signal) and two regulation loops which correct steering wheel angle signal due to minimise errors between reference signals (set point signals) and measured (actual) signals describing vehicle motion trajectory. Regulation circuits are activated in series: firstly – for transposition, and then – for stabilization.

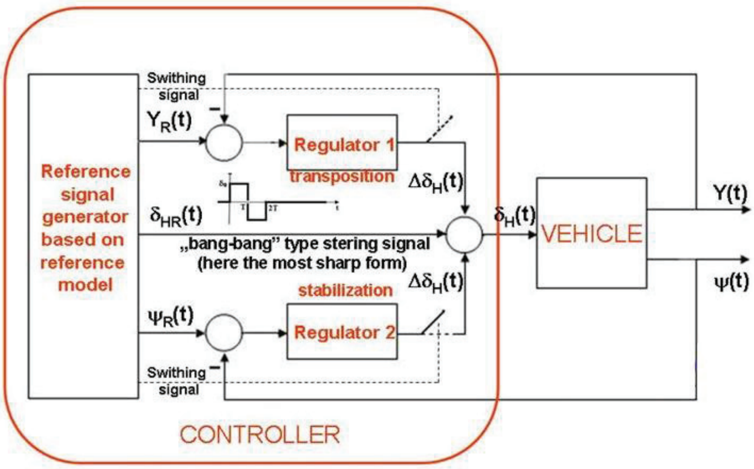


Fig. 2 The concept of lane change control system

The reference signals fulfil a reduced version of transmittance-type model of vehicle motion. This linear reference model describes the vehicle lateral dynamics in global coordinates. It is computed from the well known "bicycle model" [1] (linear dynamical model expressing lateral displacement speed and yaw speed in local coordinates (x,y)) transformed (by non-linear trigonometric formulae) to global coordinates (X,Y). Note, that after transformation, such non-linear model with "bang-bang" type input signals can be linearized, so the Laplace transfer functions can be used. The transfer functions, especially their reduced forms when small inertia effects are neglected, make easier a synthesis of control system structures and parameters (also parameters of "bang-bang" type reference steering signals). Parameters of these reduced transfer functions base on operating parameters of the car (velocity, mass, yaw coefficients, etc.) that are present in the "bicycle model". More detail information about the reference model, reference signals and regulators' algorithms are shown on Fig. 3.

The controller algorithm requires actual values of several operation parameters (V, m,…) of the car, as well as two parameters of the lane change manoeuvre (Y_0, T). An identification procedure of these parameters have to be realized before the lane change process.

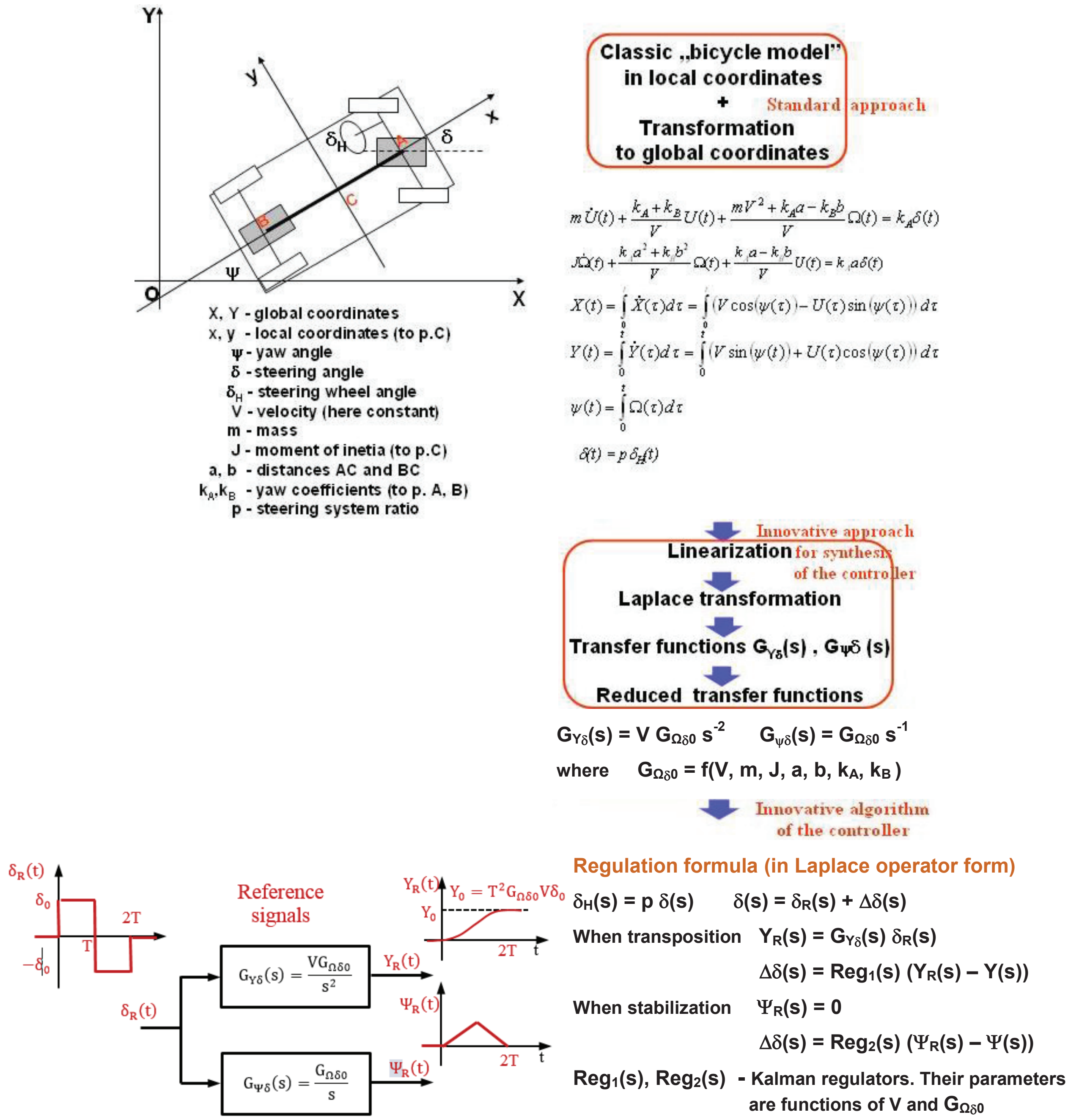


Fig. 3 The concept of lane change control system synthesis

3. Conception of Simulation- Based Sensitivity Studies of Vehicle Motion

Validation of this conceptual lane change control system should be done with using extensive simulation investigations. In such sensitive studies the control system steers a virtual object modeled with many details. A physical model of the virtual vehicle (Fig. 4) represents the medium lorry STAR 1142 fitted with typical mechatronic devises.

The lorry is treated as a multibody mobile object containing 7 masses (car body, 2 axles, 4 wheels) joined by nonlinear spring/damper elements. The model has 20 degrees of freedom. Wheel-road interactions are described by nonlinear Dugoff-Francher-Segel formulae [2] which ensure description of the vehicle motion on many different surfaces, also with a full wheel slip. The steering system model takes into consideration geometrical and kinetic properties, as well as its resilience and absorption. In our studies this system has an additional control equipment – the controller of lane change process, an electrical servomechanism with planetary gears and system of sensors which delivers signals expressing the actual linear and angular position of the car body.

From a mathematical point of view the model is a non-linear system of differential and algebraic equations. The model requires about 200 parameters (note, that the reference model demands only 7 + 2 parameters). For simulation investigations, values of the parameters were calculated on the base of many experiments with the real lorry in static as well as dynamic conditions. Investigations of tires were done on a special drum stand and a dynamometer trailer. Thank to many investigations the model of the STAR 1142 lorry were verified with success. So indeed, its numerical version could be treated as “virtual vehicle”.

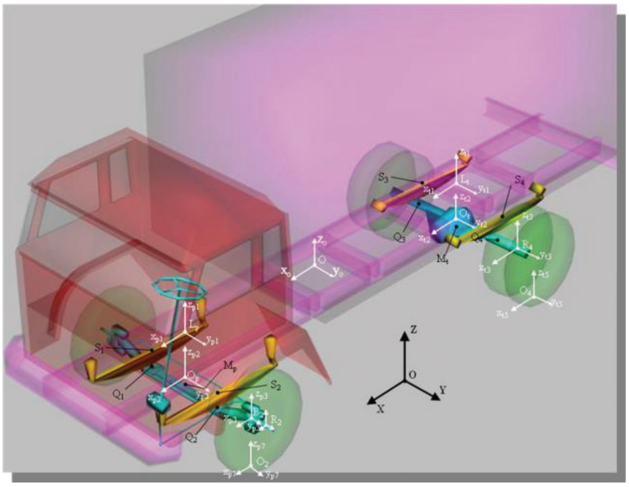
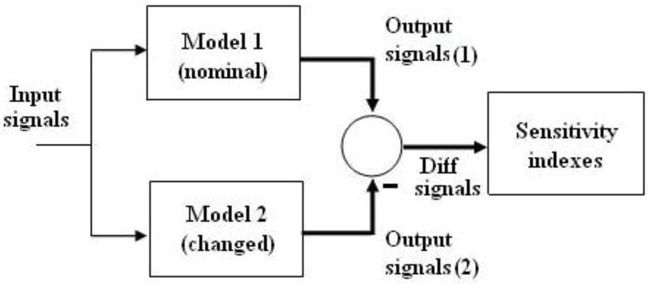


Fig. 4 The concept of the physical vehicle model

The simulation-based sensitivity analysis of mathematical models concerns calculations of signals and integral indexes witch express differences between compared models when the input signals are the same (Fig. 5).



Integral index: $$Wx = 100 \frac{\int_0^{\tau} \left(x_1(t) - x_2(t)\right)^2 dt}{\int_0^{\tau} \left(x_1(t)\right)^2 dt}$$

Fig. 5 General schematic diagram of sensitivity analysis basing on simulation investigations

By changing model equations or parameters we can observe their influence on the results of simulations. The method is very useful for validation our conceptual lane change control system. In this case the models "1" and "2" are activated by the same signals $\delta_{HR}(t)$, $Y_R(t)$ and $\Psi_R(t)$ from the reference signal generator. In this case the most important integral indexes are W_Y and W_Ψ.

4. Examples of Simulation- Based Sensitivity Studies of Vehicle Motion

In the paper fragmentary unpublished simulation investigations are presented (Fig. 6). We look for answer the question: What is sensitivity of the control system on possible disturbances (noise, offset) of the yaw signal sent to the controller. This question is especially important for the stabilization phase of the control process, but of course the registration of the yaw signal (with possible errors) concerns full time of the lane change maneuver.

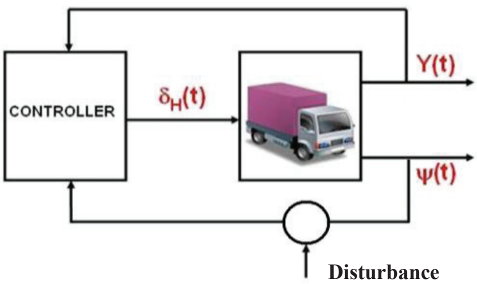


Fig. 6 General schematic diagram of sensitivity analysis due to disturbances in measured yaw signal

According to general schematic diagram of sensitivity analysis (Fig. 5) the Model 1 works without any disturbances and the Model 2 works with inclusion the disturbed signal (constant offset and white noise). The simulation studies concern rather difficult conditions of motion – strong and fast maneuvers also on a wet road. Examinations were repeated for different disturbances (noise and offset), for different vehicle speeds V, for different wheel-road friction coefficients μ and for different vehicle loading (various masses m).

Example selected results (signals of $\psi(t)$ and $Y(t)$ and their sensitivity indexes) are presented on Figs. 7-9. The results refer to the situation when the offset level $\psi_{OFFSET} \subset [-0.5, 0, +0.5]$ deg and the noise amplitude $\Delta\Psi = 3$ deg.

The notation used: Dotted lines for signals from the reference signal generator, solid lines for output signals without errors, dashed lines for output signals with errors.

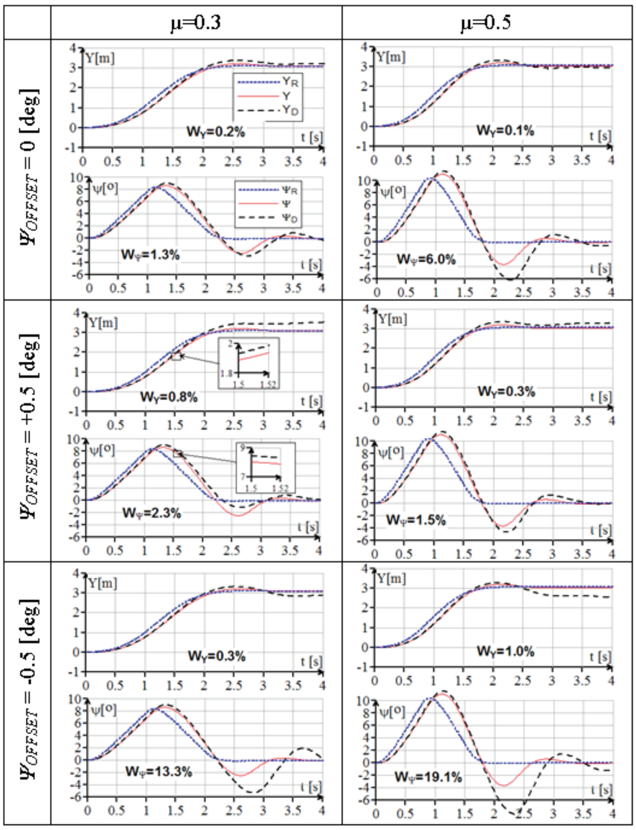


Fig. 7 Results of simulations, V = 19.4 m/s, m = 5300 kg

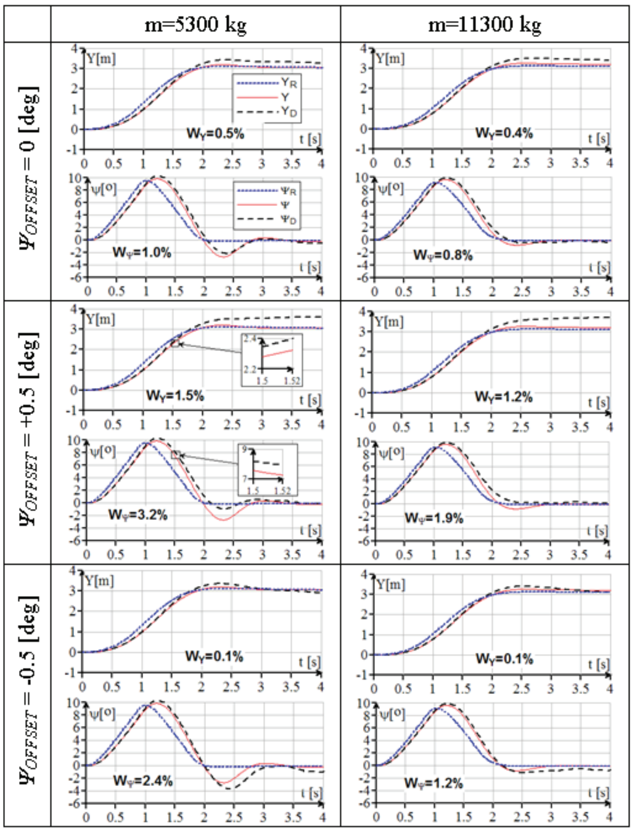


Fig. 8 Results of simulations, μ = 0.4, V = 19.4 m/s

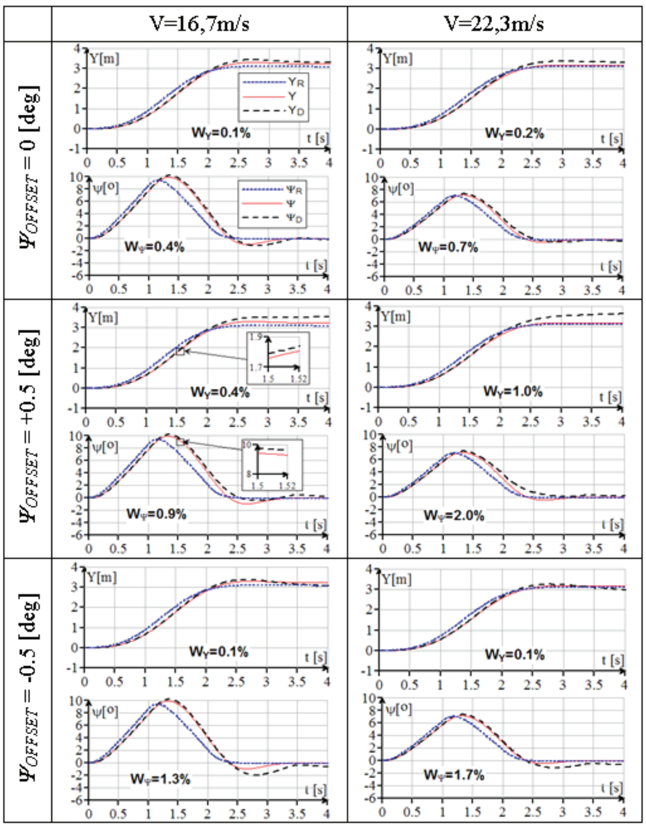


Fig. 9 Results of simulations, μ = 0.3, m = 11300 kg

5. Conclusion and Final Remarks

The simulation results show that in almost all cases the lane change maneuver has been successfully carried out, in spite of the measurement errors of the vehicle yaw signal Ψ(t). The results of simulations performed with an assumed error level in the measurement of the vehicle displacement signal Y(t), not included in this paper, also led to a similar conclusion.

Satisfactory results apply to the case when the controller parameters are properly chosen (for give operating conditions), and the measurement offset and noise are not too large. Especially dangerous for automatic control is the offset. After increasing the measurement offset a higher level (approximately +/- 1 deg) and the noise to a higher amplitude (approximately 3 deg.) it was observed, for selected operating conditions (lightly loaded lorry and wet road), that the vehicle was losing directional stability. At the small offset and the low noise levels in the measurement signals, despite wide range changes of operating conditions of the vehicle, automatically operated vehicle was able to change lane without losing directional stability.

It can be stated that the proposed control system have proven to be enough robust to the measurement errors and varying operating conditions.

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Railway Capacity Issues on Slovak International Corridors

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Abstract

Modernization of railway corridors of railway network of ŽSR is ongoing since 1999. Its main aim is to ensure the infrastructure competitiveness of ŽSR infrastructure by the increasing of the track speed up to 160 km.h-1, and thus to adjust the quality of railway transport. The railway infrastructure capacity is an important qualitative indicator which can assess an investment measures to infrastructure. The paper brings a view to the impact of modernization measures to the capacity with respect the line speed change, upgrading the interlocking systems, technology of transport operation as well the impact of modified configuration of station track layouts. These modernization measures are compared to each other on model examples, to the direct operating situations, as well as on a case study, using more scientific methods. The aim is to highlight some significant infrastructural changes in the organization and management of train traffic that modernization measures bring in the long term, and bring thus specific results which can help in other decision-making processes of ongoing preparation and work progress in modernization process of ŽSR corridors. For a schematic view, the special situational picture annexes are attached, which present the direction of this research.
KEY WORDS: *assessment, capacity, modernization, railway corridors*

1. Introduction

The Railways of the Slovak Republic (ŽSR) since 1999 are undergoing modernization of the Slovak branch of corridor no. Va from Bratislava through Žilina and Košice to the state border with Ukraine, 536 kilometres long. The total cost of modernization at that time was estimated by the ŽSR at about 2 billion. Euro. (Danielis 2004) Its aim is to increase the line speed to 160 km.h-1, then increase the safety of rail transport and to unify the transport system with European Union rules. It includes the construction of new station safety devices (SSD) and track safety devices (TSD). Currently the modernization of the Bratislava-Rača-Žilina sections (except the section Nivy-Trenčín) and Krásno nad Kysucou-Žilina are completed of before the completion of modernization and further modernization work is being carried out on some of the integrated sections of the Púchov - Žilina section, the other sections are only being prepared for the project. At present there are approximately 200 km of modernized tracks. As part of modernization works, the savings in the construction and operation are some railway stations disturbed. This state has an impact on the organization of train traffic and the permeable performance tracks. The aim of the paper is to look at some aspects of the construction of the traffic diagram after the modernization measures and thus to evaluate the possibilities of route insertion, the change in the configuration of the railway yard operating post (stations and overtaking station) to the operational traffic management. We will attempt to quantify the impact of these measures to change the practical capacity of the track section. [1]

2. The Main Principles Used in the Modernization

In the framework of the modernization of the railway infrastructure in the design and subsequent implementation of the construction works joined the use of multiple standards, some of which have a significant impact on the planning, the construction of the train traffic diagram (GVD), traffic management and the capacity performance of rail infrastructure. The main principles of designing and building corridors include:

- line guidance designed for speeds up to 160 km.h^{-1} for conventional vehicles;
- implementation of modern station safety devices (SSD) and track safety devices (TSD) as well as the European Train Control System (ETCS);
- building up platforms; Entrance edges at stations outside the running track;
- speed in the branch lines with a starting edge designed in the range of 60-80 km.h-1 (except railway station Trnava - 40 km.h-1 and ŽST Piešťany, Púchov and Poprad-Tatry - 100 km.h-1);
- using of single crossovers (SCS) usually unilaterally for development of switches, respectively for shunts;
- interference of some stations and complex introduction of simplified shunts with single crossovers (SCS) in the boundary interstationary sections (BIS), which are to be divided into more than two spatial compartments and which are generally unilaterally arranged;
- as TSD are applied automatic block signal (ABS) with the detection of latitude by computer axes (CA) without the transmission of signal (i.e. coding) and it is mostly at the abolition of the automatic block (AB) [1, 2, 8].

Selected construction and reconstruction measures for double-track lines with their respective impact on increasing capacity performance are shown in Table 1.

Table 1

Indicative values by increase track lines capacity

Measure		Range [%]	Middle [%]
Double-track boundary interstationary section			
1.	Building an automatic block signal	120–180	160
2.	Building an automatic block	160–240	200
3.	Construction of a third track rail	190–220	200

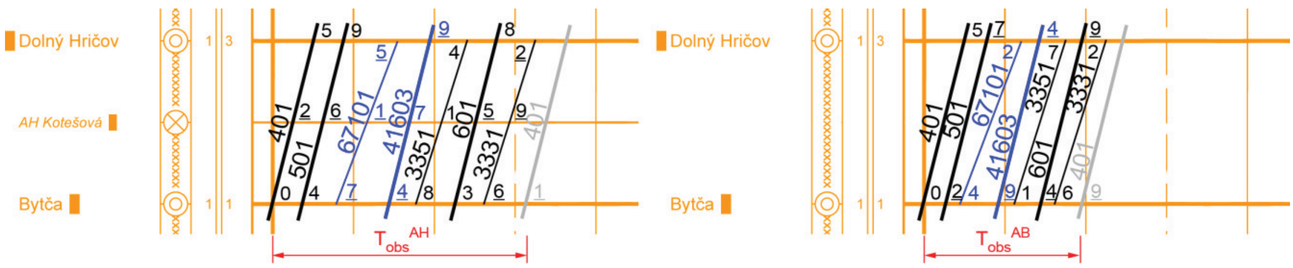
Source: (Gašparík, Šulko, 2016)

3. Assessment of the Measures in the Operational Situations

Selected building and reconstruction standards for the modernization of the ŽSR corridors were analyzed analytically, ie the theoretical calculation for the train types in the TTD, as well as graphically, respectively in a combination, by analyzing the TTD in the operational management, by simulating the lock-out TTD for unplanned shutdown and assessing the suitability of train paths for passenger trains at pick-up and exit stations [7].

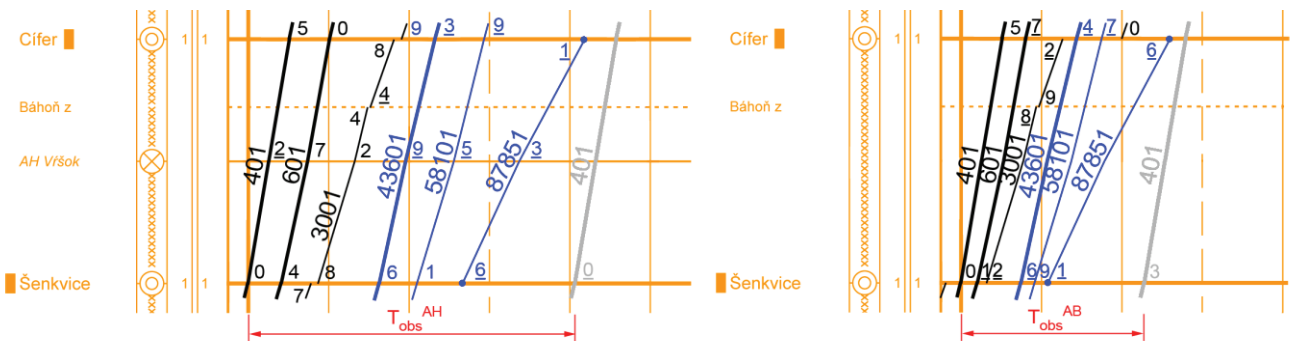
3.1. Consumption Time of the Boundary Interstationary Section

The currently undergoing modernization of corridor *Va* in the Púchov - Žilina section also brings a fundamental change in the organization of the traffic operation due to the gradual cancellation of the automatic block on the track and its replacement by the automatic block signal. As part of the change of TSD, was built in Bytča - Dolný Hričov section an automatic block signal, while in the adjacent section Bytča - Považská Teplá was temporary left a provisional automatic block. However this construction has created a bottleneck that negatively influences to the adjacent sections equipped with the original AB. The negative influence of the automatic block signal on the capacity in this section is expressed after the analytical calculation of the headways for the train sequences in the Fig. 1. Ina a section a 7,8 km length with Vmax 100 kmh-1is the total time of train sequence occupation T^{AH}_{obs} (the train sequence was simulated with seven type of trains – Ex, Ex, Pn, Nex, Os, R, Os) in the case of automatic block signal total 31.5 min and in case of automatic block is T^{AB}_{obs} only 19.5 min [3].



a b

Fig. 1 Comparison of consumption time in the boundary interstationary section Dolný Hričov – Bytča for the automatic block signal and automatic block: a - train sequences by using ABS; b - train sequences by using AB. *Source*: (Project documentation, Trnava – Piešťany, Reming Consult, a.s., marec 2004)



a b

Fig. 2 Comparison of consumption time in the boundary interstationary section Cífer – Šenkvice for the automatic block signal and automatic block: a - train sequences by using ABS; b - train sequences by using AB. *Source*: (Project documentation, Trnava – Piešťany, Reming Consult, a.s., marec 2004)

Similar comparison was made on the upgraded section, but in this section was not an automatic block before its reconstruction. The most traffic extend of utilization is the section Bratislava main station – Trnava, which has a limited section Šenkvice – Cífer – the longest section with 11,8 km length and V_{mas} 160 km.h-1, which is divided by signal device of the automatic block signal into two spatial sections (with approx. 6 km length). In this section is the total time T^{AH}_{obs} of occupancy selected train sequence of six train in the case of automatic block signal 40.5 min. By using the automatic block is total time T^{AB}_{obs} only 23 min (see Fig. 2). An automatic block has been analyzed with the selected 10 spatial sections with an average length nearly 1200 m. Comparison using a model example of selected train sequences clearly illustrates the advantages of the automatic block compared to the automatic block signal, that is used for tracing trains by train traffic diagram, which is even more pronounced in operational management [4].

3.2. Influence of Incomplete Crossovers

The modern corridor's standard is the cost-effective solution of the configuration station developments of switches and overtaking stations. In most cases, there are simple crossovers with almost oblique erasures, one for each development of switch with opposite configuration (Fig. 3). This track branch arrangement (despite the possibility of one-way operation in each line track) brings operational complications and significantly reduces performance of section capacity and possibility of constructing train route in the train traffic diagram. In the operation of the excavation works there are situations where a 20 km long single-track section can occur (in Fig. 3 track section Šenkvice - Cífer - Trnava, with the possibility of maximum crossing up two trains in Cífer station). Due to the arrangement of the platforms only at the extreme tracks (according to the standards of the modernized corridor) it was impossible to simultaneously cross the two passenger trains at this station during the lockout. This example was a planned operational limitation that can be anticipated, planned and adequately addressed in the preparatory phases. However, often unusual and unexpected operating situations often occur in operation, which often lead to a deterioration of TTD stability on the ZSR corridor track [5, 6].

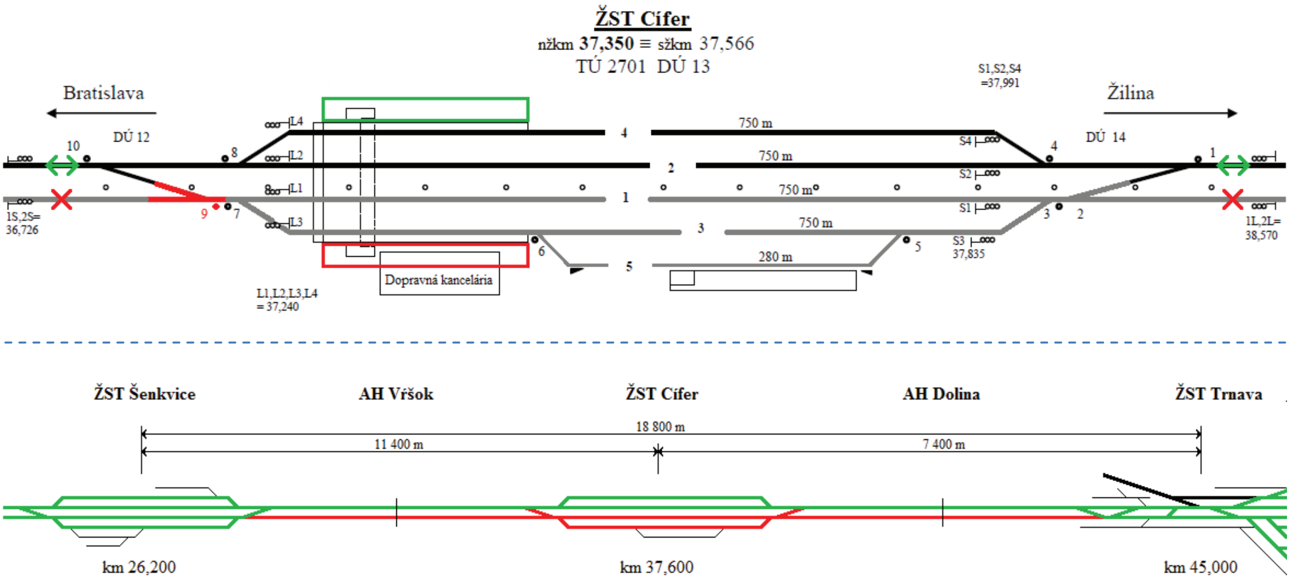


Fig. 3 The operational situation occurred in the corridor during the pre-planned maintenance and repairs. *Source*: (Project documentation, Trnava – Piešťany, Reming Consult, a.s., marec 2004)

With this exclusion was created a nearly 12 km long single-track narrow place.

The resulting values of delay due to extraordinary lockout are shown in Table 2. The average passenger train delay per train is 5.8 min and the average delay of the freight train per freight train is 120.9 min.

Table 2

The number of missed trains in the area of Šenkvice - Cífer - Trnava

	Trains [ks]		Share [%]	Delay [min]	
	All of them	Missed		The amount	To the train
Passenger trains	69	40	58.0	401.0	5.8
Freight trains	38	20	52.6	4594.5	120.9
Sum	**107**	**60**	**56.1**	**4995.5**	**46.7**

Source: (Gašparík, Šulko, 2016)

3.3. Construction of Platforms in the Side Tracks

Another fundamental principle of the modernization of ŽSR corridors is the construction of platforms with an grade-separated approach in the stations with the ascending edges in the side-track. The reason is to increase passenger safety when crossing trains at maximum speed V_{max} = 160 km.h-1. However, this argument appears to be inadequate, because the solution of the platform at the halting station on the track cannot be other than by direct buildup at tracks with the maximum through track speed. The passengers' movement on the platforms can be managed more efficiently using communication plant and information systems. Such as construction solution has contributed to reducing the number of running tracks at freight train stations (subject to the release of the main trains for passenger trains that pass through the station). Before modernization was used train ride for get off and get on passengers' movement in the direct way, after modernization it is possible ride the same train only to the junction signal box. It requires several-second increments to start and stop. In the case of the accumulation of the whole corridor branch Bratislava – Žilina, it is a significant time surcharges for running time [5-7].

4. Evaluation of the Track Section Capacity

These results are a prerequisite for the correctness of the considerations and the basis for an absolute assessment of the effect of the automatic block signal and the automatic block on the capacity efficiency using analytical method.

4.1. Methodology for the Calculation of Capacity Efficiency

The calculation of the capacity efficiency was performed by the ŽSR methodology according to internal regulation D 24 (ŽSR D 24 1965). It is applied to the perspective train traffic diagram, without the need for train traffic diagram construction. It consists in finding and limiting boundary interstationary section, which determines consumption times for each probable train sequences. There are calculated multiples of the numbers of trains in each sequence. By multiplying the respective occupation times and the multiple of the number of trains in each sequence, the total T_{occ} occupancy time is calculated, which is 10% overhead due to the reserve. Subsequently, the unit occupancy time is calculated by the average train t_{occ} and the required reserve time t_{bact}^{req} is determined according to the provisions of regulation D 24.

Practical capacity of track section n is determined by:

$$n = \frac{T - \left(T_{sfm} + T_{focc}\right)}{t_{occ} + t_{bact}^{req}}, \tag{1}$$

where n - practical capacity, vl.T^{-1}; T - calculation time, min; T_{sfm} - supplement for maintenance, min; T_{focc} - fixed occupation, min; t_{occ} - average occupation per one train path, min; t_{bact}^{req} - required backup time according to D 24, min.

Table 3

Comparison of indicators before and after modernization

Operating control point	distance [km]		running time [min]			
	before	after	before		after	
			IC	Pn	IC	Pn
Railway station Leopoldov						
Block signal Madunice/ Automatic Block Signal Madunice	4.1	3.4	2.5	6.0	1.5	4.0
Railway station Veľké Kostoľany	3.4	4.1	2.0	2.5	2.0	3.5
Block signal Drahovce/Automatic Block Signal Drahovce	4.4	5.2	2.0	3.5	2.0	3.0
Railway station Piešťany	6.0	5.2	3.5	6.0	2.0	4.0
Block signal Horná Streda/Overtaking Station H. S.	6.4	6.4	3.5	5.5	2.5	4.5
Railway station Brunovce	3.6	-	2.0	2.5	-	-
Block signal Zámlačie/ Overtaking Station Potvorice	3.8	4.9	2.0	3.0	2.0	3.5
N. M. n. Váhom Overtaking Station č. 50/51	2.3	4.8	1.0	2.0	2.0	3.0
Railway station N. Mesto n. Váhom	1.5	1.5	1.0	1.0	0.5	1.5
Together	35.5	35.5	19.5	32.0	14.5	27.0

Source: (Gašparík, Šulko, 2016)

For the current status and post-modernization condition, the same methodology was used to evaluate the results on a comparable basis. The capacity for the double-track line is determined separately for each direction. Due to the slight difference between the driving time of the trains in the event and the odd direction, it is sufficient to make a calculation for one selected direction, in this case odd. The supplement for maintenanceT_{sfm} is assumed to 60 min and the fixed occupation T_{focc} is not considered. The range of train traffic is considered under the current train traffic diagram 2014/15 (see Table 3) [9, 10].

4.2. Capacity before the Track Modernization

The Leopoldov – Nové Mesto nad Váhom line section is in the whole length 35.5 km double tracked. On the track was a semi-automatic line safety device and at the stations were centrally controlled exchanges. The track operational interval of the subsequent train ride was determined for 2 minutes by analysis of the train traffic diagram. As a boundary interstationary section was determined section Veľké Kostoľany – Piešťany, which was divided into two spatial sections by the Drahovce block signal. [7,8]

4.3. Capacity after the Track Modernization

Within the modernization, only the station Velké Kostoľany was left from the intermediate stations due to a few incoming railway sidings (especially from the Jaslovské Bohunice nuclear power plant). There is installed the electronic signalling box SIMIS-W from Siemens, with the integrated adjacent two-way automatic block signals of Madunice and Drahovce. These safety devices are connected to the remote control form the dispatcher´s Traffic control centre in Trnava. The control of the freedom is ensured by the axle computers. The section´s signal aspects of the automatic block signal have separate presages with 1000 m stopping distance and at a distance of 1500 m is built an information point of safety system ETCS, this mean that only trains run by drive unit equipped with ETCS train control can drive at speeds over 120 km h^{-1}.

The section signal devices automatic block signal Madunice were located approximately 0.7 km closer to Leopoldov station than they were originally. The section signal devices automatic block signal Drahovce are moved to a 76.5 km instead of 75.7 km. In the boundary interstationary section Piešťany – Nové Mesto nad Váhom was cancelled railway station Brunovce and was rebuilt to a stop. There were two overtaking stations – Horná Streda and Potvorice in the form of operating control point with a simple crossover between the line tracks. They are covered by the main signal devices for both driving directions, which are connected to the electronic SSD in Piešťany and Nové Mesto nad Váhom. For the purposes of calculation permissible performance, they are counted as section signal devices, because trains cannot be prevented here. The boundary interstationary section is divided into three spatial compartments.

The new SSD and TSD allowed to reduction the operational interval of subsequent ride. This was determined by calculation for 1 min. The train sequence interval range from 3.5 to 7 minutes, depending on the sequence of trains. The boundary interstationary section became Piešťany – Nové Mesto nad Váhom section, which is divided into three spatial sections by overtaking station. For comparison the performance was determined after modernization of the track, but with the construction of an automatic track safety device (three-character Automatic Block signal). The boundary interstationary section would by section Piešťany – Nové Mesto nad Váhom. Subsequent intervals would range from 1.5 to 5 minutes depending on the train sequence.

4.4. Evaluation of Permeability Performance Change

From the comparison of the above mentioned calculations (tab. 4), it can be stated that the practical foreseeable permeability after the modernization of the track in the sense of the mentioned measures has changed only marginally (in the odd direction from 121 to 129 vl.d^{-1}), thus it remained at the same level as before the modernization. This is caused by a change in the organization of the railway transport after the abolition of the Brunovce railway station, when a new boundary interstationary section of Piešťany - Nové Mesto nad Váhom with a length of 17.6 km was created. New built-in overtaking station cannot be used to prevent trains, because overtaking station is composed only of single crossover tracks. It is also given by the current train traffic diagram, where only 6 pairs of trains are traced to a maximum line speed of 160 km.h^{-1}. A much more significant impact on the increase in permeable performance should be the construction of an automatic block or the build-up of a higher ETCS level (ETCS L2, respectively L3) [9, 11].

Table 4

Variants of indicators of practical permeability

Parameter	Variant		
	before	after	
		Automatic block signal	Automatic block
Unit consumption time t_{occ}, min	7,0	6,5	4,8
Required unit backup time t_{bact}^{req}, min	4,3	4,1	3,1
Practical capacity *n*, vl.d^{-1}	**121**	**129**	**173**

Source: (Project documentation, Trnava – Piešťany, Reming Consult, a.s., marec 2004)

5. Conclusions

Permitted capacity of individual elements, i.e. tracks, development of switches and equipment is one of the most important factors in assessing the capacity of railway infrastructure. It is possible to anticipate the increased interest of domestic and, above all, foreign carriers on the routes on the international corridor lines after their modernization, it is necessary to carry out modernization measures with a view to maintaining sufficient infrastructure capacity [10].

Based on the capacity analysis in Leopoldov - Nové Mesto nad Váhom, despite the modernization and the increase of the line speed, there was no increase in permeable capacity, which, however, due to the decreasing trend of transport performance is now fully sufficient. The share of this is to take action related to the interruption of railway stations, although the remaining stations and line sections have been equipped with modern electronic safety device. The construction of overtaking stations as a single crossover, covered by main signal devices with separate harbinger, which, in view of the examination of the occupancy of the interstationary section by the train sequence, behave as section signal devices, is particularly beneficial in the sewerage of the line while simultaneously introducing the remote-controlled overtaking station. These rail connections are of particular importance for the organization of line tracks maintenance and for operational traffic management, whereby trains can be prevented. However, the use of these overtaking stations to regularly prevent and contemplate trains in constructing a route in a train traffic diagram is very questionable. This complicates the possibilities of constructing train route in the train traffic diagram, due to the smaller possibilities of positioning of train routes in reciprocal prevention, which means narrowing the supply area to the final customer - whether a passenger in the passenger transport or a freight forwarder. The conditions for the operational management of train transport in the event of train delays have also become more difficult, with longer stoppages for the prevention of trains in uninterrupted operating control point.

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Vehicle Detection Methods Used in Traffic Engineering

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Abstract

The paper aims to familiarize the reader with methods used for detection of vehicles on roads and to describe various methods (principles) for monitoring the traffic flow. The paper presents also intelligent transport systems used on highways, which main task is the detection of individual vehicles as well as the optimization and traffic management on this category of roads. In the final part of this paper the main advantages and disadvantages of described methods (approaches) for vehicle detection are summarized and possibilities for their further development are outlined.
KEY WORDS: *detectors, intelligent transport systems, traffic flow monitoring, telematic applications, vehicle detection*

1. Introduction

Vehicle detection has found its application primarily in connection with the growing trend of car transport on the road. Especially in cities and urban agglomerations, there is a daily marked fluctuation in traffic intensity (morning and afternoon peak, frequent congestion, etc.). However, in response to these daily traffic irregularities, it is also necessary to optimize transport facilities for traffic control, namely traffic-light signalling devices and some intelligent transport systems, such as variable traffic signs, road line traffic control systems, or traffic information equipment. In order to determine some traffic-engineering characteristics entering the process of optimization of these devices, i.e. intensity, density and speed of traffic flow, it is always necessary to detect individual vehicles first [1].

The following chapters describe the ways (methods) of vehicle detection used on the road and offer a short summary of advantages and disadvantages of their practical use.

2. Vehicle Detection

Detection of vehicles on the road can be carried out in several ways. The oldest and still very often used one is manual counting of vehicles recorded into pre-prepared forms. Nowadays, perhaps the most frequently used way of monitoring and evaluating the traffic flow is vehicle detection with detectors, and intelligent transport systems (i.e. telematic applications) used on selected roads.

2.1. Manual Counting of Vehicles

This refers to a visual detection of vehicles by traffic surveyors. Either individually or in groups, the surveyors (most often hired temporary workers or students – see Fig. 1) record passing vehicles into pre-prepared forms or special hand held counting devices (for example Hand Held Intersection Counter).

Fig. 1 Traffic surveyors [2]

The calculations from the entries can determine not only traffic intensity (number of vehicles per unit of time), but also the structure of traffic flow distinguishing individual vehicles by categories (e.g. cyclists, motorcycles, passenger cars, trucks, semi-trailer trucks, etc.), and traffic variations in time horizon, mostly in fifteen-minute intervals.

2.2. Detectors

Detectors designed to record the passage of individual vehicles are special devices, whose output can serve both for traffic analyses and traffic engineering calculations. They also represent input data for other telematic applications (intelligent transport systems). Instead of the previous installation of "destructive" detectors disturbing the area of the road, today we mostly encounter "non-destructive" detectors located in the vicinity of the road (e.g. on the construction of toll gates above the road, on variable traffic signs beside the road, etc.). Vehicle detection is performed by the installed cameras and sensors, which constitute an integral part of these measuring devices.

Unlike in manual traffic counting, detectors enable getting additional important vehicle information apart from traffic intensity and structure of traffic flow, for example instantaneous speed of vehicles, vehicle registration plate (can be used for destination traffic surveys), the wheelbase of axles, the total vehicle weight and the axle load on the road, queuing of vehicles in lanes, etc.

<u>The most frequently used types of vehicle detectors include the following devices [3]:</u>

a) Induction loops

This is a destructive type of detectors placed directly below the surface of the road. These detectors consisting of an induction loop and analytical unit work on an electromagnetic principle where the inductive loop generates an electromagnetic field that is affected in the presence of ferromagnetic material. The vehicle detection is enabled by the changes in the field and information is further transmitted.

Induction loops are most often used to detect vehicles at signal-controlled intersections for dynamic on-line traffic management/control or for the preference of public transport vehicles (see Fig. 2).

Fig. 2 Induction loop in a left turning lane [4]

b) Videodetection

It is a non-destructive type of detectors that can be either stationary (positioned in one fixed place) or mobile (portable). These detectors analyse the captured image - a camera record that can detect vehicle speed (speed measurement) or obstructions on the communication (a broken-down vehicle, a traffic accident, passing pedestrians, congestion, etc.). The picture is taken by a video camera, which is most often installed above the road on public lighting poles or adjacent objects (see Fig. 3).

Fig. 3 Camera for traffic flow recording [4]

c) Pneumatic detectors

These non-destructive touch detectors are positioned on the road surface and work on the principle of changing the pressure in the tube when the vehicle passes. With these detectors, it is possible to record traffic intensity, the structure of traffic flow, the number of axles, and the speed of vehicles. Because of their limited lifetime, this type of detectors is rarely used on Czech roads.

d) Ultrasound detectors

This type of non-destructive detectors works on a principle of sound waves reflection. The detector sends a sound wave (outside the audible threshold) and measures the amount of time in which the emitted sound impulse returns to the source. The output is the number of vehicles including their dimensions (i.e. height and length).

e) Piezoelectric detectors

This type of detectors is placed on the road surface. Its principle is based on the fact that the passing vehicle pressure generates an electrical voltage in the sensor, from which the load of the vehicle can be determined. Therefore, this type of detector is mainly used for weighing the vehicles while they are in motion (see Fig. 4).

Fig. 4 Piezoelectric detectors combined with induction loops [5]

f) Microwave detectors

It is a non-destructive type of detectors that measures more traffic-engineering variables at the same time (speed, traffic flow structure, traffic intensity). As well as video detection, these detectors can also be installed as stationary or mobile devices. The principle of measurement is based on transmitted electromagnetic microwaves and the Doppler phenomenon, i.e. when the transmitted waves are reflected, their frequency and wavelength are changed.

g) Infrared detectors

These are also non-destructive detectors, which are further divided into active and passive infrared detectors. The active detector transmits IR waves and is equipped with an optical sensor for receiving these reflected waves from a moving vehicle. Thus, active detectors can be used to measure traffic intensities, and traffic flow structure and speed. Passive infrared detectors, on the other hand, do not transmit any IR waves but operate on the principle of the difference of heat which individual vehicles emit when passing the detector.

h) Optical detectors

This type of non-destructive detectors operates on the so-called optical barrier principle, where the optical beam transmitter is on one side of the road and the receiver is on the other side. The passing vehicle breaks the beam and the detector records its passage. The detector measures the number and category of passing vehicles.

i) Magnetometres

Last but not least, there is a type of detector called magnetometer. Its use is similar to that of induction loops. It is installed below the road surface (destructive installation) and works on the principle of changing the Earth's magnetic field, which is deformed in the presence of the passing vehicle. This change is detected by the magnetometer and the passage of the vehicle is recorded.

3. Intelligent Transport Systems

Intelligent transport systems, also called telematic applications, are special information technologies that facilitate monitoring and real time evaluation of the current traffic situations on the network of selected communications. They also provide drivers, passengers, transport infrastructure managers and security forces with additional traffic information (negotiability of roads, travel time, etc.). Telematic applications complemented by detectors can further evaluate individual traffic flow characteristics, such as average travel speed, traffic intensity and density. By using other telematic systems it is possible to show drivers the necessary information on the current traffic situation in advance or, in the case of traffic accidents, to control traffic immediately [3, 7].

On the Czech road network the Road and Motorway Directorate of the Czech Republic (ŘSD ČR) operates several telematic applications. In case of an extraordinary traffic event, the most important telematic applications for the actual traffic management include the variable traffic signalling system, the traffic information equipment, and the system of road line traffic management.

3.1. Variable Traffic Signs

It refers to a telematic device that in the form of traffic sign pictograms informs drivers about the current traffic situation, or it controls the traffic on the road. Variable traffic signs can be mounted on the road individually (See Fig. 5); however, they are more often located alongside the traffic information equipment (Chapter 3.2).

Fig. 5 Variable traffic sign [6]

3.2. Traffic Information Equipment

This telematic device provides the drivers with information on the current traffic situation directly to the road in the form of a text message on variable message sign board (see Fig. 6). The advantage of these devices over other telematic systems is that automatically published information provided by these technologies is the fastest-released emergency information about an incident which happened on a particular section of the road infrastructure. The variable message sign board displays text in the range of 3 lines of 15 characters. The text contains information about the mileage of location or the whole section of the incident, about the type of incident, and also provides information about the extent of restriction and specific measures. Published texts on this device can be divided into four basic groups. These include events planned in advance, unpredictable situations, weather conditions on the route, and increased traffic intensity. In incident-free situations, some of the traffic information facilities also provide estimates of travel time to remote destinations. [7]

Fig. 6 Traffic information equipment complemented with variable traffic sign [8]

3.3. Road Line Traffic Management

It is a telematic application that consists of portals with variable traffic mandatory or prohibitive signs above the road or next to the road (see Fig. 7). According to the current traffic situation, this system reduces speed or modifies the traffic organization in lanes in such a way that the movement of the vehicle flow is always as smooth and safe as possible. Line traffic management thus increases smoothness of traffic, thereby reducing the likelihood of creating congestion and its range. Therefore, this system is installed primarily in sections with regular and repeated increased traffic intensity and congestion.

Fig. 7 Line traffic management portal [9]

4. Main Advantages and Disadvantages of Discussed Methods for Vehicle Detection

a) Manual counting of vehicles

- advantages: accuracy, flexibility, zero initial investment in measuring devices, independence from measuring devices (measuring failures caused by weather etc.);
- disadvantages: time consumption (training, evaluation), a large number of counters and importance of their coordination, preparation of measurements (printing of forms etc.).

b) Detectors

- advantages: reliability, fully automated operation (no counters, just device operators + monitoring), low operating costs;
- disadvantages: initial investments (price) in measuring devices + the need for purchase of a special evaluation software, limited possibility of use (e.g. induction loops on metal structures) and susceptibility to damage, dependence of a wide range of detectors on climatic conditions (rain, fog, snow, low temperatures), measurement failures, the need for proper calibration and setting of the equipment before measurement.

c) Intelligent transport systems

- advantages: reliability, partially automated operation (device operators + monitoring), roads monitoring (monitoring of the technical state of the infrastructure, i.e. maintenance planning, hazard indication, meteorological situation monitoring, i.e. early warning of frost), monitoring individual vehicles and controlling traffic processes => traffic smoothness and safety;
- disadvantages: huge acquisition and operating costs of individual devices, time required for ITS system implementation (preparation, construction, installation, calibration, verification, commissioning).

5. Conclusions

The main aim of this article was to describe different ways of vehicle detection used in transport engineering as one of the important inputs of telematic applications, i.e. intelligent transport systems. For the sake of clarity, the method of manual counting of vehicles was also described as one of the oldest ways of recording traffic flow [10]. However, the majority of the article focuses on the detection of vehicles using fully automated devices, i.e. detectors. The final part of the paper summarizes the main advantages and disadvantages of the described methods (approaches) for detecting vehicles, and provides a description of telematic applications (devices) using the aforementioned methods of vehicle detection for optimization and, possibly, for traffic flow control on the roads.

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Surroundings Visualization for Unmanned Support Platforms during Rescue Missions

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Abstract

Due to the specific nature of rescue operations, focusing on urbanized areas, priority is given to logistic support in the field of action and direct approach in open areas. This requires the development of vehicles with increased mobility equipped with control and visualization systems. On the basis of the analysis, it was found that the vehicle should have an articulated structure which, with a relatively small pitch, allows for excellent copying of the terrain.
Electronic systems installed on an unmanned platform collect and process information about the environment. The collected knowledge is stored in a map, which depends on many factors such as equipment and degree of platform autonomy, task to be performed, etc. The construction of unmanned rescue platform requires a wide range of research and development. One of the problems is to develop a control system based on positioning and mapping the route of the selected object. In this paper, a problem of the platform nearest area map building based on additional devices is considered. The platform is equipped with SICK LMS lasers, inclinometer and radars. Combining information from the devices allows to build a map which helps an operator to drive the platform more efficiently. We tested the system on a few military vehicles and the results show that our system really improves remotely driving.
KEY WORDS: *unmanned ground platform, surroundings recognition, laser telemeter, map building*

1. Introduction

For effective emergency treatment is used for rapid deployment of telecommunications systems. Current levels of autonomous or semi-autonomous solutions are not available within the time horizon below 10-15 years [2,5]. Due to the specific nature of rescue operations, focusing on urbanized areas, priority is given to logistical in the field and in direct field transits. This task require:

- teleoperation up to 3 km (min.1.5 km) - control of the lost zone of immediate danger;
- transporting goods weighing from 1500 to 3500 kg (1-3 euro pallets);
- ability to self-loading and unloading alone - indicated ability to take non-standard loads;
- moving around and overcoming terrain and urban planning at a better level than terrain.

High field mobility required, resulting from the defense system concept in the damaged area, including the need for installation, lacked the ability to solve the existing faults:

- lack of functional available selection;
- deliberate or accidental blockade of communication routes;
- the necessity of avoiding direct zones;
- desirable time reduction.

This indicates that the maximum travel speed required is below 30-40 km/h (the ability to reach the destination is more important). Ensuring the ability to meet such expectations requires:

- very low average vehicle speed (stability condition);
- multi-axis chassis (for low unit pressures on the substrate);
- very good copying of terrain (leading traps to overcome obstacles);
- very good drive system: resistant to overload, enabling rapid change of full voltage and infinitely variable temperature (diametrically facilitating remote control).

Given that the Star 266 (within 3500 kg), then it is a terrain characterized by higher characteristics, considering that it is not able to meet expectations [5].

2. Description of the Prepared Vehicle

On the basis of the analysis, it was found that the vehicle should have an articulated structure which, with a relatively small pitch, allows for excellent copying of the terrain. Multiaxial vehicles (based on ground pressure analysis estimated the required number of axles for 5-6 pcs.) Operating on large field irregularities ensure proper cooperation of the wheels with the ground. In addition, the hydraulically controlled coupling of the front (drive-transport) and rear (transport) as well as additional turbo assist, allows for greater overcoming of obstacles (Fig. 1).

Fig. 1 View of the unmanned two-wheeled vehicle

To achieve the required capabilities the vehicle is characterized by:
– low center of gravity (980 mm) and load (720 mm);
– 5-axis travel system;
– very good copying ability;
– hydrostatic drive system.

The efficient transport functions are provided by a specially designed forklift system which use standard pallets with increased transport capacity - compatible with existing systems. By providing it with a locking system, it is enable to quickly deploy (and rapidly replace) specialized work platforms (Fig. 2, a).

In order to increase the flexibility of the transport system, the vehicle is equipped with a multi-tasking manipulator with exchangeable grippers, with a lifting capacity of up to 300 kg. This allows to take not only materials prepared for transport (palletised) but also other items such as barrels filled with various materials; Wooden balls; Gas cylinders etc.. Its construction allows it to be folded to a size that does not exceed the outline of the vehicle and position it conveniently for the operator when maneuvering the vehicle. The manipulator enables not only to lift loads but also to carry out grading works, removing obstacles on the ground, installing special equipment (water cannon, camera, sensors). This will allow you to broaden the range of potential uses, combating the effects of natural disasters, catastrophes, and hazardous materials (Fig. 2, b).

a

b

Fig. 2 Lifting of loads: a - using a fork-lift self-loading system; b - loading per vehicle

3. Map Building System

The unmanned vehicle is dedicated to moving in unknown and harsh terrain. Motivation, basic idea and first results are described in [1, 3, 4, 6]. The vehicle is remotely controlled by an operator who is located several kilometers from the vehicle. The operator has a typical, paper map of the surroundings and doesn't know the environment well. Besides cameras which allow operator to drive the vehicle, it is equipped with a map building system. It consists of 5 laser SICK scanners, an inclinometer and two radar speed sensors. The heart of the system is an industrial computer mounted on the vehicle. It's task is to read data from all devices and based on it build a list of obstacles in the nearest surrounding. The laser scanners are mounted in front of the vehicle – 3 of them are horizontally facet in the center, while the other two are vertically faced facing on the both sides and are looking outside the car. Such disposal guarantee that all possible information will be stored in the system (Fig. 3). The map building system has two tasks: to protect the vehicle from obstacles in front and to build a map of obstacles in the nearest area of the vehicle. When the terrain in front of the vehicle becomes untraversable, the system reports it to the operator.

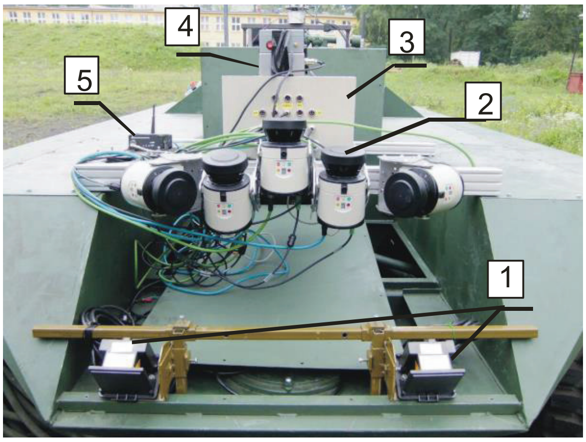
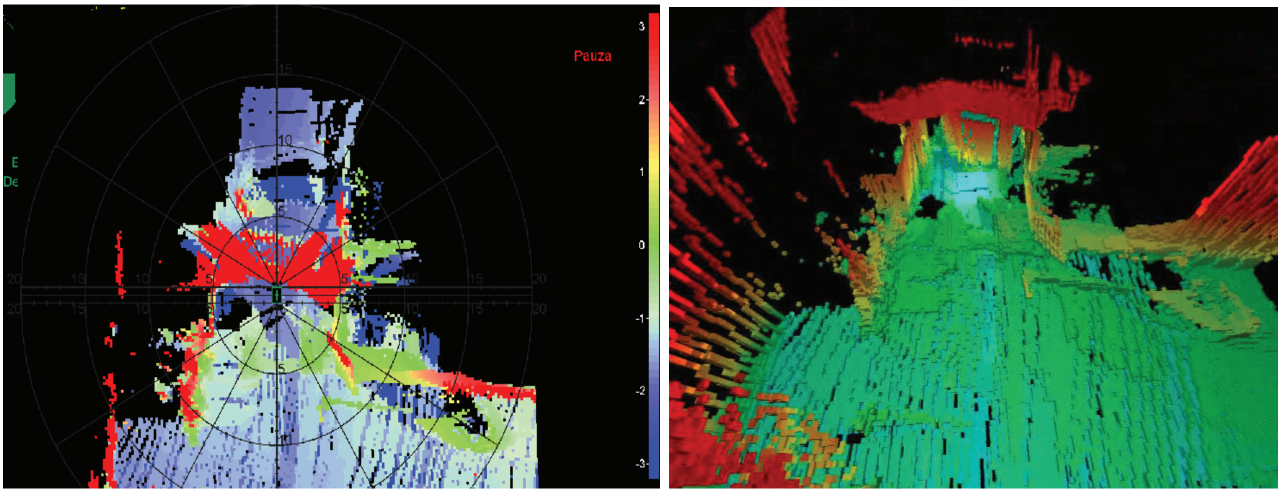


Fig. 3 Map building system devices mounted on a vehicle: *1* - radar speed sensors; *2* - laser scanners; *3* - on-board computer; *4* - acceleration and rotation sensors; *5* - a transmitter radio link

4. Experiments

An operator drives the vehicle using images from video cameras. The map building system described in the article surveys as a supporting system. One of the essential problems which have to been solved was presenting the map to the operator efficiently and to inform him about obstacles around the vehicles as well as possible dangers in front of it. To achieve this a mentioned above model of 3D voxel map is used. It allows to view the map in different ways depending of the details which are to be presented. The primary view is a standard 2,5 D map, where the height of obstacles is presented in different colors.

This kind of view is similar to typical paper maps, where different colors from deep green through yellow to red mean different height of the terrain. This kind of presentation has a big disadvantage in such places where vehicle moves under big obstacles like bridges or trees. In the typical 2,5D map this obstacles make this kind of area unavailable. To solve the problem an operator can set the maximal height which is to be presented. Obstacles above the maximal height are not analyzed. Figure 4a shows typical 2,5D map. The terrain under the bridge is treated as unavailable.



a b

Fig. 4 The vehicle moves between two buildings on both sides: a - typical 2,5D map, there is a small bridge above (in red); b - 3D map showing the way under a small bridge

The 3D voxel map model allows to present the map in many other ways. We studied also:

– a profile map which presents the path in front of the vehicle well and shows the unavailable terrain (like big holes or hills, trees, etc.);

– a polar-coordinated map which shows available directions. It can also be used to build more autonomy based functions.

All the views presented above have some advantages and disadvantages but are built in real time. A much more powerful 3D map has also been explored, but due to its computational complexity for the time being it cannot be created in real-time. The area presented at figure 4a is also presented at figure 4b. It gives much more details, e.g. one can see there is a path available under the bridge and next steps of our research will be trying to build as detailed 3D map as possible in real time.

5. Conclusions

The developed design of the vehicle, the hydraulic couplings, the loading equipment and the manipulator, both in terms of strength and kinematic performance, meet the expectation of rescue operations. The conducted polygon studies have confirmed the high credibility of virtual prototyping and the correctness of the accepted concepts of the work of the equipment. The kinematics of work equipment allows for fast realization of envisaged tasks both in terms of taking up loads as well as their transport. The vehicle is capable of developing the assumed lifting and pulling forces.

The above factors, and the ability to carry out diverse tasks by tailoring other the vehicles to the rapid take-up and installation of tools and special equipment, have created a unique unmanned platform with a wide range of applications.

The future holds a lot of promise for the continued development and deployment of unmanned vehicles of all types. Applications and missions suitable to unmanned vehicles will continue to be identified and robotic technologies will further evolve to fill those needs allowing more complex missions to be performed using unmanned systems.

The typical system of driverless vehicle is equipped with a set of cameras but they give insufficient information about the environment and an operator has difficulties to operate a vehicle efficiently in unknown terrain. In the article were considered a problem of additional map building system which is intended to help the operator. The system presented has the following features:

- it is equipped with 5 laser scanners, inclinometer, radar speed meters and on-board industrial computer;
- no GPS signal is being used;
- transmits far less data than cameras and the data has more information;
- shows the distance to obstacles which is invaluable for operators;
- gives the information about area availability in front of the car;
- a 3D map model is built which allows to create many different views accordingly to needs;
- the best view is 3D map. The bottleneck problem is building a map in real-time. In future we will concentrate to solve the problem;

Future plans include working on building a probabilistic and semantic terrain map.

Resolving problems with navigation and steering of those types of vehicles will allow expansion of its applications from a military point of view in the upcoming few years, to a wide range of applications in times of crisis with direct human life threat.

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The Analysis of the Efficiency of the Control System of Wood Chipper's Drive with Spark-Ignition Engine Based on Skoda Combustion Engine 1.4 59kW

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Abstract

Constantly exceeded permissible limits of air pollutants in urban areas around the world lead to emission reductions in all branches of industry. One of the more restrictive regulations is the one concerning emissions generated by modern passenger vehicles. Constructional solutions used there could be a guideline for the construction of drives for non-road machines, for which regulations are much more liberal. The second approach to reduce emissions, but also to increase the efficiency of the combustion engines is the adaptive control system that is used in non-road machines such as mobile wood chipper. The article gives an equation to determine fuel consumption in a selected range of one cycle of chipper work. It allows to evaluate the performance of the wood chipper depending on the control system used. In order to obtain simulation data to compare the adaptive control system and control system commonly used by manufacturers the researchers tested the combustion engine with spark ignition 1.4 59kW which was installed in the Skoda Fabia. The theoretical analysis showed that the proposed adaptive control system is much more efficient (it is characterized by lower fuel consumption) in sequential operating conditions, eg. in wood chipper used in households.

KEY WORDS: *combustion engine, wood chopping, wood chipper, combustion engine control*

1. Introduction

Air pollution in Europe has declined considerably in recent decades [10-11]. However, there are still problems with air quality [6, 13, 16], due to human activities, for example, through the production of biomass, the use of road vehicles [7-8], air transport [9, 12, 17], maritime transport [1], mining and quarrying [5] household use [3, 14], power plants and CHP plants [2, 4], etc. Structures used in the automotive industry, especially passenger vehicles, are characterized by relatively low exhaust emissions. Contrary to the motors driving non-road mobile machinery, in among which may include mobile wood chippers driven by combustion engines. Some regulations are to be introduced leading to the reduction of exhaust emissions by these devices by introducing more strict European emission limits for toxic exhaust gases, now and after the introduction of 2016/1628 / EU [15] in 2019, they are very liberal compared to the directives for passenger vehicles. Because of the considerably different nature of the work of vehicles and chippers, the article proposed drive control chipper, limiting fuel consumption and emissions of toxic fumes.

Combustion engines used to drive chipper usually work at a constant rotational speed to achieve the maximum torque or the maximum power. The obtained torque value depends on the generated load. Work at idle speed at such a rotational speed generates higher fuel consumption than as if it was operating under these conditions at a lower rotational speed. This conclusion suggests that this parameter influences fuel consumption which leads to the assessment of the effectiveness of shredding process. One way to reduce the fuel consumption in the process of shredding waste wood is to change the drive control system of the chipper.

The proposed control system solution is designed to reduce fuel consumption in the shredding process during the chipping work cycle without the load of the internal combustion engine. This will allow the adaptive control system of the chipper drive to change the rotational speed of the combustion engine according to the object in the working space. During this process chipper works with idle speed. In the case of an object in the working space, it increases the rotational speed so that the maximum torque required for the wood chopping process can be achieved.

The paper also presents a description and theoretical analysis of injection timing control for two control methods. The first is a control that is generally adopted by chaff makers, whose functions can be performed by even the simplest carburetors. The second is the adaptive control of the injection time dependent on the object in the working space. This control requires, among other things, electronic fuel injection with an electrically controlled throttle. On the susceptible theoretical characteristics of the chipper cycle, depending on the type of control system, equations were determined to describe the fuel consumption in the selected section of one chipper operating cycle. The chopping cycles of the chippers were compared for the control system in terms of their efficiency. For this purpose it was necessary to carry out tests of the internal combustion engine, which would supply simulation data. Research and analysis of simulation of efficiency of chipper's drive depending on the control system was carried out for 1.4 59 kW drive unit mounted in the vehicle Skoda Fabia. The study measured the injection time according to the operating conditions of the engine.

2. The Theory of Control of the Wood Chipper Drive

Commonly used chipper drive control system engines with spark-ignition internal combustion is limited to the basic relations. The engine, after starting and reaching operating temperature, operates in two operating conditions (red characteristic Fig. 1):

- no load at idle, at a rotational speed that achieves maximum torque We3;
- under load, at the same speed, generating torque dependent on the resistance of the crushed object within a range not exceeding the maximum torque We5.

Then fuel consumption in one cycle of the chipper with this type of process control depends on how long was the no-load operation (stage a2) and the load one (the section b2) as shown in Fig. 1.

Adaptive control system of the wood chipper drive with combustion engines with spark ignition depends on many control signals. One of the primary signal is the object in the workspace that changes the operating states of the internal combustion engine in one cycle of the chipper. The following states of operating conditions are generated (blue characteristic of Figure 1):

- no load at the idle speed of the We2 internal combustion engine (without the object in the chipper working area);
- temporary state - unstable (section c1) increase in rotational speed from steady state at idle speed We2 to speed enabling work condition with maximum torque We3 (appearance of object in working space, no load - grinding, time to change speed);
- under the load (wood chopping), work at a speed to reach the maximum torque that is generated according to the resistance of the crushed object within the range not exceeding the maximum torque We5;
- transition state - fixed We1 is a time in which there is no chipper object in the working space and the system reduces the speed to the level of We2, generating no injection.

In this type of control system, the fuel consumption depends on the 4 operating conditions of the internal combustion engine, which make up one shredder cycle, and the number of shredder cycles generates total fuel consumption. The reported work conditions neglect the state of the transient operation associated with starting and heating the system.

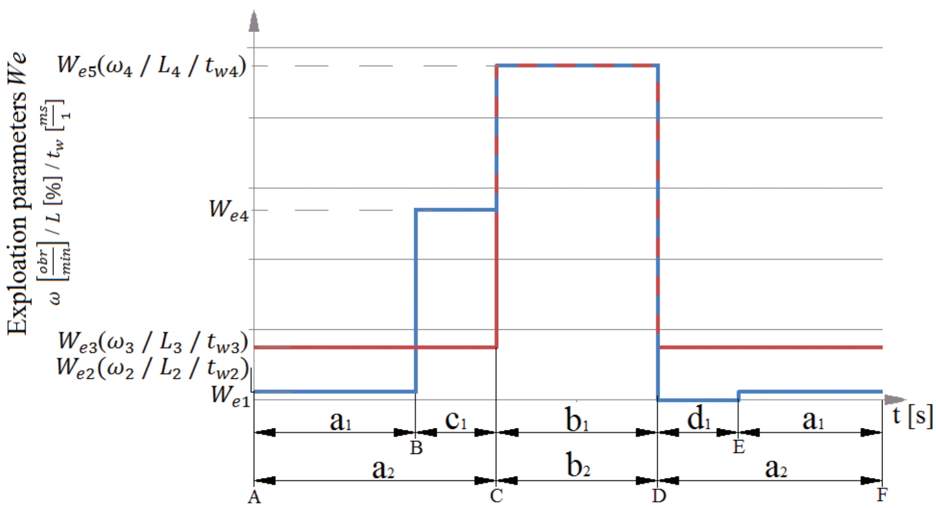

Fig. 1 Exploitation parameters for one work cycle of the internal combustion engine as a function of one chipper cycle depending on the control type: red- factory control; blue- adaptive control where:

$$W_{e4}\left(\begin{array}{l}\left(\dfrac{\omega_2-\omega_4}{B-C}\right)t+\left(\omega_4-\dfrac{\omega_2-\omega_4}{B-C}C\right)\in<B,C>/\left(\dfrac{L_2-L_4}{B-C}\right)t+\left(L_4-\dfrac{L_2-L_4}{B-C}C\right)\in<B,C>/\\ /\left(\dfrac{t_{w2}-t_{w4}}{B-C}\right)t+\left(t_{w4}-\dfrac{t_{w2}-t_{w4}}{B-C}C\right)\in<B,C>\end{array}\right);$$

$$W_{e1}\left(\begin{array}{l}\left(\dfrac{\omega_4-\omega_1}{D-E}\right)t+\left(\omega_1-\dfrac{\omega_4-\omega_1}{D-E}E\right)\in<D,E>/\left(\dfrac{L_4-L_1}{D-E}\right)t+\left(\omega_1-\dfrac{L_4-L_1}{D-E}E\right)\in<D,E>/\\ /\left(\dfrac{t_{w4}-t_{w1}}{D-E}\right)t+\left(t_{w1}-\dfrac{t_{w4}-t_{w1}}{D-E}E\right)\in<D,E>\end{array}\right).$$

3. The Relationship between the Operating Parameters of the Chipper and the Fuel Consumption

One work cycle of a four-stroke internal combustion engine means 2 turnings of the crankshaft. If we know the rotational speed of the crankshaft it is possible to set the number of cycles per one second of engine's work and then calculate the time each cycle lasts in accordance with the equations 1 and 2.

$$n_c = \frac{\omega}{2}\left[\frac{\text{cycles}}{\text{s}}\right], \tag{1}$$

where n_c - number of cycles per one second of combustion engine work $\left[\frac{\text{cycles}}{\text{s}}\right]$; ω - engine crankshaft rotational speed $\left[\frac{\text{rotation}}{\text{s}}\right]$.

$$t_c = \frac{1}{n_c}\,[\text{s}], \tag{2}$$

t_c - the duration of one cycle four-stroke internal combustion engine [s].

Assuming constant pressure in the injection system and constant geometric parameters of the nozzle, the flow rate of the injected fuel is constant. On this basis, the maximum injection volume can be determined in one cycle as follows:

$$V_{C\,max} = Q\,t_c \left[\frac{\text{cm}^3}{\text{s}}\right], \tag{3}$$

where Q - intensity of flow $\left[\frac{\text{cm}^3}{\text{s}}\right]$; V_{Cmax} - maximum injection volume in one cycle [cm^3].

On the basis of the rotational speed and the load of the internal combustion engine, by a suitable control algorithm, injection time of one cycle of the internal combustion engine is selected. The volume ratio of the injected dose to a maximum volume of dose injected may be determined based on the opening time of the injector during the cycle (Eq. 4).

$$\frac{t_w}{t_c} = \frac{V_w}{V_{C\,max}}, \tag{4}$$

where t_w - injection time per one cycle of internal combustion engine [s]; V_w - the volume of the injected dose at the opening of the nozzle of the injector for one cycle [cm^3]

It may be concluded that if the crankshaft rotational speed is changed it influences injector's opening time and the duration of one cycle of work of four-stroke combustion engine In addition, the change also affects the load on the opening time of the injector, which affects fuel consumption.

For a particular operating state, the times of the various operating cycles of the chipper can be determined by the number of cycles of the internal combustion engine in each of the chipper operating compartments in accordance with Eq. 5:

$$\frac{t_r}{t_c} = n_{cr}, \tag{5}$$

where t_r - duration of the selected operating range with one operating cycle of the chipper; n_{cr} - number of cycles of the internal combustion engine during the selected time of one cycle of the chipper

To designate the fuel consumption in the selected unit of one chipper working cycle, equation 6 was used, in which we introduced the coefficient of characteristic drive times of the wood chopping process k_e shown in Eq. 7. This coefficient depends on the injection time and the time of the work cycle of the internal combustion engine which changes as a function of engine speed and load, as well as the time t_r, which will serve as a variable in the analysis of various injection control processes.

$$q = k_e\,V_c\ [\text{cm}^3]; \tag{6}$$

$$k_e = \frac{t_w t_r}{t_c^2} \tag{7}$$

where q - fuel consumption in selected chipper operating range.

In order to determine the fuel consumption in one cycle of the chipper, should sum up the fuel in the individual compartments. To this end, it was necessary to substitute the simulation data that was set during the experimental study.

4. Object and Methodology of Research

The 1.4 kWk Magneti Marelli type BUD internal combustion engine was tested in the passenger car Skoda Fabia 6Y (1999). It can be haracterized by electronic fuel injection and diagnostic capabilities of the EFI system. The tests were performed using the Brain Bee F-Touch 9100 mobile universal diagnostic tester, which enables, among other things, monitoring and recording of ECU parameters.

The tests were performed on a warm engine monitoring in parallel: engine crankshaft engine speed, average injection time per cycle, and engine load. In the first part of the study, the injection time was monitored according to the steady-state speed, without the motor load. In the second part of the study, the fuel injection time was monitored at the maximum engine load. During the third attempt the injection time was recorded during the dynamic increase of the rotational speed and the dynamic relief of the engine and the decrease of the rotational speed to the idle state.

5. Research Results

The results of the injection time study according to the operating conditions of the internal combustion engine are presented in Figs. 2 and 3. The comparison of the injection time according to the conditions of exploitation of the chipper are shown in Table.

The injection time during the maximum engine load is shown in Fig. 2. The injection timing characteristics during dynamic engine loading and unloading are shown in Fig. 3. The load was generated by increasing the rotational speed. The indicated injection time is an average value which, due to the low sampling frequency, is lowered for characteristic 3. As during the dynamic increase injection time is 19 ms, and after decrease 0 ms.

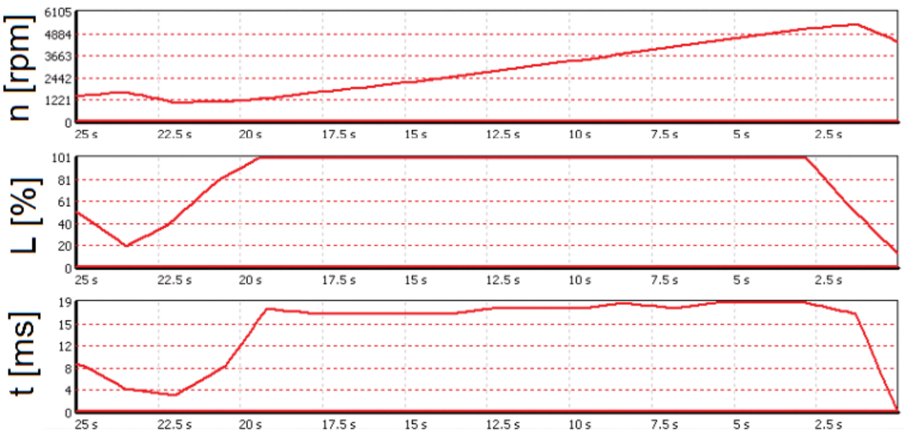

Fig. 2 Characteristics of injection time *t*, vacuum values in the suction manifold indicating the load of the engine *L*, engine speed n under exploitation conditions when reaching and maintaining the maximum load

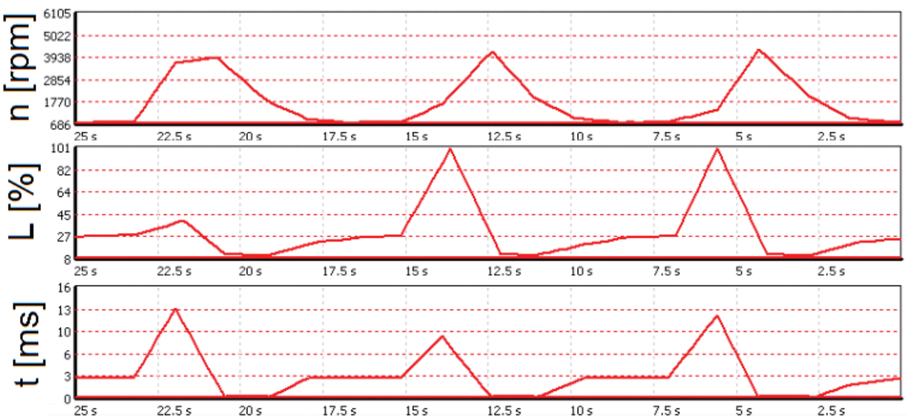

Fig. 3 Characteristics of the injection time *t*, vacuum values in the suction manifold indicating the load of the engine *L*, engine speed n in operating conditions during dynamic maximum speed and dynamic loss of it

Table

Study results of injection time, load and rotational speed under specified exploitation conditions

Reference to states during one chipper cycle		Exploitation of engine conditions				t_w
		ω [obr/min]		t_s [s]	L [%]	[ms]
Operating conditions of wood chipper	W_{e2}	Idle work	780	0 - ∞	26	3
			1000	0 - ∞	27	3,5
			2000-4000	0 - ∞	17-18	2
	W_{e3}		5000	0 - ∞	17	3
	W_{e5}	Constant load	1500-5000	0 - ∞	100	19
	W_{e4}	Dynamic increase ω	780-4500	2,5	27-100	19
	W_{e1}	Dynamic loss ω	4500- 680	2,5	100-8	0

t_s - time of state lasting

6. Analysis of the Efficiency of the Control Systems Drives of Wood Chipper

The analysis was performed for the two control systems described in point 2. Fuel consumption in one cycle of chipper work depends on the length of time the individual operating conditions. In idle operation, the factory control system generates significantly higher fuel consumption than the adaptive system as in Fig. 4. The reason for this is the difference in the rotational speeds when working under these exploitation conditions.

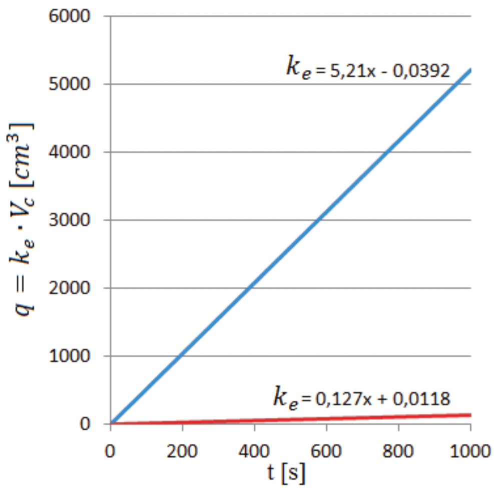

Fig. 4 Fuel consumption during idle operation of the wood chip as a function of time depending on the control type, blue- factory control, red-adaptive control

Fuel consumption when the chipper does not shrudder is the same as at idle gear. The adaptive control system at the same time generates three types of exploitation conditions (idling, acceleration to maximum torque or power, idle speed after shredding) that affect fuel consumption. Consumption of fuel over this period is their sum and is considerably lower than that of the fuel consumption in the factory system, as shown in Fig. 5. In addition, the starting point of the characteristic is shown (detail A), where for the first 2.5 seconds the injection time is increased due to accelerating the engine to the maximum torque. During the next 2.5 seconds the average fuel consumption drops as this represents the return to idle speed. The first 5 seconds is the time when the chipper only rises and decelerates during the break, then fuel consumption is added during idling. As indicated by the mix enhancement characteristics associated with dynamic acceleration to achieve the desired coin characteristic the engine does not significantly affect fuel consumption with respect to the factory control system. In addition, this consumption is partially compensated when the rotational speed decreases with the injection time being 0.

Fuel consumption during operating conditions when the chipper crushed during one cycle of the chipper is the same for both control processes, so the analysis of their effectiveness has been omitted.

The analysis of the effectiveness of control systems drives chippers due to exploitation conditions during a break in one cycle chipper have the most significant impact on the efficiency of chipping processes. They indicate that the proposed control is justified in a chipper operated in non-continuous work cycles. So in applications such as households where grinding an object is delivered cyclically to the machine without turning it off. Volumetric lower fuel consumption will also emit less exhaust gases.

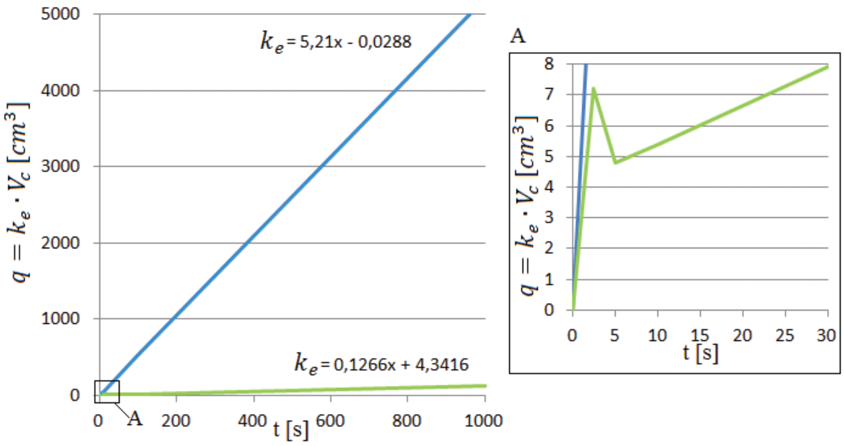

Fig. 5 Fuel consumption during pause in one duty cycle of the wood chipper as a function of time, depending on the type of control, blue factory control, green adaptive control

7. Summary

Mobile wood chipper devices are more and more popular among households. Research is ongoing on improving the efficiency of these processes. Proposed in an article control system of chippers drives may influence the efficiency of grinding processes by reducing fuel consumption. The comparative analysis of the wood chip control systems has shown that control using the adaptive system is characterized by significantly lower fuel consumption. This system is effective for the construction of discs with discontinuous operation. So, like in households where waste is supplied to the device with breaks, and the device is idling at this time. Reducing fuel consumption is important not only because of the lowering the costs of the operation but also the amount of air pollution emitted. It should be bared in mind that the emissions generated by the wood chips affect global pollution but also significantly affect the human organism of the operators and the people nearby the machines. Further research will be carried out on: construction of an adaptive control system for the chipper drive, real fuel consumption by the indicated control systems, analysis to assist the efficiency of combustion process in combustion engine in chipper drive conditions, quantitative and qualitative assessment of exhaust emissions due to control systems.

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The Effects of the Combustor Fuel to Air Ratio, Turbine Inlet Temperature, Compressor Bleed Air, Turbine Blade Cooling on the Gas Turbine Performance

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Abstract

One of the most important improvements, the gas turbine has experimented, is the increase of the gas turbine inlet temperature. It has been possible thanks to improvements on the turbine blade cooling techniques, and of course, metallurgical advances. Bleed air is extracted from the compressor for many different purposes like air conditioning, engine start, hydraulic and fuel system pressurization, compressor stall prevention. The specific stage of the compressor from which the air is bled varies by engine type. In some engines, air may be taken from more than one location for different uses as the temperature and pressure of the air is variable dependent upon the compressor stage at which it is extracted. What is common of all compressor bleed is the deterioration of engine performance caused by the extraction.
Although, one of the compressor bleeds far from decreases but rather increases the gas turbine engine performance. That is when the colder bleed air is used for the turbine blade cooling increasing the allowable Turbine Inlet Temperature (TIT). In this paper, using our in-house developed thermal mathematical model we examined the negative effect of compressor bleed and the positive effect of the extracted bleed air used for the turbine blade cooling comparing its negative and positive effect on the engine performance.
KEY WORDS: *combustor, fuel to air ratio, excess air, compressor, bleed air, turbine blade cooling, turbine inlet temperature, thermal mathematical model*

1. Introduction

The modern trends of gas turbine engines focus on increased TIT in order to increase the engine Thermal Efficiency (TE) reducing the Specific Fuel Consumption (SFC) and increase the Specific Net Work Output (SNWO) of the engine. However, operation at very high temperatures reduces the life time of turbine vanes and blades while the allowable temperature level of the cycle is limited by the melting point of the materials. Therefore, turbine blade cooling is necessary to reduce the blade metal temperature to acceptable levels for the materials increasing the thermal capability of the engine. Fig. 1 represents the evolution of turbine blade cooling. Due to the contribution and the development of turbine cooling systems, the TIT has been over doubled over the last 60 years.

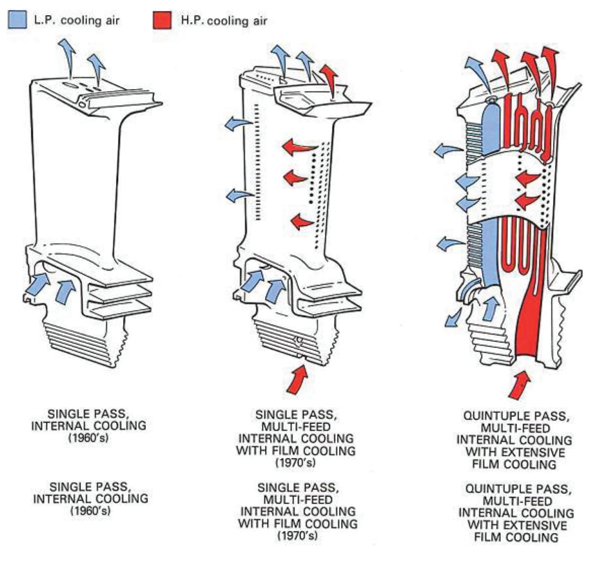

Fig. 1 Evolution of turbine blade cooling technology [1]

The universal method of blade cooling is by air bled from the compressor flowing through the internal passages in the blades. In the case of film cooling, the coolant exits from the leading edge of blade and a film is formed over the blade surface, which reduces the heat transfer from the hot gas to the blade surface.

The specific stage of the compressor from which the air is bled varies by engine type. In some engines, air may be taken from more than one location for different uses as the temperature and pressure of the air is variable dependent upon the compressor stage at which it is extracted. What is common of all compressor bleed is the deterioration of engine performance caused by the extraction. But if the bleed air is used for the turbine blade cooling, the expected advantage can be higher than the suffered loss.

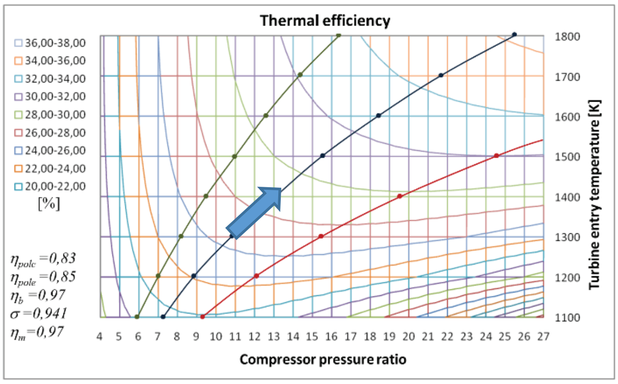

Fig. 2 TE curves in TIT versus CPR diagram [4]

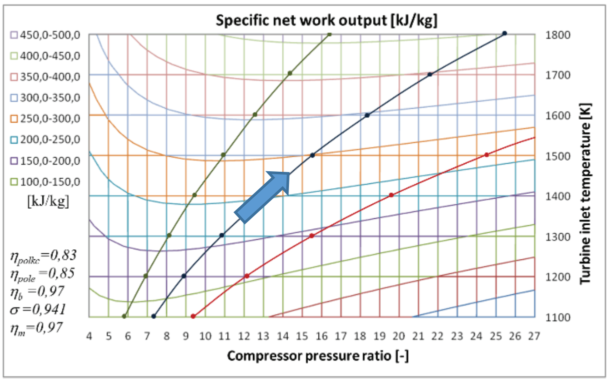

Fig. 3 SNWO curves in TIT versus CPR diagram [4]

In Fig. 2 the TE curves can be shown from 20 to 36%, while in Fig. 3 the SNWO curves from 100 to 500 kJ/kg. In both cases the component efficiencies are shown in the bottom left corner. The above mentioned phenomenon clearly visible in these two diagrams. The higher TIT results higher TE and SNWO. Increasing the TIT and Compressor Pressure Ratio (CPR) (blue arrows) without higher or even sometimes with lower engine element efficiencies, higher SNWO and TE can be achieved. Without being precise, about 100 K TIT and 2.5-3 CPR raise results (absolute) 2% TE and 50 kJ/kg SNWO raise with unchanged element efficiencies.

Fig. 4 represent how the TE ~ 30% curve changes its position if the compressor polytrophic efficiency decreases from 0.83 to 0.82 (1%). We can presume that the effect of bleed air from the compressor can be very similar to the situation shown by Fig. 4. In accordance with it, considering only the air bleed the same TE (30%) curve slips up (through point “D”) to the direction of higher TIT-s. In this case the original curve (through point “A”) represents a less than 30% TE. The air bleed from the compressor used for turbine blade cooling is useful if the higher TIT rises the engine operational point over the upper curve (through point “D”).

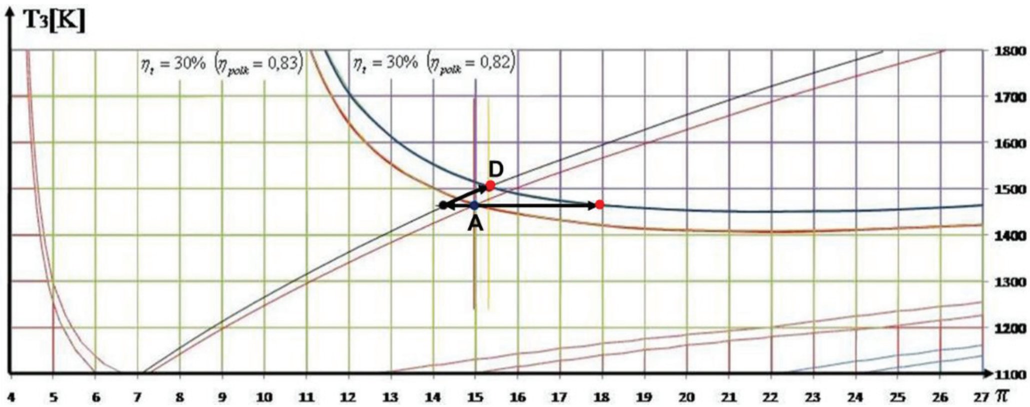

Fig. 4 The effect of decreasing compressor polytrophic efficiency on engine thermal efficiency [4]

Shortly the question is the rate of deterioration caused by the air bleed versus the improvement of engine performance (TE and SNWO) coming from the air bleed used for turbine blade cooling. Creating thermal mathematical model, we intended to answer numerous questions arisen with the work of gas turbine engines, most of them analyze the effects of above mentioned question.

For the analyzes we have chosen two vital performance indicators of gas turbine engines, namely the SNWO and TE of gas turbine cycles. Both of them are primary performance indicators and suitable for the evaluation of any kind of gas turbine engines.

SNWO ($w_{net}(\pi)$), is the desired output of the thermodynamic cycle. In accordance with the second law of thermodynamics the mechanical work is always less than the input heat and in addition the friction in the real gas turbine components causes some more heat loss. This heat is dissipated as waste heat into the environment.

$$w_{net}(\pi) = w_e(\pi) - w_c(\pi). \tag{1}$$

TE ($\eta_{th}(\pi)$), in general, energy conversion efficiency is the ratio between the useful output of a device ($w_{net}(\pi)$) and the input, in energy terms. For thermal efficiency, the input ($q_{in}(\pi)$), to the device is heat, or the heat content of a fuel that is consumed.

$$\eta_{th}(\pi) = w_{net}(\pi) \;/\; q_{in}(\pi), \tag{2}$$

where $w_c(\pi)$ - specific compression work, J/kg; $w_e(\pi)$ - specific expansion work, J/kg; $q_{in}(\pi)$ - specific input heat, J/kg; π - CPR.

2. Relationship Between the Combustor Fuel to Air Ratio and Turbine Inlet Temperature

The turbine inlet temperature implicitly depends on the air to fuel ratio in the combustion chamber. Considering stoichiometric combustion 14-15 kg air is necessary to burn 1 kg kerosene while the fuel to air ratio is at about 0.066. In this case the flame temperature can be 2600-2800K. It is far too hot, so it is necessary to cool the hot gas in combustor saving the turbine blades from harmful over temperature. In normal operation, the overall air/fuel ratio of a combustion chamber can vary between 45:1 and 60:1, consequently the fuel to air ratio is 0,0166 to 0,0222.

Practically it means that 20 per cent of the air mass flow travels through the snout or entry section into the primary combustion zone. The air from the swirl vanes and that from the secondary air holes interacts and creates a region of low velocity recirculation. This takes the form of a toroidal vortex, which has the effect of stabilizing and anchoring the flame. It is arranged that the conical fuel spray from the nozzle intersects the recirculation vortex at its center. This action, together with the general turbulence in the primary zone, greatly assists in breaking up the fuel and mixing it with the incoming air.

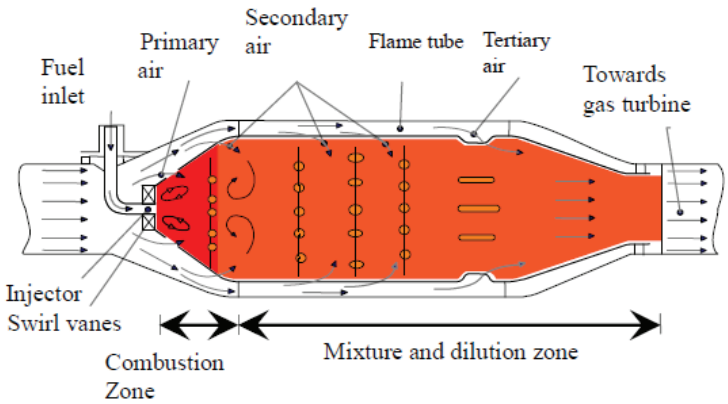

Fig. 5 Gas turbine engine combustion schematics [2]

Through the wall of the flame tube body, adjacent to the combustion zone, are a selected number of secondary holes through which a further 20 per cent of the main flow of air passes into the primary zone providing nearly stoichiometric combustion. The remaining 60 per cent is divided into two parts. 40 per cent for the film cooling of flame tube, and the other 20 per cent for dilution to cool the hot gas before entering the turbine. This kind of air distribution can be seen in Fig. 5 [2].

The heat addition in gas turbine combustion chamber is nearly isobaric, so applying the usual thermal equation for isobaric heat addition the final temperature can be determined relatively easy.

$$\eta_b \cdot \dot{m}_{fuel} \cdot FHV = \dot{m}_{air} \cdot c_p \cdot \left(T_2 - T_3\right) \rightarrow T_3 = T_2 + \eta_b \cdot \frac{\dot{m}_{fuel}}{\dot{m}_{fuel}} \cdot \frac{FHV}{c_p\left(T, f\right)} = T_2 + \eta_b \cdot f \cdot \frac{FHV}{c_p}, \tag{3}$$

where $\dot{m}_{fuel}$ - fuel consumption, kg/s; FHV - Fuel Heating Value, J/kg; $\dot{m}_{air}$ - air mass flow rate, kg/s; $c_p\left(T, f\right)$ - isobaric specific heat constant; T_2 - combustor inlet temperature, K; T_3 - Turbine Inlet Temperature, K; f - fuel to air ratio, -; η_b - burner efficiency, -.

The gas properties, including isobaric specific heat constant (c_p) are in reality not constant but change significantly with temperature. Moreover, the magnitude of gas properties depends also from the composition of the combustion gases, i.e. the fuel to air ratio, so it is highly recommended using temperature dependent gas properties.

Creating the temperature dependent gas properties, we used a polynomial approximation which can be expressed by the equation 4 and the polynomial coefficients (x_i; y_i) can be seen in table 1. Here the $R(f)$ is the specific gas constant, currently not used, but to determine the adiabatic exponent (γ) it can necessary, however its composition dependence is almost negligible and its value is approximately 287 J/kgK [4].

$$c_p(T,f)=\sum_{i=0}^{7}\frac{f\cdot y_i+x_i}{f+1}\cdot\left(\frac{T}{1000}\right)^i \quad \text{and} \quad R(f)=287,04\cdot\frac{1+1,0775667f}{1+f}. \tag{4}$$

Table 1

i	x_i	y_i
0	1043,7970	614,786
1	-330,6087	6787,993
2	666,7593	-10128,910
3	233,4525	9375,566
4	-1055,3950	-4010,937
5	819,7499	257,610
6	-270,5400	310,530
7	33,6067	-67,426

Using the temperature dependent isobaric specific heat $[c_p(T,f)]$ and considering 800 K as combustor inlet temperature we created the red (straight) line in the diagram shown on Figure 6. The exit temperature in this case is the TIT. Comparing the result to the diagram created by Technical Team of the NATO on the topic of Performance Prediction and Simulation of Gas Turbine Engine Operation for Aircraft, Marine, Vehicular, and Power Generation [3], there is a considerable alignment with their kerosene temperature curve while the fuel to air ratio is 0.0166 to 0.04, see Fig. 6. This range of fuel to air ratio is largely covers the normal operation of gas turbine engines.

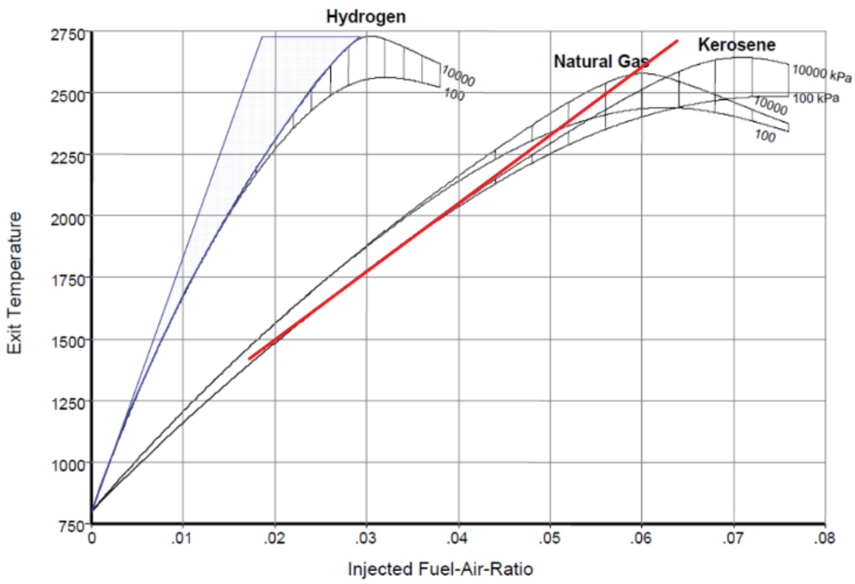

Fig. 6 Turbine inlet temperature versus fuel to air ratio [3]

However, over 2000 K there is significant difference between the theoretical and real temperature curves even taking into consideration the high pressure in the combustor. Considering, that even in this range of operation the TE improvement per 100 K TIT raise is less and less. We can presume that over 2000 K the ratio of TE improvement to TIT raise will be even worse, which practically questions the worthiness of turbine blade cooling. Under this temperature almost sure the turbine blade cooling despite the negative effect of compressor air bleed, improves the TE of the given gas turbine engine. In the next part of paper we examine this problem.

3. Air Bleed from the Compressor

Building up the thermal mathematical model of gas turbine engine we took into consideration two air bleeds. For one of them the specific stage of the compressor from which the air is bled as well as the amount of air is variable. This air bleed is considered costumer air bleed and it has no effect on turbine work because it is used anywhere else (air conditioning, hydraulic and fuel system pressurization, compressor stall prevention) but not for turbine cooling. If there is multiple air bleed of a particular engine the optional place made it possible the examination of their effect on the engine parameters one by one, but at the end their effect can be summarised.

The other air bleed is used for the turbine air cooling. The amount of air is variable but the place of the extraction is fixed to the last stage of the compressor. It is reasonable because the blade cooling of the first turbine stage in most cases gets the cooling air from the last compressor stage. It is partly because the turbine inlet is the hottest part of the engine so even the relatively high temperature air from the last compressor stage cools effectively the turbine vanes and blades, on the other hand the high pressure in the first turbine stage needs high pressure cooling air which is available only at the last stage(s) of the compressor. In the next turbine stages due to the expansion both the pressure and temperature sharply decreases, consequently the extraction of the cooling air can be somewhere in the mid stages of the compressor.

4. Effect of the Cooling Air Flow on the Turbine Work

Fig. 7 shows a cooled single-stage turbine with a typical cooling air supply system. Compressor exit bleed is the source of the cooling air, and the control volume is identical to the turbine annulus.

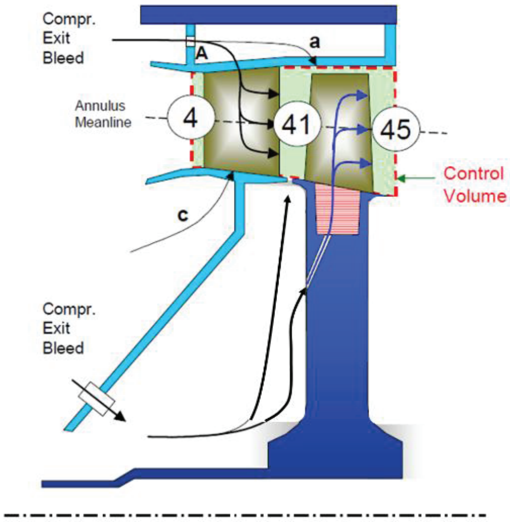

Fig. 7 Schematic of a Single-Stage Cooled Turbine [3]

The effect of the turbine cooling air stream on the turbine specific work can be examined in two ways. First when we try to examine the cooling effect of different cooling air streams on the turbine gas flow, Fig. 8. In the nozzle guide vanes the cooling air increases the mass flow rate meanwhile decreases the temperature of the turbine gas flow considering isobaric heat exchange.

The situation is same in the rotor, where the mass flow rate further increases and temperature decrease due to the heat exchange. However, we have to underline that the TIT even considering these effects of cooling streams is considerable higher than the initial TIT, which would be allowable without cooling by the given turbine stage. What gives the problem in this method is to determine the amount of the different cooling air streams and the temperature after their mixing.

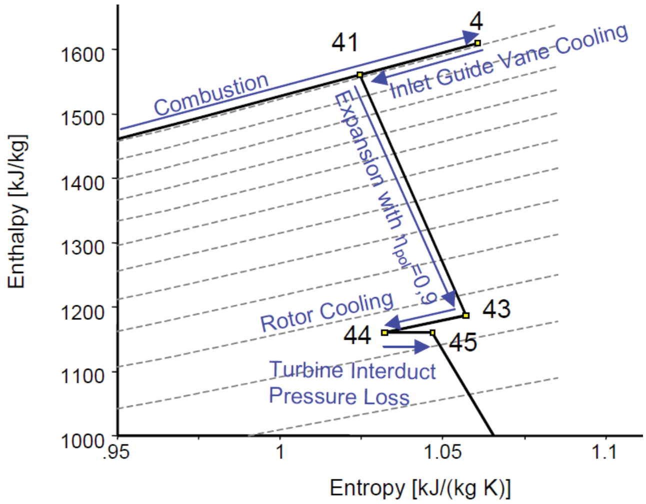

Fig. 8 SNWO and TE curves in compressor polytrophic efficiency versus pressure ratio diagram [3]

The other method is considerably easier. In this case we don’t deal with turbine respectively, but we consider that the turbine is such a machine (a black box) which convert the thermal energy into work. The work potential of these streams are defined via their respective pressures and temperatures, which at least theoretically all can be measured. In accordance with it we don't deal differently the different gas flows either it comes from the combustion chamber or from any part of the compressor as cooling air, see Fig. 9. All of these energy streams have the work potential which results from an isentropic expansion from their individual total pressure Pi to the turbine exit pressure p_{45} in Fig. 9 (pressure at the exit of last turbine stage).

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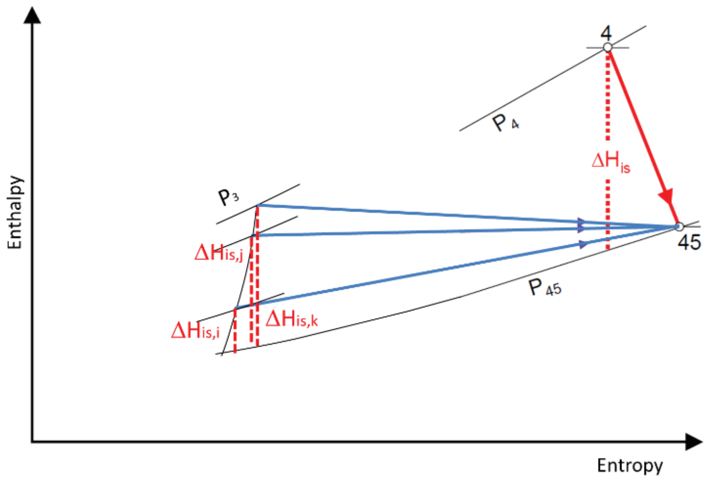


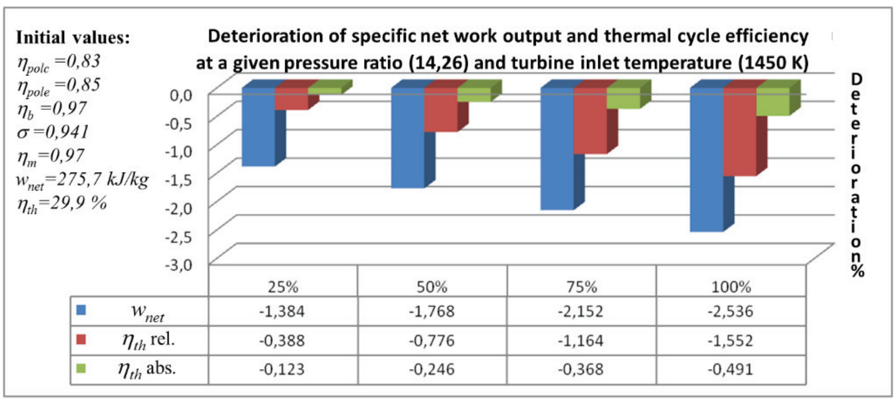
Fig. 9 SNWO and TE curves in compressor polytrophic efficiency versus pressure ratio diagram [3]

Of course, the examined cooling air streams also suffer pressure loss flowing through the different engine element and at last through the turbine blades. What is more the pressure loss is expected much higher than the pressure loss in the combustion chamber. However, the turbine work from the cooling air streams is much less than comparing the turbine work of main gas flow due to the small amount of gas and the much lower initial temperature of expansion, but the negligence of their effect would deform the results of the mathematical model.

The equations have become much more difficult but the basic principle is unchanged, namely the SNWO is defined by the difference of Specific Expansion Work and the Specific Compression Work, see Eqs. 1 and 2.

5. Effect of the Costumer air Bleed on the TE and SNWO

The results are represented in Fig. 10. The costumer air bleed is 1% of the total amount mass flow rate, extracted respectively at the places of 25-50-75-100% of compression process. The 25-50-75-100% of compression process means that the place of extraction is not a given stage or geometric point of compressor rather the place where the 25-50-75-100% of the whole compression work is done on the airflow. Clearly visible that the air bleed has dominant effect on the SNWO, while the TE is much less effected.



	25%	50%	75%	100%
w_{net}	-1,384	-1,768	-2,152	-2,536
η_{th} rel.	-0,388	-0,776	-1,164	-1,552
η_{th} abs.	-0,123	-0,246	-0,368	-0,491

Fig. 10 Effect of 1% air bleed respectively at places of 25-50-75-100% of compression process on the TE and SNWO

In a previous analysis, we made a parameter sensitivity examination using the same model which result can be seen in Fig. 11. Comparing the effect of compressor air bleed clearly visible that its effect on TE (*$\Delta\eta_{th}$rel and $\Delta\eta_{th}$abs*)) and SNWO (Δw_{net}) is very similar like the effect of the deterioration of compressor polytrophic efficiency (η_{polc})

1% air bleed at the exit section of the compressor has more or less the same effect like 1% deterioration of compressor polytrophic efficiency (see last columns of Fig. 10 and first columns of Fig. 11).

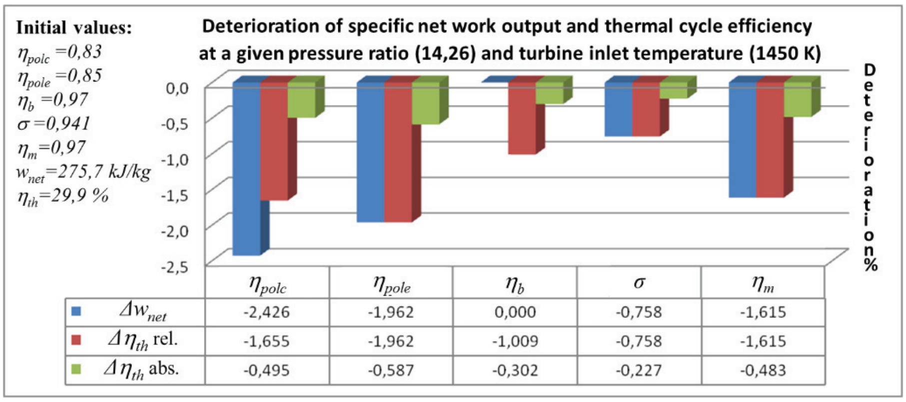


Fig. 11 Results of parameter sensitivity examination [4]

6. Effect of the Air Bleed Used for Turbine Air Cooling (without its Effect on the Turbine Work) on the TE and SNWO

In this case the amount of extracted air is variable, respectively 1-2-3-4%, but the place of the extraction is fixed to the last stage of the compressor, see Fig. 12. 1% air bleed here practically the same like in the previous examination, when the place of extraction was variable and the amount of air was fixed (see last columns of Fig. 10) and first columns of Fig. 12.

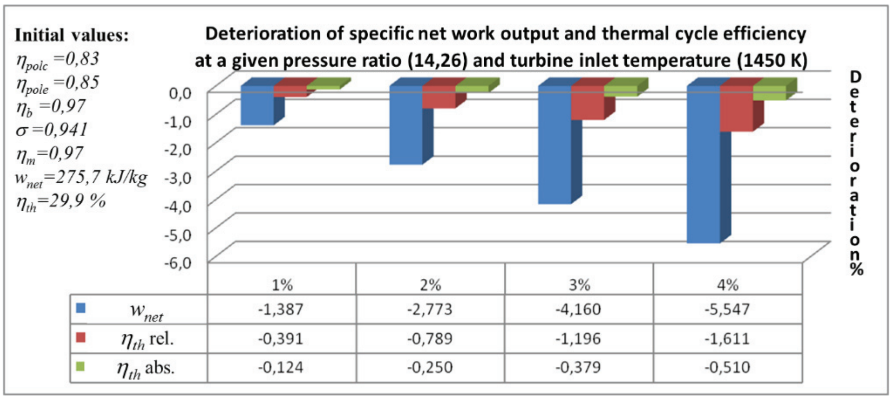


Fig. 12 Effect of 1-2-3-4% costumer air bleed respectively at the end of the compression process on the TE and SNWO

Despite the same air bleed here, the caused deterioration is much less. The reason is that the extracted air flow isn't a loss for the expansion process in the turbine. However, the turbine work from the cooling air streams is much less comparing to the turbine work of main gas flow but considerably decreases the deterioration of the TE and SNWO.

7. Compensation of the TE Deterioration Increasing the TIT and the CPR

As I mentioned earlier the compressor air bleed itself decreases both the TE and SNWO even if it is used for turbine blade cooling. The possible improvement of these vital performance indicators (TE and SNWO) can be originated from the resulted higher allowable TIT by the turbine blade cooling. The main question is if certain TIT rise compensates the initial deterioration?

We made an examination for this situation. We doubled the air bleed for the turbine blade cooling is from 2% to 4% and theoretically presumed that the more intense cooling allows the raise of TIT from 1450K to 1500K. In this case despite the negative effect of air extraction the final result is positive. The SNWO increased by 5.66% and the TE increased by 0.809% (absolute raise of the TE). However, we have to note that to achieve the best possible result the Compressor Pressure Ratio should be raised by about 7%, namely from 14.4:1 to 15.5:1, see Fig. 13.

Explaining the different effects of the air bleed and turbine blade cooling Fig. 4 can be used again and the process can be represented between point "A" and "D" except in Fig. 4 the negative effect was only compensated by the higher TIT meanwhile in this case the 50K TIT raise overcompensated giving performance improvement for the engine.

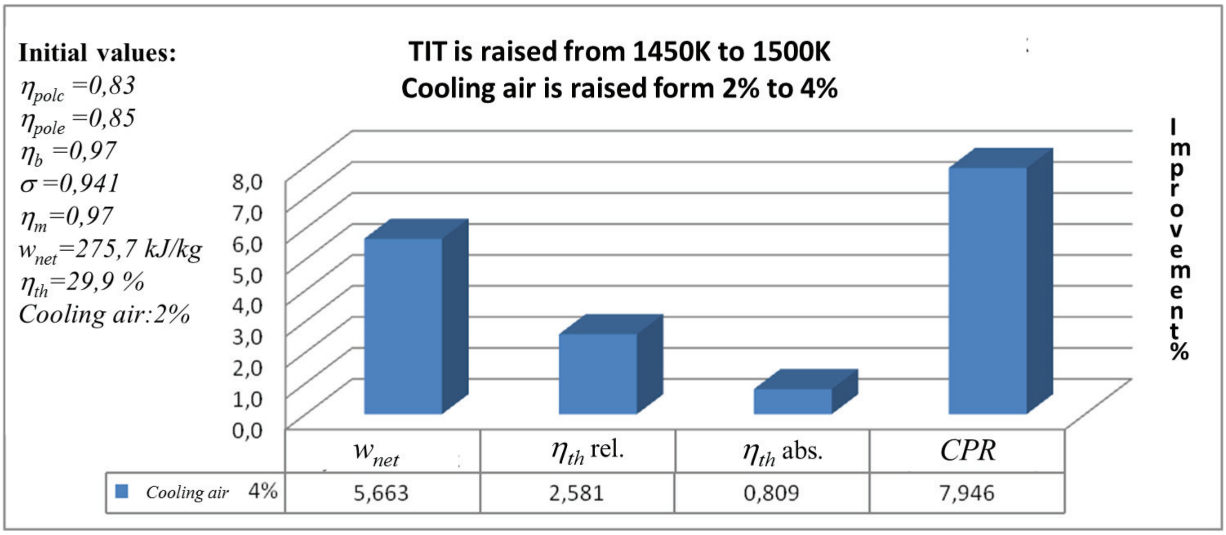


Fig. 13 SNWO and TE curves in compressor polytrophic efficiency versus pressure ratio diagram

8. Conclusions

Increasing the TIT and CPR without higher or even sometimes with lower element efficiencies, higher SNWO and TE can be achieved. Without being precise, about 100 K TIT and 2.5-3 CPR raise results (absolute) 2% TE and 50 kJ/kg SNWO increment at the examined TIT and its close range. In this paper we didn’t examine that how much TIT raise can be achieved by a certain amount of air bleed. It is the question of the cooling efficiency, which with the continuously improving cooling technology, higher and higher. In addition, the blade cooling isn’t the only technology improving the turbine TIT. The super alloys, single crystal blades, blade coating has also important role in today achieved extra high TITs. It wasn’t the matter of this paper. But what is clear that relatively low TIT raise compensates the deterioration of engine performance caused by the compressor bleed air at the close range of the examined TIT (1450 K).

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Road Traffic Rules Violations among Lithuanian Traffic Offenders: the Importance of Driving Self-Efficacy

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Abstract

The aim of this study was (1) to compare driving self-efficacy among Lithuanian traffic offenders and non-offenders; (2) to evaluate differences in driving self-efficacy among male and female traffic offenders taking into account the type of committed road traffic rules violations; (3) to evaluate the relationship between driving self-efficacy and road traffic rules violations taking into account demographic factors. 684 Lithuanian traffic offenders and 171 non-offenders drivers participated in this study on voluntary basis. Mean of age was 31.97 (±11.38) years among traffic offenders and 32.71 (±12.03) among non-offenders drivers. Driving self-efficacy was measured with Adelaide Driving Self-Efficacy Scale. One subscale from Driver Behavior Questionnaire was used to evaluate self-reported road traffic rules violations. The results of this study showed that only female traffic offenders have higher driving self-efficacy than female non-offenders do. Despite the type of committed road traffic rules violations, male and female traffic offenders possessed similar driving self-efficacy. Only male traffic offenders who lost driving license because of driving under the influence of alcohol and who possessed higher driving self-efficacy reported less road traffic rules violations while driving taking into account their age and driving experience.
KEY WORDS: *driving self-efficacy, road traffic rules violations, traffic offenders, non-offenders*

1. Introduction

Road accidents are global phenomenon that represents serious public health concern [11]. Lithuania, together with Latvia, Romania, Bulgaria, and Croatia are the leading countries by people' deaths in traffic accidents. Moreover, increasing number of traffic offenders all over the Europe indicate that interventions for road traffic rules violations should be taken more seriously, especially among novice drivers. Therefore, the analysis of psychological factors that significantly relate and enhance the probability to violate road traffic rules remains meaningful.

Driving is a self-paced task, which means that the driver can influence the difficulty of the driving task through his or her own driving behaviour [15]. An accurate assessment of driving skills (the strengths and the weaknesses of one's own driving skills) and perception of the complexity of various driving situations are found to be significant psychological aspects for regulating the difficulty of driving behaviour. Therefore, self-confidence and a specific competence perception of driving skills, possessed by drivers is defined as driving self-efficacy [5, 13].

High driving self-efficacy is one of the motivational risk factors that may enhance risky behaviour while driving and increased accident risk [8]. In addition, high driving self-efficacy was shown to be important for frequent intentional road traffic rules violations and re-offending [2, 14]. It was found that drivers with high driving self-efficacy tend to perceive low probability to cause an accident while driving under the influence of alcohol [7] as well as to get penalty because of speeding [9]. Even more, drivers with high driving self-efficacy treated fast driving as a good way to test their driving skills and by doing this to get approval from others about expected excellent driving skills [2]. Also, highly confident drivers usually were less able to perceive how alcohol impairs their driving performance. As the result, these drivers possess an overestimation of driving ability when they are intoxicated that leads to more frequent re-offending [14]. Therefore, high driving self-efficacy is the main reason for feeling secure while driving on the risky manner and doing intentional road traffic rules violations [1].

The majority of drivers overestimate their own driving skills compared to the average driver [15]. However, drivers' gender and age are important factors, significantly related to driving self-efficacy [3, 16, 17]. Male drivers were found to have higher sense of driving competency in the variety of dangerous driving behaviours comparing them to female drivers [4, 10]. Besides, young drivers more often than elderly ones use the car for showing independence, emotional expression and rebelliousness as well as to satisfy peer-acceptance needs [3, 16, 17]. Thus, it implies that younger male drivers tend to violate road traffic rules because of expectations that they can handle dangerous driving situations more efficiently. These expectations are enhanced by actual psychological needs (e.g. get acceptance by others for showing good driving skills).

Presented results represent the group of non-offenders drivers, but it remains unclear whether the same results could be found in traffic offenders group. No information about the differences in driving self-efficacy among traffic offenders and non-offenders was found. Also, no studies were found about the relationship between the type of committed road traffic rules violations and driving self-efficacy. Thus, the aim of this study is (1) to compare driving self-efficacy among traffic offenders and non-offenders; (2) to evaluate differences in driving self-efficacy among male and female traffic offenders taking into account the type of committed road traffic rules violations; (3) to evaluate the relationship between driving self-efficacy and road traffic rules violations taking into account demographic factors.

2. Method

Participants. The sample of this study consisted of drivers, who have driving license and did not violate road traffic rules in the past (non-offenders) and those, who have lost their driving license (traffic offenders) because of various road traffic rules violations. Data from traffic offenders was gathered in Kaunas and Vilnius driving schools, which were licensed to organize additional driving courses for traffic offenders. Non-offenders drivers were asked to fill in a self-report questionnaire (half of them participated using web page survey; other half used a paper-pencil method). All participants took part in the study on voluntary basis.

684 traffic offenders (611 males and 73 females), averagely 31.97 (±11.38) years old participated in the study. Male and female traffic-offenders did not differ according to their age ($p = 0.476$). However, male traffic offenders reported longer driving experience (averagely 10.83 years) than females (averagely 7.93 years ($p = 0.008$)). Even though all traffic offenders had license to drive vehicle (B category), 52.9% of them lost their driving license because of driving under the influence of alcohol (DUI), 31.3% exceeded speed limit and 15.8% of them committed other road traffic rules violations (e.g. driving without wearing a seat belt).

Non-offenders drivers group consisted of 171 drivers, who had driving license and they never lost it due to road traffic rules violations. Non-offenders were averagely 32.71 (±12.03) years old and they reported averagely 10.72 years (±8.99) of driving experience. Analysis revealed that traffic offenders and non-offenders were at similar age ($F = .449$, $t = 1.846$, $p = .065$) and driving experience ($F = .342$, $t = 2.716$, $p = .007$).

Instruments. Adelaide Driving Self-Efficacy Scale [6] measured driving self-efficacy. Twelve items in a Likert scale from 0 (not confident) to 10 (completely confident) were used to evaluate self-rated confidence of different driving behaviours (e.g. driving in heavy traffic or driving at night, parallel parking, etc.). Higher scores indicated higher driving self-efficacy. Adelaide Driving Self-Efficacy Scale was translated into Lithuanian with double-check procedure. Internal validity of this scale was sufficient for the analysis: Cronbach α was .91 in traffic offenders and .92 in non-offenders group.

Subscale of Driver Behavior Questionnaire (DBQ) [12] was used to evaluate self-reported intentional road traffic rules violations while driving. Eight-items scored on a 5-point Likert scale ranged from ‘strongly disagree’ to ‘strongly agree’. Higher scores indicated more deliberate deviations from safe driving practices. The internal validity of the scale was sufficient – Cronbach α was .72.

In addition, demographic data was obtained and it included gender, age and driving experience. Participants were asked to name traffic offences they committed, which was the reason of their lost driving license.

Statistical analysis. Statistical analysis was performed by using SPSS 17.0 Statistical package. The Kolmogorov-Smirnov test was used for the assessment of normal distribution in quantitative data. Analysis revealed non-normal distribution of the data. Therefore, non-parametric Mann-Whitney U test was used in order to compare driving self-efficacy between two different drivers’ groups (traffic offenders and non-offenders) as well as to compare driving self-efficacy between male and female traffic offenders. Also, partial correlation was used in order to find out if driving self-efficacy was related to road traffic rules violations while driving. Thus, partial correlation analysis was made in separate groups by gender and type of committed traffic rules violations. The age and driving experience was taken into account too.

3. Results and Discussion

It is stated that drivers, who overestimate their driving skills, are more accident prone, because they underestimate strengths and weaknesses of their driving skills that leads to inefficient compensatory actions to moderate risk and to ensure safety in dangerous driving situations [15]. However, there is a lack of information whether drivers, who committed road traffic rules violations, overestimate their driving skills while comparing them to drivers, who did not lose their driving license because of committed road traffic rules violations. In addition, no research was found about the relationship between driving self-efficacy and the type of road traffic rules violations. Therefore, at the beginning driving self-efficacy was compared in traffic offenders and non-offenders group. Then, driving self-efficacy in male and female traffic offenders groups was compared, taking into account the type of committed road traffic rules violations.

Table 1

Differences in driving self-efficacy among non-offenders and traffic offenders

	Group	N	Mean	St. deviation	p
Driving self-efficacy	Non-offenders	114	93.11	17.5	**.002***
	Traffic offenders	684	98.91	16.5	
	Non-offenders males	75	96.77	2.4	.198
	Traffic offenders males	611	99.49	1.8	
	Non-offenders females	40	46.46	17.5	**.017***
	Traffic offenders females	73	61.86	16.5	

*significance level.05

Results show that in general traffic offenders had higher driving self-efficacy than non-offenders. The similar results were found when comparing female traffic offenders and female non-offenders. Female traffic offenders had higher driving self-efficacy than female non-offenders. However, male traffic offenders and non-offenders did not differ according to their driving self-efficacy. Results imply that while comparing traffic offenders and non-offenders, those drivers, who violated road traffic rules, possess more confidence in their driving skills; perhaps they possess more superiority, competitiveness and sense of power and control while driving [13]. Unexpected results that male traffic offenders and non-offenders have similar driving self-efficacy may appear because of unequal male traffic offenders and non-offenders sample size. Also, these results imply that despite the fact of committed violations, in general male drivers tend to riskier driving in order to show-off, to attract attention or impress members of the opposite sex or to obtain excitement and to display competitive courage [17]. However, the results about differences among female traffic offenders and non-offenders are quite new. Nevertheless, it could be assumed that those females, who committed road traffic rules violations, use more compensatory driving strategies that leads to higher confidence in their driving skills. Compensatory strategies enhance the feeling of less risk in most hazardous driving situations [15].

Table 2

Differences in driving self-efficacy between male and female traffic offenders taking into account type of violation

	Gender	Type of traffic rules violation	N	Mean ± St. deviation	χ^2 (df)	p
Driving self-efficacy	Males	Drink-driving	331	99.79 ± 16.6	.342 (2)	.843
		Speeding	184	99.61 ± 15.6		
		Other violations	96	98.21 ±18.0		
	Females	Drink-driving	31	91.32 ± 19.4	2.63 (2)	.267
		Speeding	30	94.27 ± 12.0		
		Other violations	12	100.58 ± 10.5		

*significance level.05

The results revealed that traffic offenders' males as well as females, who lost their driving license because of DUI, have similar driving self-efficacy as those, who exceeded speed limit or did other road traffic rules violations. These results could be explained by increased illusion of invulnerability. The more illusion of invulnerability are expressed, the more drivers feel safe by doing risky actions on the road as well as perceive capability to control any driving situations [5]. Therefore, despite the type of committed road traffic rules violations and driving context, driving self-efficacy is enhanced by illusion of invulnerability. As the result, traffic offenders might have lower possibility to differentiate seriousness of the different road traffic rules violations.

Table 3

The relationship between driving self-efficacy and road traffic rules violations among traffic offenders (taking into account the type of traffic rules violation and demographic data)

Driving self-efficacy** / Road** traffic rules violations	Type of traffic rules violation: Driving under the influence of alcohol (DUI)	Speeding	Other violations
Male traffic offenders	**-.184***	-.118	-.032
Female traffic offenders	.017	-.052	.312

*Partial correlation coefficients are significant at the level .05

** Partial correlation analysis was made taking into account traffic offenders' age and driving experience

The main findings showed that male traffic offenders who lost driving license because of DUI and who possessed higher driving self-efficacy tended to report less road traffic rules violations while driving taking into account their age and driving experience. No other significant relations were found between driving self-efficacy and road traffic rules violations among male traffic offenders, who exceed speed limit or committed other violations as well as female traffic offenders. These results confirm previous premise that increased self-efficacy plays an important role in driving while intoxicated [14]. However, the fact that driving license is lost perhaps play important role for this result. On the one hand, those male traffic offenders, who lost their driving license because of DUI reported less committed road traffic rules violations because of the decrease in driving self-efficacy that happened after received penalty for risky behaviour on the road. And these male traffic offenders reported less committed road traffic rules violations perhaps in order to demonstrate themselves as good, skilful and socially acceptable drivers.

4. Conclusions

The results of this study leads to the conclusion that driving self-efficacy could be defined as one of higher-level function (together with self-control, self-evaluation, planning skills, hazard perception etc.) which is significantly related to road traffic rules violations. The results of this study imply that possession of higher driving self-efficacy means having inaccurate beliefs about one's driving capabilities that might limit cognitive performance, self-monitoring and self-regulatory processes while driving. Results imply that people who overestimate their skills might take on activities that are too difficult (e.g. driving under the influence of alcohol). Therefore, they do not consider probability to lose driving license and do not perceive DUI as one negative consequence of demonstrated risky driving.

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An Information System Project Supporting Transport Management

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Abstract

The article describes an information system project that supports the decision making process relating to transport management. It is designed for medium size transportation companies with a dozen or so vehicles which deal with material means transport. The chief tasks of the system are: to plan timely deliveries of goods, to manage a transportation fleet and employees, to remind about the dates of vehicle inspections, to remind about the dates of medical examinations of drivers, etc. The system and its application will optimize transportation tasks and will consequently reduce transportation costs by rational use of transportation means. The application of such a system, through reliable and fast order processing, should also improve the company's image in the market and increase the level of customer service, and thereby help to acquire new customers. SYBASE program which is compatible with the Borland Builder program will be used to create a system database. Simultaneously, the database will be built on the SQL standard. The system database will consist of six main tables, while the system interface will be based on windows with the ability to enter data and select commands.
KEY WORDS: *logistics, transportation system, IT system, information systems*

1. Introduction

The Currently, information is perceived as one of the core resources of any organization and is one of the key success factors for “raison d'être”. Moreover, it enables the development of a given subject in an economic and social setting. Information is an intangible value that includes a statement of existing assumptions, facts, or forecasts concerning past, present, or future events [6]. Its value depends primarily on two factors. Firstly, the source of information, i.e. how close the information regarding the reality is (the quality of information). Secondly, the purpose of the final destination, i.e. who the recipient is, and what capacity to use the received information this person has (the value of information) [5]. However, the greatest value of information does not depend on itself, this value depends primarily on time and place. That is, on the ability to make concrete use of it, maximizing its real value.

The purpose of the integrated information systems, including logistics, is to increase the competitiveness of each institution by providing end-users with permanent access to the information they need while minimizing system operating costs [3]. Taking into account the above, the article presents the concept of the information system that supports transport management. The system can be used by a transport manager in a company, a warehouse, or by another person who is responsible for solving transportation problems in an enterprise [7]. In such a situation, the system will be able both, to create entire transport plans based on the received orders, and to verify individual orders, suggesting better (different) possibilities for solving a given transport task. The system can also keep accounts and give a person responsible for invoicing substantial assistance. An invoice will be issued on the basis of a placed order.

The ultimate prospective users of the system will be persons who accept the orders; their task will be to enter the order details and alternatively, the customer data to the system database. This will be necessary if the customer is serviced for the very first time by the company, or if customer data has changed. The system will support the person entering the order by storing data, e.g. of customers, so that while processing the next order, the amount of information needed to enter will be reduced.

2. Information Structure of the System

The information structure of the proposed system will be primarily based on orders submitted by customers, information on the quantity of the item, its form, the starting point and the ending point of the route [8]. Products in the system will be distinguished by identifiers. This will facilitate faster processing of orders. The identifier will consist of several digits, because such a solution will make it easier for a computer to process orders. The system database will also contain the verbal names of the goods, but they will not be unique identifiers. They will only facilitate the product identification by system users. In addition, the system will have information on transport resources, their quantities, transport capacities, and the types of goods they are able to transport [1]. It is also assumed that the system should include information on the technical equipment of a vehicle, e.g. whether it is equipped with a hydraulic lift or not. The system will also contain data on the current use of transport resources, the list of available means at a particular time and their location (some vehicles might be on route). This data will be indispensable while verifying the placed orders in terms of their implementation. In case of the absence of a vehicle capable of carrying a particular cargo, the system should generate information about the nearest planned date of order fulfillment. The system should also have access to current operating costs such as fuel costs (Fig. 1).

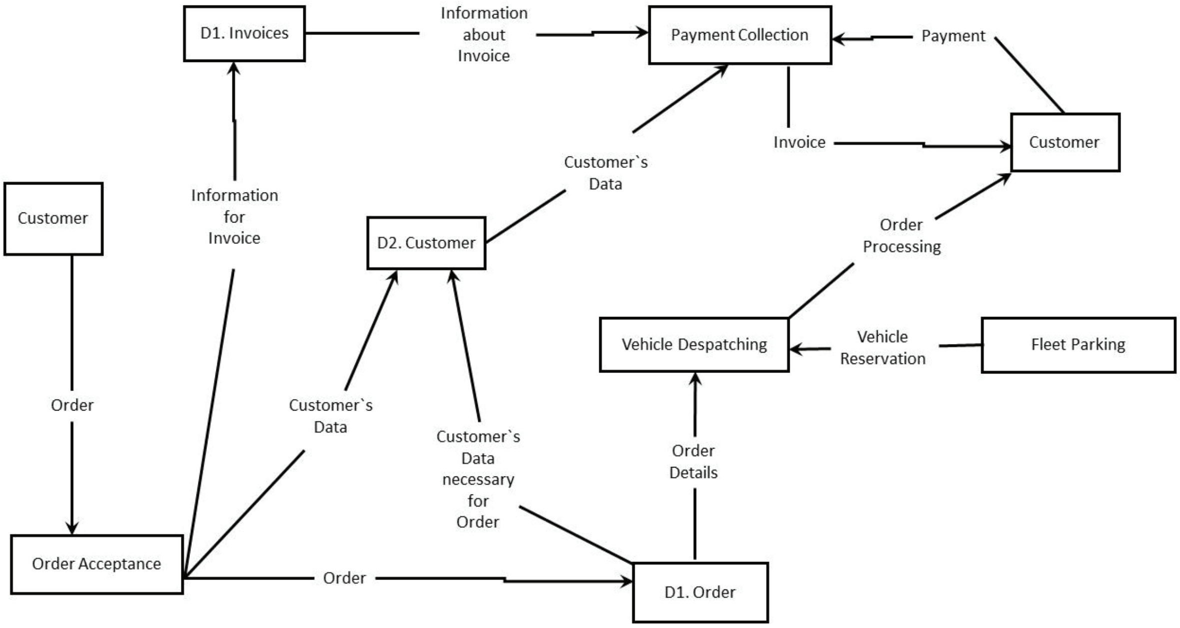


Fig. 1 Diagram of information flow in the information system

3. Functioning of the System – Typical and Non-typical Procedures

On the one hand, in the System there are included the following typical procedures:

1. **Acceptance of orders issued by customers.** The company receives orders from the ordering parties. The order should include the list of goods to be transported, their quantity, and the starting and ending points of the route. After receiving the order, the system will firstly check which vehicles are suitable for the carriage of the goods. Thereafter, it will search for a free vehicle. If the system does not find a free vehicle at the present time, it should search for the closest possible date for the order to be completed and it will reserve the proper vehicle. If the cargo does not use the full capacity of the vehicle, it is required to book the appropriate payload and space on the vehicle.
2. **Processing of orders.** Based on the transport resources usage plan generated by the program, the system should create a transport order for each vehicle and transfer it to the appropriate driver as soon as possible. The transport order will be forwarded by the transport manager or other person responsible for the transport issue within the company. When a company is able to mount special electronic devices for the transmission of digital information [4], the transport order may be forwarded directly to the driver in an electronic form. After the goods have been delivered to the destination point and there are no customer complaints, the customer should sign the delivery confirmation. The system should obtain information on the completion of the order as soon as possible [9]. In case of any complaint or customer's negative comments, they should be forwarded to the manager of the transportation company, or to the relevant complaint department.

On the other hand, in the System there are included non-typical procedures which are as follows:

1. **Customer complaint.** In case of a customer complaint, this information should be entered in the system. The complaint must contain information about its cause and the order number. The system should verify the correctness of the complaint. If the complaint involves not handing over a product or delivering it too little, then the missing goods should be delivered in the shortest possible time. If the complaint concerns damage of the goods, the cause of the damage of the cargo should be examined. Every complaint must be notified to the transport manager and to the person responsible for verifying the complaint. If the complaint is granted, and its execution requires additional carriage of the cargo, the carriage will be added as a new order and the system should ensure its proper delivery. This order will be distinguished by the system from the others by the unique first letter of the identifier, e.g. "z".
2. **Breakdown of a vehicle.** In the case of a failure of one of the vehicles, the customer should be noted on the time extension of the order processing. Afterward, the system based on the commodity data should check if there is a possibility to reload the goods to another car. If so, it ought to check if another car capable of carrying the goods on the route is available. If the system finds such a vehicle, it will suggest sending this car to the point of failure and cargo handling. The suggestion will be considered by the administrator of the system [11], as the system is not able to assess the possibility of reloading in reality. This will happen, for instance, when a breakdown occurs on the highway. Subsequently, the system should verify if the damaged transport resource had not been assigned other subsequent

orders; if there are such orders, they have to be divided amongst other vehicles. The program must also exclude the corrupted transportation means from the accessible assets for a specified time of repair.

3. **Technical inspections and periodical repairs.** Having information about the transportation orders, the system will also have information regarding vehicle technical inspections, periodical repairs, and other vehicle regular check-ups, for example: oil change. In case of expiring of technical inspections or periodical repairs, the system will check if other vehicles do not require such inspections or repairs. If so, it will plan the maintenance schedule in such a way that at one moment there are as few vehicles excluded from use as possible. After a successful inspection or repair, the system attaches the car to the list of available resources and places the date of the next inspection in the database.

4. **Absence of a driver.** In this case, the system will check for other drivers with the same driving license categories. If there are any, the system will propose to assign one to the vehicle. In the opposite situation, it will block the vehicle and will transfer its transportation obligation to another person who will be able to complete the order. The system will storage the data relating to the dates of medical examinations of drivers. When a driver needs to be sent for a medical test, the system will require another driver to be assigned to the vehicle. If this is not possible, the system will lock the vehicle on the list of available vehicles for the examination period. Obviously, it will be done early enough to avoid a sudden lack of the vehicle for which the transport orders are prepared.

4. Documents in the System

Electronic documents in the system will be in the form of appropriate tables forming relational databases. The system should print or display the documents based on calling the appropriate records. The system will archive all orders, their processing, and a customer base. For this purpose, an external USB hard disk drive will be used [8]. The system will automatically continue to archive data entered into the computer. The data saved on the backup disk will be saved either as database tables or as text documents, where each order will be separated by twenty "-" characters. The test document will be coded by Unicode – this will ensure greater system compatibility. The system user will choose a system for saving data. Verification will make it easier to handle potential complaints.

The following documents are provided for the system (Tables 1-4).

Table 1

Order Acceptance (paper version of the document)

Order acceptance form:				
Company:				
Order Number:			Date:	
Ordering Party:				
No.	Goods	Quantity	Route	Price
1.				
2.				
3.				
			Total:	
In Words:				
Ordering Party`s Signature:				

Table 2

Confirmation of Order Execution (paper version of the document)

Acknowledgement of Receipt of Goods		
Company:		
Order Number:	Date:	
No.	Delivered Goods	Delivered Quantity:
1.		
2.		
3.		
Recipient`s Signature:		
I hereby declare that I have no objections to the order execution:		

Table 3

Invoice (invoice template)

Invoice of the order:				
Company:				
Order Number:		Date:		
Ordering Party:				
Tax Identification Number of the Ordering Party:				
Goods	Quantity	Price	VAT rate	Total
	Total:		Total:	
Total Due:	In Words:			
Signature and stamp of the issuer:				

If the ordering parties are not satisfied with the service, they have possibility to download a complaint form from the company website. In this documents there are special spaces in which the customers are able to write the cause of their dissatisfaction and their negative comments and remarks concerning the order execution.

Table 4

Complaint (complaint template)

Complaint Form		
Company:		
Order Number:	Date of complaint:	
Ordering Party:		
Reason for complaint:		
Examination of complaint:		Date:
Justification:		
Signature and stamp of the contractor:		

5. System Database

The database will use SQL technology, i.e. relational databases. This technology is currently a standard for database creation. Hence, SYBASE program will be used to create the information system database, as it is compatible with the Borland Builder program in which the system will be designed [2]. The database will consist of six main tables (Figure 2). There are also two auxiliary tables. The system will remember once entered records, such as customers, routes, goods, and transportation fleet. Hence, once entered data − is saved. The following sections describe the individual tables included in the database [10]:

1. The Routes table which describes the transportation routes contains information such as the unique route number (ID), the start and end of the route, and the length of the route recorded in kilometers.
2. The Transportation_Fleet table describes the transport resources that the company possesses. In addition to basic information about the vehicle such as loading capacity, type of transported cargo, or loading volume of cargo space, it stores information about the vehicle driver's identifier, and whether the vehicle is equipped with a hydraulic lift facilitating loading. Each vehicle is also assigned with a unique number. The type of cargo will be indicated by the appropriate number. Using the same numbers will determine the types of cargo carried by the vehicles, so that the system will be able to match the appropriate vehicle to the particular load.
3. The Customers table stores data about customers. In addition to the basic customer`s data, there will be a unique number which will unambiguously identify the customer. While the “Name” and “Surname” fields are for individual customers, the “Company” field is for businesses and enterprises.
4. The Goods table collects all information with regard to transported goods. The “Type” field will identify the cargo type, so that the system can match the right car to transport the cargo. Furthermore, the name of the item and its

unit volume will also be included. Yet, the "Loading Volume" field will only be used for certain goods having a fixed unit volume.

5. The Drivers table gathers information about drivers employed in the company. This also includes data on the employees` working period. After dismissing an employee, his or her record will be saved in the archive and deleted from the database. In the last field, "Availability", there will be information whether the particular driver is available at the very moment.

6. The Inspections table includes information concerning the inspections dates, so as to avoid the sudden absence of the vehicle that is sent for the periodical inspection.

7. The Examinations table records the dates of the examinations of drivers. This data helps to avoid problems associated with the lack of an employee who is sent for the examination. Furthermore, this data holds information regarding expiration dates of tests and licenses. If the date is about to expire, the system reminds about necessity to send a particular driver for the tests.

8. The Customers table stores information concerning the company customers, which is used to issue invoices. Once customer`s data is entered, it is remembered that the next time there is no need to enter it.

9. The Invoices table is an auxiliary table of the Ordering Parties table. The included information in it is used to issue invoices.

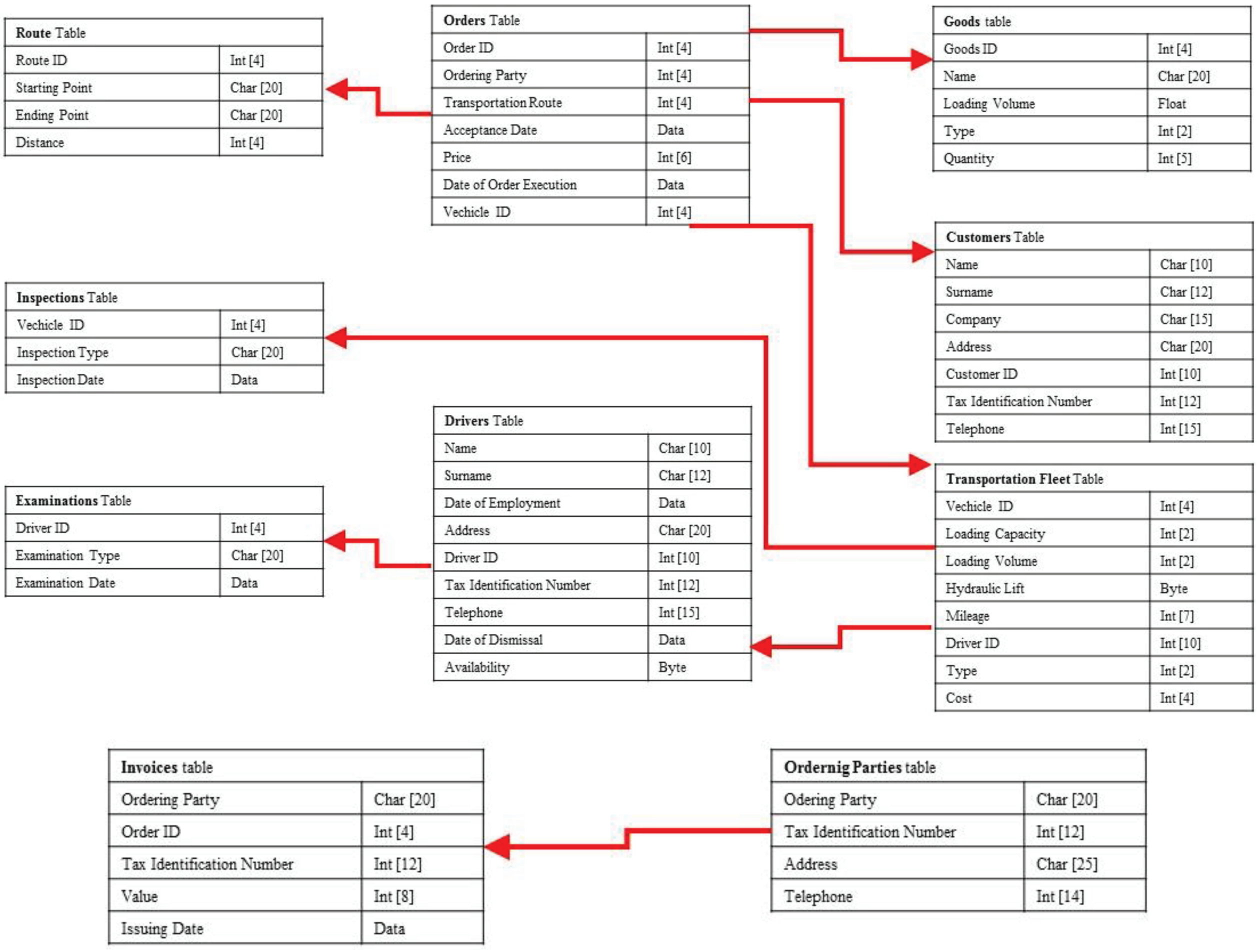


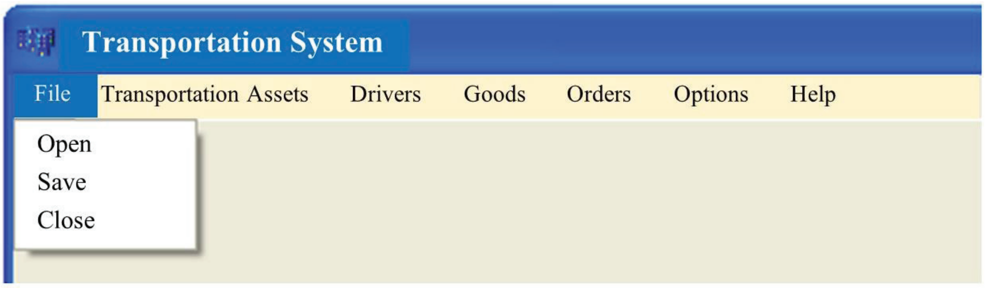
Fig. 2 Database structure

6. System Interface

It is assumed that the program will be written in C++ standard with using Borland Builder application. To design the discussed information system, the above program has been selected. The pivotal criterion for choosing this software has been the fact that it provides a high speed of application creation. By extension, the time of development of the system will be shortened. Additionally, programs written in C++ are fast and they are operable without the need to install additional applications, e.g. Java. All dialog boxes in the program will have the standard appearance of Windows system interface − this will ensure better system compatibility [10]. Below there are several examples of the program boxes with their descriptions:

1. Main menu of the program: All basic system functions will be stored in the main menu of the program. The menu will consist of several submenus, i.e.: *File, Transportation Assets, Drivers, Goods, Orders, Options*, and *Help*.

2. The *File* menu will contain options for saving and opening system configuration files.



3. *Transportation Assets*, *Drivers*, and *Goods* menus will be used to manage company resources, i.e. transportation vehicles and drivers, and to verify the goods being transported.

4. The *Orders* menu will be the most significant tab because this is the place where the user will enter all orders (Fig. 3) and will be able to edit them.

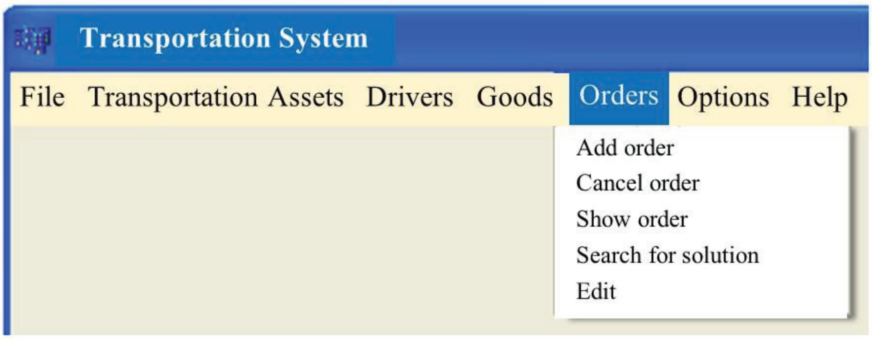


Fig. 3 Order input interface

5. In the *Options* tab, the user will have the possibility to change particular options of the program, e.g. the user will be able to set here whether the program is to add new routes automatically, or every time it has to ask about it the user.

6. The *Help* menu is the last tab, which will contain practical tips on how to use the program.

7. Implementation Plan

It is believed that the discussed system will not generate any significant problems in the course of its implementation. This system can successfully run on one computer. Nonetheless, in larger enterprises there should be at least two computers. One in the transport department, used to create routes, and the second one in the accounting department, supporting the issuance of invoices and bills. This solution is intended to increase safety, as transport managers do not particularly need to have access to information on costs. Simultaneously, persons who issue invoices do not need information on, for instance, vehicle inspection dates.

In the first place after installing the system, there is the necessity to input all information and data about the transport resources, drivers and goods that the company will carry. In order to avoid any mistakes and possible problems it is recommended that one of the system creators is present when the date is entered. This work should be done carefully as a possible error, e.g. when typing a type of goods carried by a vehicle, may result in incorrect means of transport being selected.

When the required data has been entered into the system, there will possibility to input orders. It is highly suggested that while the process of order input the company does not execute any orders and all vehicles are in the base. Nevertheless, in practice such conditions are not likely to occur. Therefore, the vehicles that are currently executing orders – those ones which have been in progress before the start-up of the system are eliminated from the decision-making process. However, if their transportation capacities are not fully used, they can be edited by reserving a part of their volumes. When the orders have been completed, the used transportation assets will be activated in the database, so that the system can use them for subsequent orders.

8. Operating Instructions of the System

Working with the system should begin with entering data concerning resources. To do so, go to the *Transportation Assets* tab and then *Add asset*, then the system will ask to provide data on a particular resource such as: payload, load volume, vehicle equipment (e.g. hydraulic lift), cargo type, etc. Red highlighted windows are very important to the operation of the system and special attention should be paid when filling them. The *Loading volume* and *Driver ID* fields are optional, and the system allows drivers not to be entered. When filling in the *Type* field, enter the number of the appropriate goods that the vehicle is capable of carrying. This means if you enter “1” and this is a dump truck, then all loose materials like sand, gravel, etc., must be denoted in the system in the *Type* field “1” as well.

After adding all resources, move on to add the goods that the company transports. To do so, go to the *Goods* tab -> *Add new* and enter the data that the system will ask. Here, all significant fields are marked red as well.

The data concerning drivers is entered analogously; yet, there is no necessity to do so. Then, the system will not take drivers into account at all, and it will only deal with the layout of the transports. However, if one decides to enter the drivers into the system, one must remember to input their eligibilities and licenses (a type of a driving license), so that the system can match the vehicle with the appropriate driver. Still, there is the possibility to manually assign a driver to a vehicle. To do so, in the *Driver ID* field enter the appropriate driver number. Then, the system will check if the driver is eligible to drive the vehicle. If the system informs the user that this particular driver is not allowed to drive this particular vehicle, it will ask for the confirmation of the previous command. If confirmed, the program will ignore the mismatch and will assign the driver to the vehicle without considering his or her eligibilities. This system behavior can be changed using the *Options* tab.

All orders are entered into the program via the *Orders* tab -> *Add order.* Here, all information concerning the order is entered. Nevertheless, all data of the ordering party is to be entered previously. If there is no particular ordering parties in the system, the system will ask for their details. All relevant information is highlighted red. After entering orders, click on *Search for solution* option. Then, the program will assign a transportation order for particular vehicles.

9. Summary

The article presents the concept of the information system supporting transport management which can be used by a small or medium size transportation company. The system will be able: to create customer databases and transportation plans, to verify transportation orders, to optimize transport solutions, and to issue financial documents. The information structure of the system will include the order details, the quantity of the goods and their form, the starting and ending points, the resources and transport possibilities, and the types of goods transported. Thanks to this data, the system will be able to verify placed orders with regard to the possibilities and dates of their execution. The system should also provide access to the current operating costs of the enterprise.

The system database will use SQL technology, and SYBASE program will be used to create it, as it is compatible with the Borland Builder program in which the described system will be written. The database will consist of six main tables. These tables will be as follows: Orders, Transportation_Fleet, Drivers, Goods, Routes, Customers. There are also two auxiliary tables: Examination_Dates and Inspection_Dates. The program will be written in C++ standard with using Borland Builder application. All dialog boxes in the program will have the standard appearance of Windows system interface − this will ensure better system compatibility. The implementation of the system should be relatively simple and the system will be able to run on one or several computers. In the first place after installing the system, there is the necessity to input all information and data about the transport resources, drivers, and goods that the company will carry. When the required data has been entered into the system, there will possibility to input orders. Whenever the order is completed, the used transportation assets will be unlocked, and the system will be able to consider them for the next transportation orders.

In conclusion, it seems that the proposed system will not only facilitate the planning and organizing of transportation tasks, but it will also be relatively inexpensive and easy to implement. These advantages make the presented system suitable for use in small and medium size transport companies that expect efficient and cost-effective decision support tools.

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Dynamic Analysis of Single Stage Gearbox Focused on Input Parameters Influence

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Abstract

Investigation of NVH parameters becomes one of the most important research topics in automotive industry. The main reason is that the limits are getting stricter because of increasing number of vehicles, which are dominantly used in cities. The noise level is composed of contribution of the main components, such as powertrain, transmission, tyres, turbocharger and airflow. This article is focused on transmission dynamics numerical simulation. The simplified single - stage gearbox is used for building the computational model and its experimental validation. Afterwards the input parameters influence is investigated to deep understanding of dynamic behaviour on the base of surface normal velocity, which is the key parameter for air-borne noise emitting process.
KEY WORDS: *single stage gearbox, noise, vibration, harshness, damping*

1. Introduction

Automotive is one of the rapidly growing industry in the world. Number of produced vehicles is increasing every year. For that reason, there are institutions, which are responsible for overseeing environmental impact forced to be on the alert. Lot of legislative limitations regarding mainly combustion emissions are in force. Simultaneously with increasing traffic density in the cities, the restrictions, which determine the noise limits for car passenger and also for people around, are getting strict. The dominant source of noise depends on operating state, where in lover speeds, which are characteristic for city, the powertrain unit is dominant. The level of noise plays also an important role from the comfort point of view, thus it belongs to one key factor of competitiveness between products in automotive industry. To decrease the overall noise level of the car, the dominant sources of noise have to be investigated and then eliminated. The main vibro-acoustic excitation is based on functional principle of each component. With increasing trend of electromobility transmissions become one of the key components regarding vibrations and emitted noise. The dominant excitation of these components is due to gear meshing phenomena [1]. Initiated vibrations are transferred through the structure components such as gears, shafts and bearings to the housing, where part of the vibration energy is transformed to acoustic and emitted to the surroundings.

A numerous mathematical models were developed in the past decade to simulate and understand dynamic behaviour of transmission. The models are based on from single degree of freedom to multiple degree of freedom. The analytical method often includes spring-damper couplings, inertia properties, constant gear mesh stiffness and rigid bodies. The numerical modelling is dominantly based on the model with multiple degree of freedom and enables to include variable gear mesh stiffness and damping, backlash and modal properties of gearbox component. The methodology is mainly performed on the single stage gearbox with simplified housing, which can be easily modifiable to compare the numerical to the experiment results. [2] The main excitation of the gearbox is caused by time-varying gear mesh stiffness, where the gearbox housing emits 80% of total noise [3]. The goal of the gear manufacturer is teeth optimization to reach smooth gear mesh stiffness.

2. Methods

With modern computer technologies, the numerical simulation enables to perform sensitive study for deep understanding of the dynamic behaviour of gear, for that reason it is widely used in research and at developing phase of transmission. [4] The presented virtual prototype is based on dynamic model with multiple degree of freedom, which is shown in Fig. 1. This model incorporates influence of the gear mesh stiffness, which is expressed as rotational displacement dependent time-varying function. Further the elasticity of shafts and the bearings cannot be normally neglected. The equation of motion of a dynamic system is based on Newton-Lagrange method and can be symbolically written by Eq. 1.

$$M\ddot{q} + \dot{M}\dot{q} - \frac{1}{2}\left[\frac{\partial M}{\partial q}\dot{q}\right]^T \cdot \dot{q} + Kq + f_g + B\dot{q} + \left[\frac{\partial f}{\partial q}\right]^T \cdot \lambda = \tilde{Q}, \quad (1)$$

where ***M*** is the generalized mass matrix, which is in Eq. (1) related to kinetic energy. ***C*** is generalized stiffness matrix, related to potential energy and damping matrix ***B*** is related to Rayleigh's dissipative function. Generalized gravitational force is presented by $\boldsymbol{f_g}$, vector $\boldsymbol{q}$ stands for generalised coordinates, $\boldsymbol{Q}$ is vector of forces and $\boldsymbol{\lambda}$ are Lagrange's multipliers.

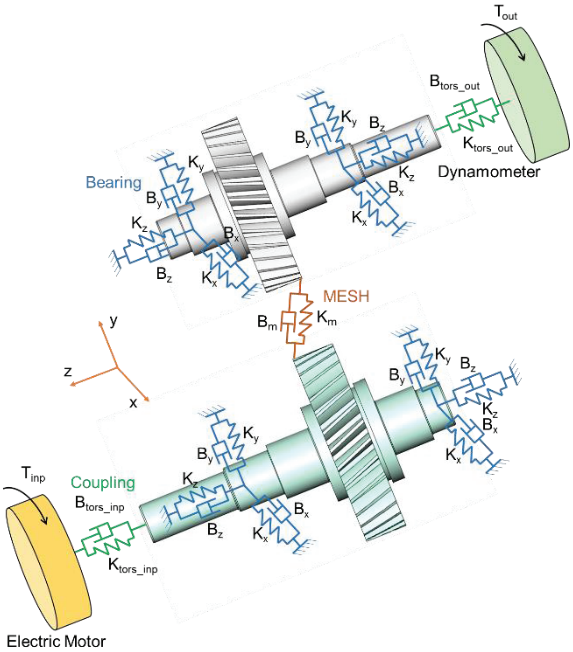

Fig. 1 Single – stage gearbox dynamic schema

Used methodology of single stage gearbox combines the finite element methods (FEM) and multibody software ADAMS. The FEM is dominantly used for obtaining inputs and ADAMS is used to perform dynamic simulation. The whole method is validated by technical experiments at each part of model level (modal analysis, harmonic analysis, complex virtual prototypes). The virtual prototype concept is created in ADAMS software without any subroutines, this open code enables to easily perform sensitive study of the key components, bearing stiffness, gear mesh stiffness, backlash, variable input speed and torque.

The input parameters as bearing stiffness and gear mesh stiffness are calculated by using FEM. The bearing stiffness is calculated on one rolling segment and afterwards converted to the whole bearing, this approach corresponds to the another research study [5]. The variable gear mesh stiffness significantly affects the dynamic behaviour of whole gearbox, for that reason, increased attention is paid to gear parametrical model with possibility to intercorporate tooth modification. The gear tooth real geometry is discretized with focus on fine mesh on four teeth gear pairs, which gets into touch during simulation. The simulation results are used for angular displacement period of one tooth, which can be used periodically afterwards. On the other side this method does not enable to include the effect of eccentricity, damage of teeth and so on. For that reason no misalignment and manufacture error are presented in investigated cases. The stiffness, which corresponds to the results mentioned in [6], is shown in Fig. 2.

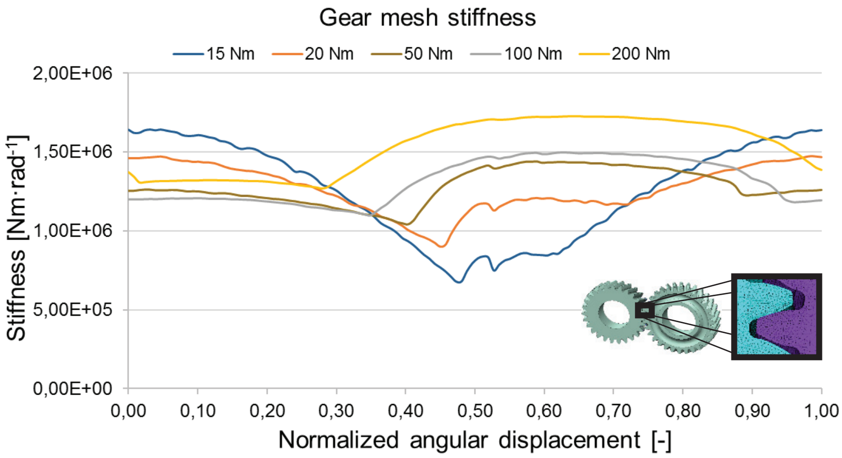

Fig. 2 Gear mesh stiffness

The backlash value 100% corresponds to measured value from the manufactured prototype. Two another variants are used in this study, ideal – without backlash, 200% – two times higher than measured. Backlash influence is incorporated into simulation by stiffness–based function with dependency on gear mesh deformation in rotational direction, which is stated by angular displacement of both gears. The function for specific load is shown in Fig. 3.

The modal properties of each component are incorporated into simulation by using Craig-Bampton modal reduction method, which replaces real modal properties with simplified approximation established from the two variants of degree of freedom and multiplied by the special Craig-Bampton transform matrix.

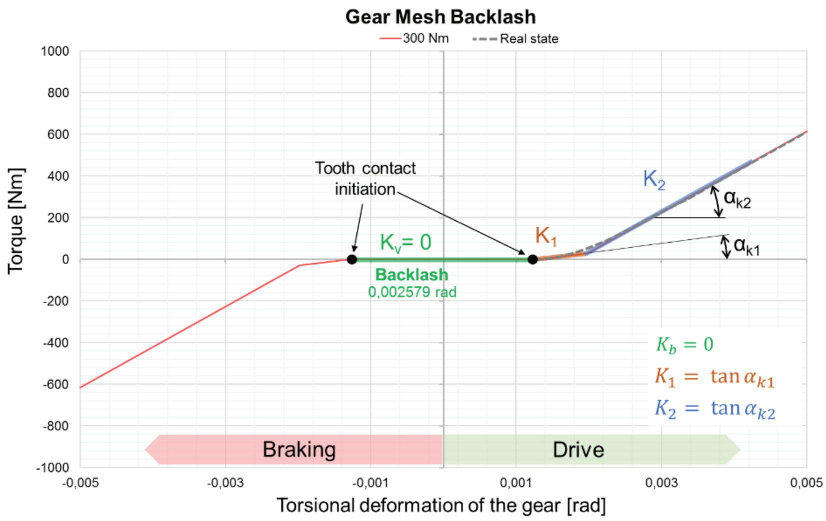

Fig. 3 Gear mesh backlash

3. Results

Backlash significantly affects the dynamic behaviour of transmissions due to nonlinear character. The gear mesh contact can be in some operational conditions released periodically, because of presence this phenomenon. These critical states can occur at relatively low level of carried torques and are accompanied by impact forces which is noticeable by increasing noise.

The simulations are performed for three values of backlash, which are marked as above mentioned 0%, 100% and 200 % at variable input speed in range from 0 to 3000 RPM. The course of used variabilities are shown in Fig. 4. The variable input speed is very important to simulate real dynamic behaviour, thus the technical experiment is performed on manufactured prototype.

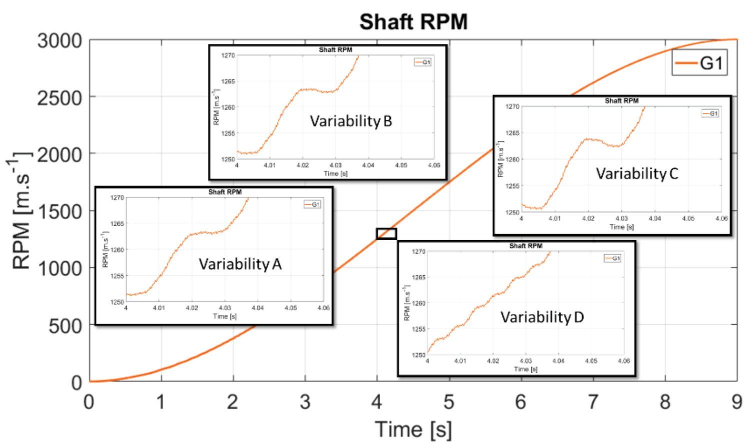

Fig. 4 Types of input speed variability

The multispectrum of run up simulation for variable input speed of surface normal velocity at top cover middle point is compared for moment 6 Nm at three values of backlash (0 %, 100%, 200%) in the Fig. 5. The results show that new critical operation conditions are visible with variability B at 100% backlash, this operation condition are getting more critical with increasing variability type C and D. The angular deformation is plotted to see progress of gear mesh contact, if the rattle occurs. The tooth contact loosening and repeated closing cause peaks in the carried torque, see Figs. 6 ÷ 13.

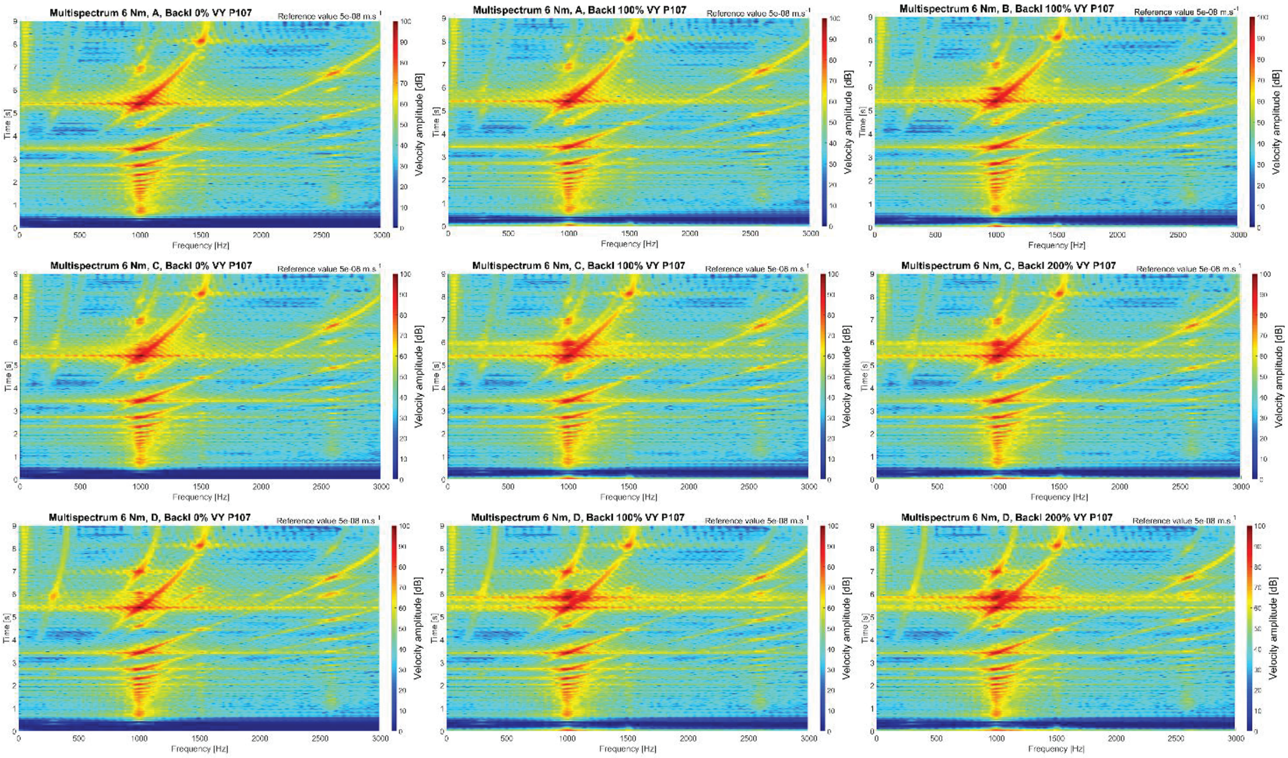

Fig. 5 Multispectrum of surface normal velocity at top cover middle point

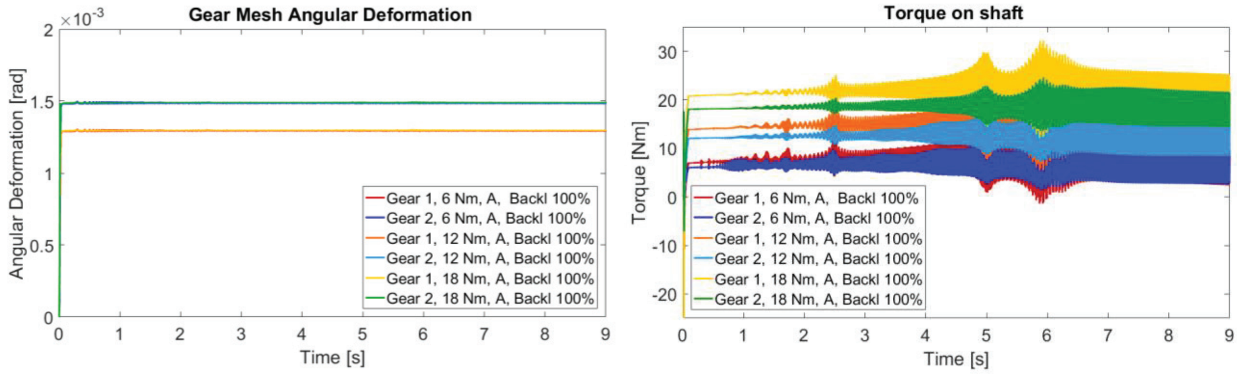

Fig. 6 The gear mesh angular deformation and torque on the shaft during whole simulation for variability A and backlash 100%

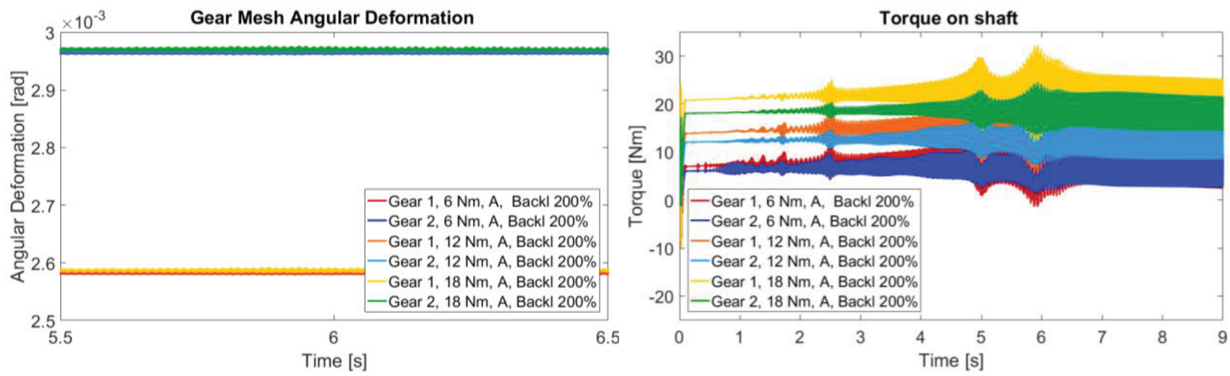

Fig. 7 The detail of gear mesh angular deformation at critical operation conditions and the course of torque during whole simulation for variability A and Backlash 200%,

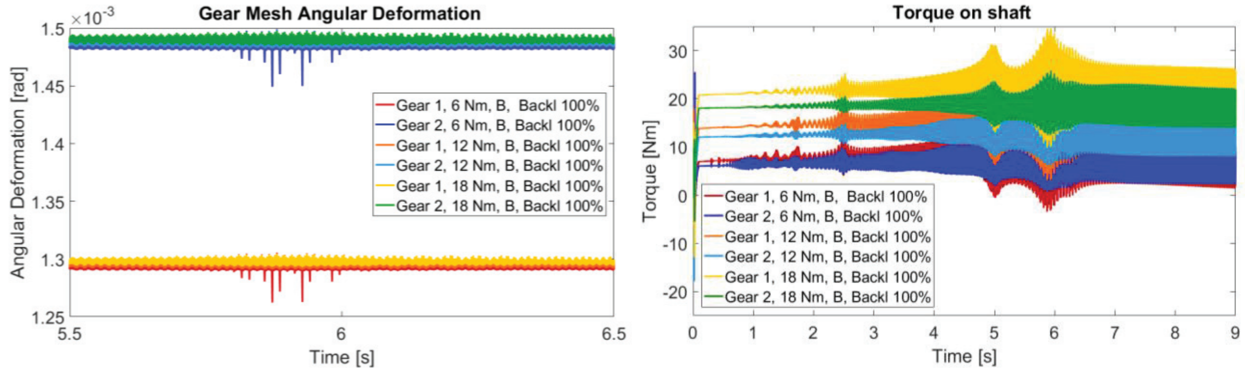

Fig. 8 The detail of gear mesh angular deformation at critical operation conditions and the course of torque during whole simulation for variability B and Backlash 100%

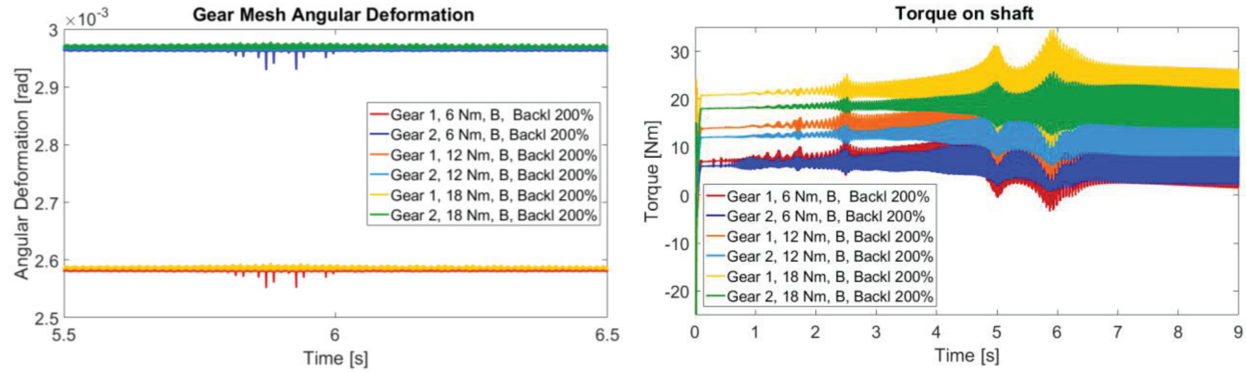

Fig. 9 The detail of gear mesh angular deformation at critical operation conditions and the course of torque during whole simulation for variability B and Backlash 200%

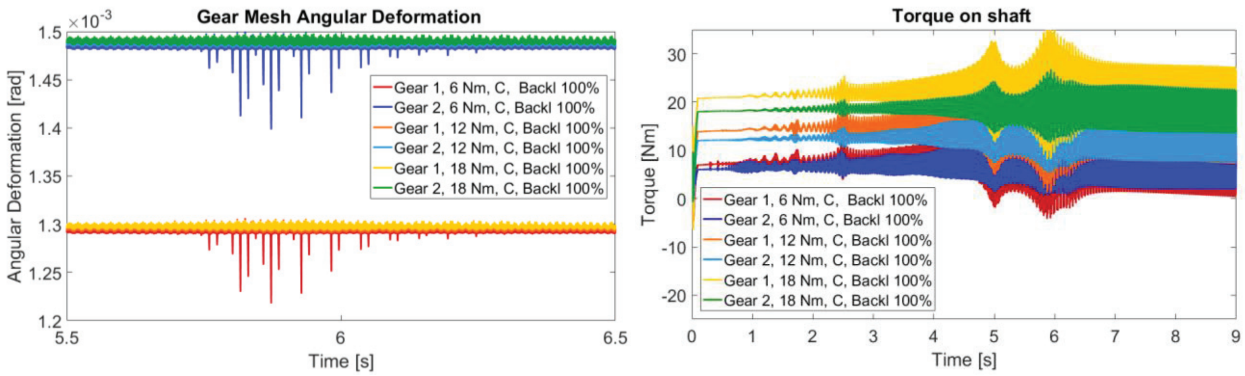

Fig. 10 The detail of gear mesh angular deformation at critical operation conditions and the course of torque during whole simulation for variability C and Backlash 100%

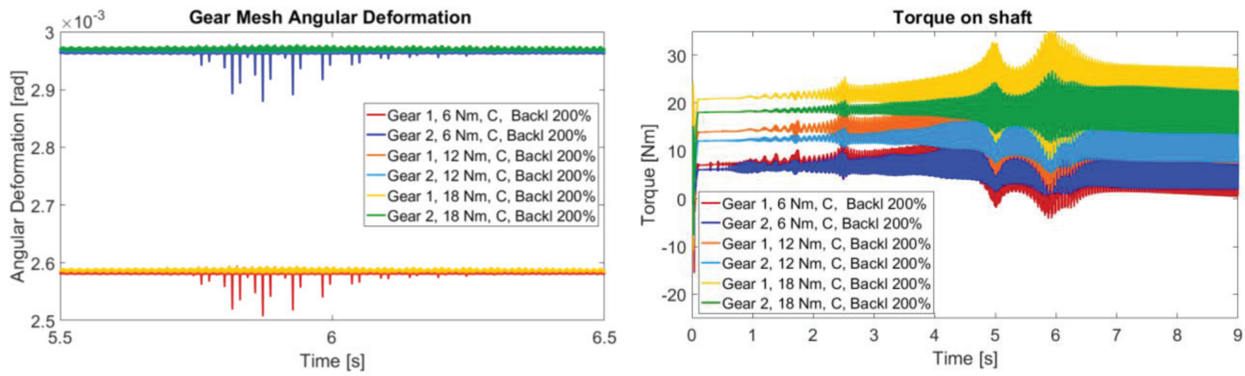

Fig. 11 The detail of gear mesh angular deformation at critical operation conditions and the course of torque during whole simulation for variability C and Backlash 200%

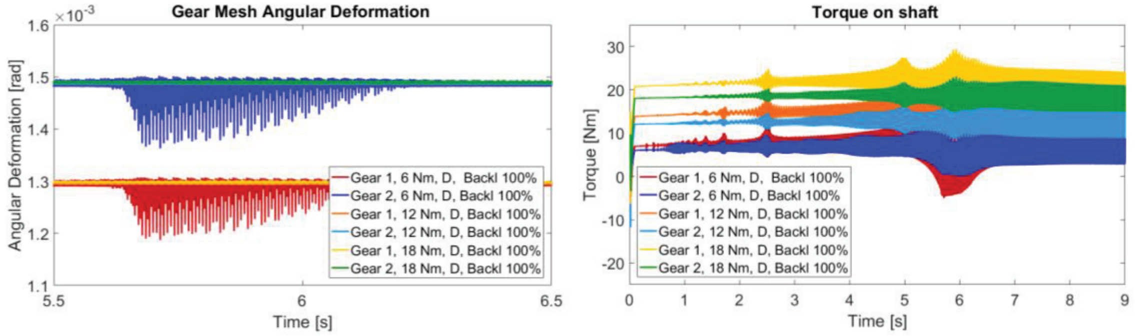

Fig. 12 The detail of gear mesh angular deformation at critical operation conditions and the course of torque during whole simulation for variability D and Backlash 100%

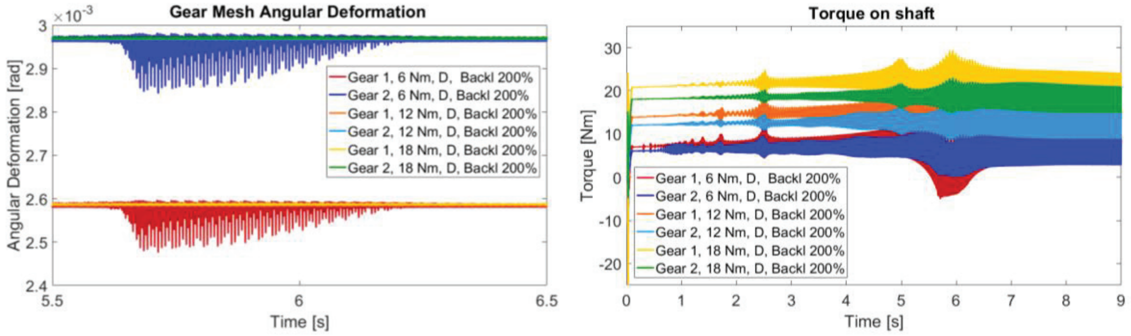

Fig. 13 The detail of gear mesh angular deformation at critical operation conditions and the course of torque during whole simulation for variability D and Backlash 200%

4. Conclusions

The methodology developed and evaluated on the single stage gearbox is used for simulations of variability influence on the transmission dynamic behaviour. The identification of critical operation conditions is done by multispectrum results of surface normal velocity on the middle point of the top cover. This location is very sensitive to changes in comparison to the rest of housing, because of low thickness. The results show that the variability of input speed is very important for dynamic behaviour simulation. Three cases of backlash are incorporated into simulation. In the ideal case, where no backlash is present, results reach minimal difference. With real backlash value, the tooth contact is lost and the rattle occurs, but the backlash 200% achieve the same value. The increasing variability of input speed or the torque could cause getting in touch the teeth in negative side, which makes more characteristic noise of rattle.

Acknowledgement

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Special Urban Transportation Service for People with Disabilities in the Czech Republic

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Abstract

People in wheelchairs, those who use crutches, elderly people, temporary disabled people and others – all these people belong to the group of people with reduced mobility. These passengers need special conditions for transportation. The paper is focused on special urban transportation services in selected Czech cities. It describes analysis of transportation possibilities, optimization methods and measures increasing efficiency of such services from the point of view of operators.
KEY WORDS: *disabled people, optimization, people with reduced mobility, special urban transportation service*

1. Introduction

Mobility, as well as safe and independent moving belong to the one of the basic needs of all people regardless their age or health state [1], [2]. Transportation problems for persons with reduced mobility (PRM) have been discussed as a point of interest since 70´s in some countries, e.g. USA, UK, France [3]. However, Special Urban Transportation Service (SUTS) remains the only possibility to travel round the city for some people with reduced mobility, despite long-standing efforts to make public urban transport more accessible. Wheel chair users, especially those with non-standard dimensions of wheelchairs, cannot use ordinary public transport vehicles (buses, trams, etc.) or specially adapted taxis. In addition to people in wheelchair, SUTS can be used also by people with cognitive limitations, as mentioned [4], elderly people, people with crutches or with other walking aids. Such transportation services are financially and technological demanding and so it is necessary to search for possibilities how to optimize its operation. This is the aim of the Project [5], whose introductory part is presented in this paper.

2. Definitions of SUTS in the Czech Republic and Abroad

There is no official definition of SUTS in the Czech Republic. According to [6] such a transportation service is defined as a "System of urban transportation exclusively for defined group of users. Transportation must be booked in advance". Persons making use of the service are disabled people, their accompaniment or other PRM specified in carrier's transportation rules. Unlike some other countries, this service is not considered public transport in the Czech Republic. The term "paratransit" is defined as "a type of public transport providing services in particular to persons with disabilities or other persons with special needs – e.g. seniors, small children" and used in countries like the USA, Australia or Japan [7]. Another definition specifies this transportation system as: "a type of on-demand (on-call) transport service as one of multimodal urban public transport subsystems with a wider range of services and a position on the interface between traditional public and individual transport" [8]. In Scandinavia, the concepts of 'Special Transportation Services (STS) [9] or ‚Special-needs transport services' [10] have been used for long time.

Common characteristics of this type of transportation across different countries are:

- vehicles adapted for transportation of PRM (persons in wheelchair or with other disabilities) - low floor / low entry, boarding platform, interior layout);
- routing (if fixed) between localities with higher PRM transport demand or booked transportation (door-to-door);
- special tariffs;
- limited operation time period;
- transportation across the city (agglomeration), regional, long distance rather exceptionally;
- various service operators (municipality, non-profit organization, public transport operator etc.).

In the Czech Republic, this type of transportation is operated by municipalities, private transport companies or non-profit organizations.

In West European countries (e.g. Germany, Great Britain, France, Spain, Belgium, Nederland), in Scandinavia, USA or Japan the special transportation services for PRM or taxis are operated more often, because they are subsidized by local authorities, national budget or paid from health insurance [11]. In the CE countries, special transport services have been developing more slowly; in the Czech Republic since approx. 1996 [12]. SUTS is being considered in EE countries as a possibility, e.g. in Vilnius, Lithuania it was in the project phase in 2012 [7].

SUTS is operated not only in large cities in the Czech Republic (250 000 or more inhabitants) where higher demand can be expected (Prague, Ostrava, Brno, Plzeň), but also in smaller - regional towns (about 50-100 thousand inhabitants) e.g. Hradec Králové, Pardubice, Olomouc, Liberec and small towns (about 10 thousand inhabitants) - Tábor, Ústí nad Orlicí. In 2013 SUTS was operated by 23 different subjects in Prague and other 13 cities in 7 regions. There are also special lines with low-floor buses for transportation of PRM - between hospitals, sheltered housing or workshops of PRM.

Special taxis with modified vehicles for transportation of people in wheelchairs and their accompaniment represent another alternative of transportation for these people. These taxis are operated in large cities only – e.g. in Prague, Olomouc or Brno.

3. Analysis of SUTS in selected cities in the Czech Republic

The use of public urban transport and SUTS depends not only on accessible vehicles, information systems and infrastructure (stops, access roads), but also on external conditions (parameters). These are variable, controllable or uncontrollable. Variable and uncontrollable parameters include weather, (changing) health condition of potential passengers etc. People with disabilities may have a problem to reach the public transport stop due to slippery ice or snow in winter, and consequently may not be able to get to the hospital, work or school. Variable parameters involve accessibility of vehicle and infrastructure, fares and operating time. In the short term, the fundamental parameter - the capacity of the vehicle– is invariable and uncontrollable. Number of available vehicles belongs to controllable parameters (e.g. per strategic decision) but invariable in the short term.

3.1. SUTS in Pardubice and Hradec Králové

In Pardubice the SUTS has been run since 1999, initially operated by SPID Handicap (non-profit civil society organization of people with disabilities). Pardubice Public Transport Company (DPMP) has been operating SUTS since 2004. Dispatch control is outsourced to SPID Handicap, purchaser of this service is Pardubice Municipality. Pardubice have one specially modified car Fiat Ducato available (+ one replacement car). Table 1 provides selected characteristics of SUTS in two regional cities and their comparison. When comparing services provided by DPMP to DOSIO (non-profit organization), it becomes clear that DOSIO in Hradec Králové operates very old cars (approx. 4 times older than in Pardubice). All 6 DOSIO cars are in service approx. 3.5 times longer (unit: vehicle-kilometer/year) than DPMP car. Provided subsidies are higher in Hradec Králové in total amount, because they include all DOSIO activities (not only for SUTS). Although both cities are similar in size (Pardubice nearly 90 thousands of citizens, area: 7.800 ha; Hradec Králové nearly 95 thousands of citizens, area 10.500 ha), it is evident that fares are nearly 3 times higher In HK than in Pardubice.

Table 1

Parameters of SUTS in Pardubice and Hradec Králové (2015)

	Pardubice DPMP	Hradec Králové DOSIO
Number of cars	1 (+1 replacement)	6
Average age of cars (year)	3	13,3
Transport service (vehkm/year)	38 114	140 700
Number of passengers / year	10 800	16 823
Provided subsidies (CZK / year)	700 000*	1 149 500**
Provided subsidies / Transport service (CZK / vehkm)	18,37	8,17
Fare (CZK / 1 journey across the city)	17	48

*from the Municipality of Pardubice for SUTS
**total amount from Municipality of Hradec Králové for DOSIO (2 dispatchers, 5 drivers, 2 administrative officers)

The situation in both cities shows long-term excess demand over SUTS capacity which results in rejecting customers. This phenomenon is related to price and cross-elasticity of transport. Public transport shows minimum elasticity in long-term point of view. If the goal form the municipality lies in reduction of subsidies for SUTS, new fares should be set for this kind of service together with optimization of operating concept and total costs. A different approach implies reducing operator's costs, to achieve their higher income while maintaining the subsidies. Project [5] is elaborated upon request of the Pardubice Municipality aiming at optimized SUTS concept and reduced subsidies.

Selected technological parameters have been analyzed in cooperation with DPMP and SPID dispatching – data showing SUTS demand and passengers structure. SUTS is used by regular as well as by ad hoc passengers. Passengers who use SUTS at least 4 times per week are considered to be regular passengers. There is about 60% of regular passengers in Pardubice. Based on these facts it is possible to expect requirements of more than 50% of passengers (time, origin – destination stop). Figure 1 represents map of Pardubice and origin (blue) and destination (orange) places / address. Most requirements occur in district of Nemošice (Day-Care Centre and School for Children and Youth with Disabilities. Due to excess demand (above clients of the Day-Care Centre) over capacity, Municipality representatives have considered a special line for this Centre. Another important destination stop outside Pardubice is Živanice (suburban district).

Fig. 1 displays relatively balanced frequency at origin and destination stops. Passengers mostly require return transport.

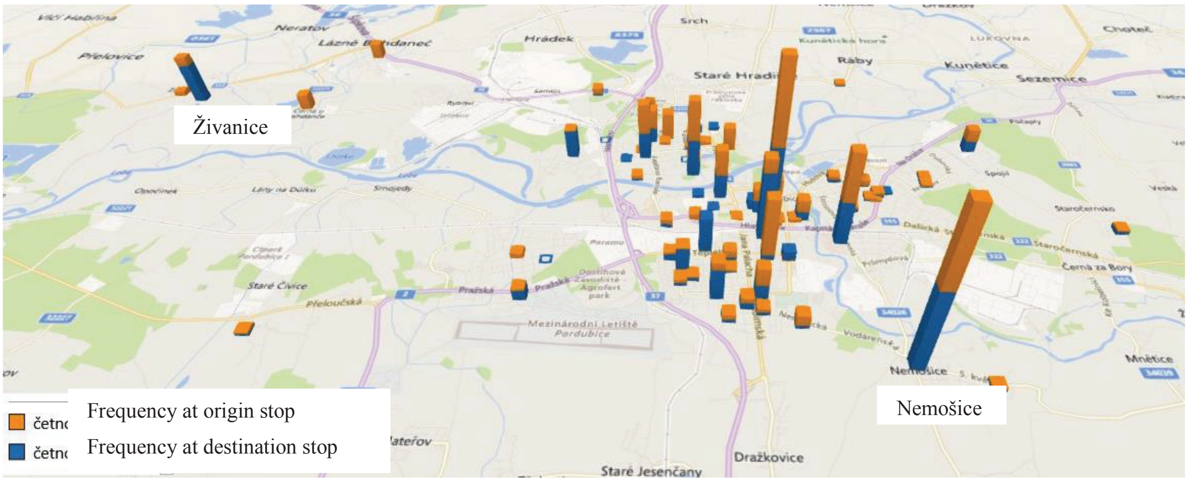

Fig. 1 Map of transport frequency

Dispatch control of SUTS Pardubice is located at SPID Handicap. The dispatcher accepts and organizes transport booking and route plans 24 hours ahead using application of MS Excel, however that is not a very effective way of management. It is relatively demanding to insert data about booking (departure time, origin – destination stops, number of passengers, type of disability, type of wheelchair or other aids). The software does not check either data correctness (accuracy) of inserted data or feasibility of daily route plans. Another problem lies in fixing transportation; the dispatcher does not calculate, only estimates. Cars lack GPS locator, the dispatcher cannot see on-line the position of the car and therefore it is not possible to control the route flexibly. These conditions enable planning routes for one car only.

4. Optimization Options

A new software application supporting dispatcher decision-making process can make SUTS operating more effective while maintaining present technical aid and organization (1 car without GPS, MS Excel). This software will enable calculation of optimal routes by means of a request clustering algorithm. A request clustering can be carried out by more methods; it is important to determinate optimized feasible solution of clustering. The aim is to maximize coefficient C_{cu} (journey utilization). C_{cu} value is maximum if traveling distance is minimum between customers. One of the restrictive conditions is total time which is acceptable for passenger(s) in car. This problem can be solved by means of heuristics Clark-Wright sequential method or exact method of exhaustive search. Exhaustive search method is more accurate and more applicable from the point of view of computer technology. Its disadvantage is high computer technology requirements.

Options for optimizing increase when organization and technical aids change It is possible to plan routes (car) and timetables according to following 4 concepts (operating models):

- Fixed routes, fixed timetable (regular service),
- Fixed routes, service on demand,
- Flexible routes, service on demand (current situation in Pardubice),
- Combination of flexible and fixed routes, service on demand.

a) Fixed routes, fixed timetable

This transportation concept is typical for standard (scheduled) public bus transport. There are defined stops and fixed arrival / departure time for each service (car). Stops are situated inside the isochrones of the locality with a certain level of demand. This concept is not flexible, it is not able to reflect change of demand or departure time requirement etc.

Fixed scheduled bus services are appropriate for transportation of PRM (people with disability) if cars (buses) are accessible for these people (low-floor, boarding ramp etc.). Line No. 910 is designated only for clients of the Day Care Center and School for Children and Youths with disability in Pardubice. Similar line services are also operated in other cities (e.g. in Prague).

b) Fixed routes, service on demand

This transportation concept uses pre-defined pick-up points (located inside of isochrones of locality with transport demand). Cars are operated on fixed network but only when transport is required. The client selects origin and final stop from the list of stops; departure time is determined according to client's requirement. This concept is beneficial for operators because more passenger demands can be concentrated to one journey (from one origin stop). On the other hand, this transportation concept is of a limited use for disabled people as they have to get to / from the nearest stop.

c) Flexible routes, service on demand

The aim of transport operator is to satisfy all customers' requirements. Transportation is ordered in advance, possibly from door-to-door, from anywhere to anywhere according to the time requirements. This concept is also used for SUTS in Pardubice, Hradec Králové and other Czech cities.

d) Combination of flexible and fixed routes, service on demand

This is a combination of concept b) and c). Cars are operated among defined stops, limited service outside the basic network is possible upon request. This concept is also appropriate for transportation of disabled people, seniors and other PRM. From the operator's (dispatcher's) point of view, this concept and concept c) are the most demanding as for organization and management.

5. Conclusion

SUTS are relatively common in the Czech Republic, in 2013 operated in 13 cities. Financial costs make the operators (or purchasers) search for more effective ways. This is also the case in the city of Pardubice. The Municipality together with the University initiated the project [5], which will propose possibilities of operating SUTS in Pardubice more effectively after detailed analysis of basic technological and economic indicators. Investigators will probably make choice between the concepts of 'Fixed and flexible routes with service on demand' and 'Flexible routes with flexible timetable' using a request clustering algorithm (to maximize coefficient of journey utilization). The total time which is acceptable for passenger(s) in car represents the parameter of key importance to be determined.

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Remote Piloted Aircraft Using for Sampling of Oil Spill

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Abstract

The objective is to carry analysis of oil spill sampling using Remote Piloted Aircraft (RPA). Authors are using analysis of existing ecological oil spill sampling methodology. Recommendations for implementations of sampling devices and payloads are proposed in paper. The difficulties during taking samples were defined and possible solutions described. Oil spill sampling device was developed for minimizing time of sampling program and deployments solutions for dedicated tasks of sampling had proposed.
KEY WORDS: *oil spill, oil spill sampling, remote piloted aircraft*

1. Introduction

Oil spill and oil pollution monitoring is necessary for many objectives. One of these objectives is detection of illegal or emergency pollution from ship's, shore terminals or oil producing platforms. Sea water quality monitoring also can be made for identification of specific existing or emergency water quality problem [8]. Information on the type of petroleum products is very important for making a decision on the strategy of eliminating oil spills and dangerous to humans. During performing monitoring can be collected information, that will be used for development oil pollution prevention and eliminating program. For ecological friendly oil transportation system in defined time water sampling for presence of oil is necessary. This activities allows detect regions or coordinates where oil contaminate sea water.

2. Sampling Methods and Requirements

When monitoring the water area, the most important actions are measuring the dynamics of pollution and the level of oil content in the water surface. Obtaining these parameters is possible only with the use of sampling devices. The change in the parameters of the oil spill during the time interval of 24 hours is shown in Fig. 1.

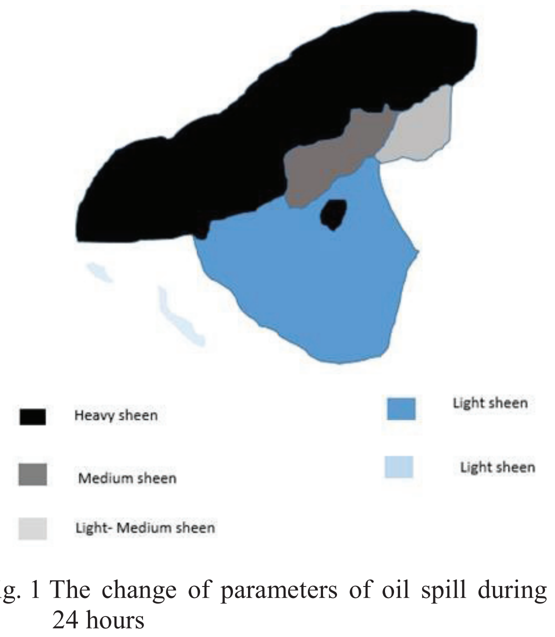

Fig. 1 The change of parameters of oil spill during 24 hours

International Maritime Organization IMO has developed a special document with recommendations for sampling in the case of oil pollution. According sampling guidelines sampling equipment is not limited [5]. Usually sampling equipment may include vessels or devices for oil films collection. The base sampling programme should include detection of oil product type. During development of sampling programme establish kind of sample: depth sample or surface sample. The quantity of oil samples depends of oil spill size. Large oil spill should be split into subareas. For each subarea 3 samples will be taken.

Sampling methods are divided into 2 main oil film withdrawals by scooping with a jar and sampling using a special Teflon fine mesh.

Ideally, an infrastructure should be established to enable all of the water samples to be returned to a central or regional laboratory within a few hours of sample collection [3].

The oil spill sample should represent oil contamination degree at the time of taking sample. The reference samples will be taken near oil spill for elevation of sea water condition before oil spill.

Procedures for taking samples from the water surface will vary depending on the size and thickness of the oil film, weather and sea conditions at the site of the spill, such as petroleum products, and taking into account all necessary precautions. During conducting of the analysis, various sampling techniques were studied. Taking into account variety of sampling methods from oil spills, is established that the reliability of the determination of oil contamination mainly depends on the way of sampling.

When monitoring an oil spill to determine the severity of contamination, a sampling program should be used to assess the overall environmental impact. Samples should be selected in spatial regions with given coordinates throughout the contamination site. The samples are divided into two main types: oil, oil films, emulsified oil and mixtures of oil with absorbents. The main problem of manual sampling is quality of samples. During manual sampling procedure, risk of sample contamination exist. Performing sampling necessary information should be collected for each sample. These data include geographical position, depth or water surface and reference location inside oil slick. After sampling sample must be sealed and special labels with identification information should put on the bottle. . The sampling method also has a number of drawbacks due to the possibility of sampling only by the personnel of the floating facility. The sampling device (vessel) is lowered into water and a layer of oil or particles of oil is collected from the surface of the water. The process continues until the sampler is filled to approximately ¾. The procedure, if necessary, will be repeated until the collection of oil is completed. This method can not also be used for the sampling of thin films.

When sampling using a special Teflon fine mesh, sampling is carried out slowly, dragging a fine mesh net through an oil film and using the physical properties of the oil. Oil film samples contain a very small amount of oil and the thinner the film whose sample needs to be obtained, the higher the risk of contamination of the sample with substances on the sampling device. After the end of the procedure, the fine mesh is packed into a container. The disadvantage is that sample can be contaminated and after the procedure it is necessary to attach a label with identification data.

3. Using of RPA for oil Spill Sampling

RPA are using to perform different environmental monitoring task, due to high actuality of obtained data. RPAs offer a remotely sensed data at high spatial resolution, a flexible local control for vehicles that is fuel efficient and an operation with minimum visual intrusion [9]. RPAs are suitable for remote sensing applications because of their capability of carrying sensors and ability to monitor large areas in a relatively short period of time [6]. Small RPAs potentially offer a low-cost alternative to conventional remote sensing platforms, and research to date shows promise[10]. During analysis external factors, which may impede operation of RPA dedicated for oil pollution sampling were defined.

These factors are wind speed and wave height. The implementation of RPA for oil pollution sampling mission is limited by wind speed more 14 m/s and wave height more 2 meters.

Taking into account specific of RPA mission for oil spill sampling weight of sampling payload should be included in the weight balance equation for RPA. Due to, main requirement for payload is small weight of sampler. The RPA has to produce enough thrust for lifting its payload [2]. Difficulties of taking oil spill samples, connected with landing over water surface can be removed be development remote sampling device. RPA that is used for flight over water should be equipped with special device, for floating in case of emergency landing.

Measuring the thickness of the oil film is important in order to create a model for the dynamic spread of the oil spill. Measuring the thickness of the oil film on the water surface can provide information on the amount of oil. When the surface area of the spill is known, based on this information, the total oil volume can be calculated. In the case of a dispersant and the containment system, they must be applied on a thicker part of the oil slick. The use of samplers can give some idea of the relative thickness of the oil slick and help in the establishment of a methodology for cleaning oil contamination. All of the above conditions show the need to develop the RPA with a device for sampling oil contamination from the water surface.

Unfortunately traditional oil spills sampling methods take many time, labour and are high costly. This type of measurement may cause problems, when time and area scale not reached [4].

The use of RPAs to obtain visual data on the contaminated by oil area provides initial information for the development of a new monitoring program and sampling points. The monitoring system using RPA with an integrated sampling device will allow to assess the degree of hazard of the spill and to estimate the consequences for natural resources based on databases for characteristic types of oil products.

By facilitating data collection, lightweight RPAs, together with our collaborators, will improve, if not "revolutionize" spatial ecology [1]. Sampling technique based on RPA platform would provide near real time accurate data about oil spill. Mission planning with the integration of information from the Automatic Identification System (AIS) and the shore radar surveillance systems will allow minimizing the flight time of the monitoring mission and the RPA operational cost [11].

Two scenarios were proposed for sampling model of medium size oil spill. In the first scenario sampling were conducted by environmental officers using boat for sailing in spill area and car for transportation to laboratory. In the second scenario, oil spill samples were collected by RPA with integrated sampler.

Implementing of RPA in comparison with traditional manual sampling methods, time for performing oil spill sampling programme will be reduced by 80 percent. RPA can be used as platform of autonomous system assisting in sampling of oil spills. The existing water sampling systems are based on implementation of autonomous water surface crafts. The sampling device is integrated inside hull of water surface crafts. Unfortunately, speed of surface craft is small. The next problem is, that after using inside oil spill they should be recovered and cleaned, because can contaminate clean water around spill. The main disadvantage is that containers with samples should be removed from surface craft ashore and transported to laboratory by car. In comparison with autonomous surface crafts and underwater crafts with sampling devices RPA provide additional aerial visual information.

The sampling payload should be installed at the bottom side of RPA with special device for disconnecting in emergency case.

Sampling system can include as sampler pumps with control from RPA control module. This type of sampler have difficulties because after each sampling pump should be flushed with clean water. The next type of sampling device is container with messenger. The disadvantage is, that sampling device after taking sample is closed and hanging below PPA on messenger. The best solution will be sampling system inside of RPA, which after sampling retracts inside RPA hull. For large area of monitoring can be used group of RPA. This solution allow RPA equipped with sensors detect points where need oil pollution samples for confirmation of water condition.

Usually oil spill is accidental event, due to need sampling platform based on RPA for effectively monitoring program.

The RPA sampling platform can replace hand sample collecting, minimize risk of poisoning with oil products and personal safety in oil slick area for environment officers. RPA reduce time of sampling program. Aerial water sampling has the potential to vastly increase the speed and range at which scientist obtain water samples while reducing cost and effort, and RPA have been used for this task. [7].

4. Development of RPA for Oil Spill Sampling

For development of RPA for oil spill sampling was used Multi-rotor platform with the possibility of vertical take-off and landing and long-term hovering with the holding of a given position. For development of RPA for sampling off oil spills were defined following objectives:

- ✓ integrate sampling system module in RPA hull;
- ✓ optical sensors and algorithm for safe navigation during sampling process;
- ✓ Global Positioning System GPS module for identification sampling time and position;
- ✓ mechanism of sealing sample during transportation to the laboratory;
- ✓ surface sampling device for thick oil film and depth sampling;
- ✓ possibility of remote sampling on low altitude;
- ✓ installing in RPA hull module with main containers;
- ✓ taken oil spill samples without pump due negative suction and minimizing weight of RPA.

This type of platform allows to avoid labour-cost and inefficient methods of pollution monitoring using mobile sampling stations and boats. Sampling device should be integrated with light weight remote sensors for oil pollution detection such as hyperspectral. A special algorithm allows the use of a platform for monitoring oil contamination and sampling from the surface of water. In the event of an emergency caused by a spill of oil, RPA will provide monitoring of the dynamics of oil spill spreading in real time and taking samples from the surface of water using a special container. In sampler should be integrated device to determine the thickness of the oil film. During development RPA for this mission, the main objective was sampling with container, sealing of it and registration in RPA control module memory data of samples: time, position.

During research, a method was proposed for sampling water for the presence of oil pollution in the water area, which includes taking a sample from the surface of the water, preparing for transportation and delivery of samples to the specified location, using an RPA.

For sampling in coastal areas, a device consisting of a RPA of vertical take-off and landing, which is equipped with a special device for sampling in a sampler, made in a plastic container with positive buoyancy, was developed during the research Fig. 2 [12].

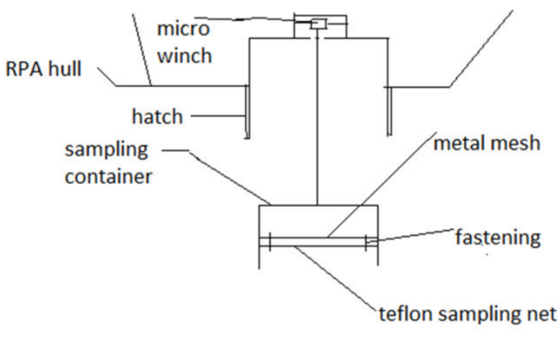

Fig. 2 Sampling device

The structure of the container includes a metal mesh and a special thin Teflon mesh. The container is designed to carry out the procedure for taking samples from the water surface. The RPA complex selects samples from the surface of the oil spill. The container is lowered onto the surface of the water and the container is lifted into a special compartment of the RPA using a compact winch. A container with positive buoyancy ensures that the sample is taken from the surface of the water, despite the state of the sea surface and the height of the waves.

After sampling the water on the surface and lifting the container onto the RPA, it is placed in a sealed compartment that is designed to accommodate one or more containers.

The hermetic compartment of the RPA is equipped automatically or by means of a remote control of the closing flaps with sealing teflon seals.

Sampling and the transportation process are carried out automatically. After the RPA is landed on the basing site (for example, on the shore or on board the vessel), the container is transferred to the laboratory for sample analysis and a new container is installed on the RPA. If a monitoring plan requires sampling from a number of points in a sealed compartment, several independent modules with containers are installed. Unlike the existing sampling methods, RPA vertical take off and landing for sampling is equipped with a special compact winch. The winches allow remote sensing with sampling regardless of weather conditions. The innovative solution is that the sampling device is made in the form of a plastic container with positive buoyancy, and is equipped with a special Teflon mesh with small cells to obtain a sample from the surface of the water. The method using RPAs with containers placed in a sealed compartment allows fulfil legal requirements for oil contamination probes. In the course of the study, an analysis was made of existing methods and means for determining oil contamination.

After landing, the container is handed over to the laboratory for analysis if it is necessary to take samples at several points, a module with 10 micro-containers with a separate hatch for each microcontainer and a winch in which 10 reels are mounted on the working shaft are installed in the compartment. When sampling, the electronic control module o turns on the electromagnetic clutch of the drum of the sampling container, instructs the hatch to open. Micro-winch lowers the container to take a sample. After taking the sample, the winch lifts the container, the control electronics module commands the hatch to close and disconnects the electromagnetic clutch of the drum of the container.

5. Conclusions

This paper is aimed to analyse possibilities to use RPA system for solving existing problem of sampling of oil spills. The problem and challenges of sampling of oil spills using RPA were overviewed. Practical recommendations for sampling oil spills using RPA's were offered. Implementation of RPA platform for sampling reduce by 80 percent time of sampling, increase samples quality and actuality. It is necessary to design algorithms for RPA's sampling mission tasks for large areas for group of RPA. Performance of RPA sampling system can be improved by adding additional pollution sensor in payload. The automation of sampling process can be improved by using electronic charts for planning mission flight and presentation of points where samples were taken.

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Selected Problems of Tracked Vehicle Movement Modelling

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Abstract

Presented paper deals with an issue of oscillatory response of tracked vehicle during a movement at diverse terrain. At the beginning of paper are stated tracked vehicle movement requirements and influence of oscillation on human body. Complex mathematical model has been suggested. The article is supplemented by partial calculation of outcomes by using Matlab Simulink.
KEY WORDS: *vibration, tracked vehicle, terrain*

1. Introduction

It is not so long time ago, when the need of tracked vehicles in armies was questioned. Eventually, it turned out that tracked vehicles have its own place in armies over the world. Combat and special vehicles on tracked chassis represent a combination of good mobility, armour protection and firepower. This connection is unique for army technique.

In the last few years, a battlefield is transformed from woods, fields and wastelands to urban areas. The using of heavy tracked vehicles was questioning in these areas. However, after some technical adjustments, the tracked vehicles has found their use. High requirements on mobility of tracked vehicles, comes out from environment in which the vehicle operates. All these requirements are reflected to construction design. Construction of undercarriage has a major impact to vehicle mobility. Ensure a cross-country capability and comfort of crew is the main task of tracked chassis. When the vehicle is moving after rugged terrain, it leads to emergence of oscillation, which is influenced by overcoming various obstacles. Presented paper deals with an issue oscillation in view to interaction between bedrock and hull of tracked vehicle.

2. Tracked Vehicle Cross-Country Capability Requirements

Terrain is an integral part of land surface created by horizontal and vertical dimension. Terrain relief is completed by terrain objects of artificial or natural origin. Cross-country mobility represents the capability of tracked vehicle overcoming thru different types of obstacles in terrain relief. Table 1 shows the obstacles distribution and its requirements on tracked vehicle.

Table 1
Obstacles distribution and requirements on tracked vehicle [3]

Obstacles types	Max. requirements on tracked vehicles
Slope angle	30 – 32°
Side slope	20°
Cut	2,8 m
Vertical obstacle	1,8 m

Armored tracked vehicles like MBT, armored personnel carrier etc. have to fulfill a tactical mobility requirement – capability of motion under enemy fire. Vehicle velocity demands are: maximal speed - forward ca. 65 km/h, backward 30 km/h (on communication) and approximately 45 km/h in terrain. Undercarriage design has a significant affect on the comfort and health of crew [3].

3. Influence of Oscillation to Human Body

Vehicle shocks and vibrations occurring during vehicle movement may have fatal consequences to human health. Each part of human body has a different natural frequency. If the vibration frequency approaches the natural frequency of some of parts of human body, the resonance occurs. Damage to health occurs after that the human body is exposed to resonance frequency over a longer time period. Simple ways how to evaluate the effect of vibrations on human body is according to literature [3], where the limit curves are given for acceleration depending on frequency.

Detailed and the most widely used international standard for influence of oscillation to whole human body is ČSN ISO 2631-1:1997, “Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 1: General requirements “. The standard defines methods to quantify WBV in relation to human health, perception and motion sickness. Three criteria for defining methods of vibration are recommended in the standard in relation to [1]:

- Human health and comfort (for scope 0,5 Hz to 80 Hz);
- The probability of vibration perception (for scope 0,5 Hz to 80 Hz);
- The incidence of motion sickness (for scope 0,1 to 0,5 Hz).

Human body has not only single natural frequency. Each part of body has its own. For example, the span of frequencies of head (20 – 30 Hz), legs (2 – 20 Hz), chest (5 – 10 Hz), hand (30 – 50 Hz), arm (5 – 10 Hz) [2].

4. Tracked Vehicle Modelling

Mathematical model of half tracked vehicle (Fig. 1) is represented by 6 degrees of freedom in vertical direction of movement. There are also *n* degrees of freedom in horizontal direction of movement (as the motion of tank tread). This type of motion is in the presented calculation neglected. Vehicle body performs a vertical movement (bouncing) x_5 and angular motion θ. Ground wheels and track links are other parts of mathematical model. The mathematical model is excited by inequality of terrain or different types of obstacle - $u_1(t)$ and $u_2(\Delta t)$. Front and rear wheel suspension are crossing the obstacle in out-of-phase (time delay Δt).

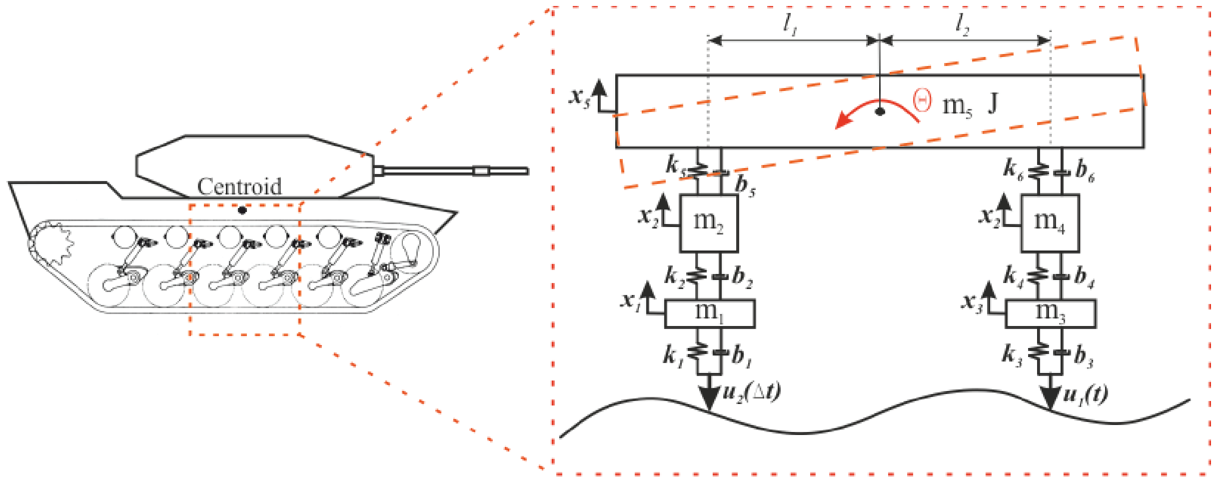

Fig. 1 Mathematical model of half tracked vehicle (2 wheels)– u_1 a u_2 – terrain unevenness, m_2 a m_4 – mass of wheels, m_1 and m_3 mass of track link, m_5 mass of hull, *J* inertia moment of hull, k_5 and k_6 stiffness of torsional bar, b_5 and b_6 damping of hydraulic dampers, k_2 and k_4 stiffness of ground wheels, b_2 and b_4 damping of rubber on ground wheels, k_1 and k_3 stiffness of track links, b_1 and b_3 damping of track links

Equations of motion are obtained according to Lagrange's equations of second kind. Kinetic, potential and dissipative energy of mathematical model is represented by the following equations:

Kinetic energy:

$$E_k = \frac{1}{2}m_1\dot{x}_1^2 + \frac{1}{2}m_2\dot{x}_2^2 + \frac{1}{2}m_3\dot{x}_3^2 + \frac{1}{2}m_4\dot{x}_4^2\,\frac{1}{2}m_5\dot{x}_5^2 + \frac{1}{2}I\dot{\theta}^2\,; \tag{1}$$

Potential energy:

$$E_p = \frac{1}{2}k_1\left(x_1 - u_2\right)^2 + \frac{1}{2}k_2\left(x_2 - x_1\right)^2 + \frac{1}{2}k_3\left(x_3 - u_1\right)^2 + \frac{1}{2}k_4\left(x_4 - x_3\right)^2 + \frac{1}{2}k_5\left(x_5 - x_2 - l_1\theta\right)^2 + k_6\left(x_5 - x_4 + l_2\theta\right)^2\,; \tag{2}$$

Dissipative energy:

$$E_d = \frac{1}{2}b_1\left(\dot{x}_1 - \dot{u}_2\right)^2 + \frac{1}{2}b_2\left(\dot{x}_2 - \dot{x}_1\right)^2 + \frac{1}{2}b_3\left(\dot{x}_3 - \dot{u}_1\right)^2 + \frac{1}{2}b_4\left(\dot{x}_4 - \dot{x}_3\right)^2 + \frac{1}{2}b_5\left(\dot{x}_5 - \dot{x}_2 - l_1\dot{\theta}\right)^2 + \frac{1}{2}b_6\left(\dot{x}_5 - \dot{x}_4 + l_2\dot{\theta}\right)^2\,; \tag{3}$$

By applying the Lagrange's equations of second kind to energy equations leads to obtaining the equation of motion of tracked vehicle.

Lagrange's equations of the second kind:

$$\frac{d}{dt}\left(\frac{\partial E_k}{\partial \dot{x}_j}\right)-\frac{\partial E_k}{\partial x_j}+\frac{\partial E_D}{\partial \dot{x}_j}+\frac{\partial E_P}{\partial x_j}=Q_j(t)\,; \tag{4}$$

Differential equation of mathematical model of half tracked vehicle are presented below:
For rear part of tracked vehicle:

$$m_1\ddot{x}_1+(b_1+b_2)\dot{x}_1-b_2\dot{x}_2+(k_1+k_2)x_1-k_2x_2=b_1\dot{u}_2+k_1u_2\,; \tag{5}$$

$$m_2\ddot{x}_2-b_2\dot{x}_1+\dot{x}_2(b_2+b_5)-\dot{x}_5b_5+\dot{\theta}b_5l_1-x_1k_2+x_2(k_2+k_5)-x_5k_5+\theta k_5l_1=0\,. \tag{6}$$

For front part of tracked vehicle:

$$m_3\ddot{x}_3+(b_3+b_4)\dot{x}_3-b_4\dot{x}_4+(k_3+k_4)x_3-k_4x_4=b_3\dot{u}_1+k_3u_1\,; \tag{7}$$

$$m_4\ddot{x}_4-b_4\dot{x}_3+\dot{x}_4(b_4+b_6)-\dot{x}_5b_6-\dot{\theta}b_6l_2-x_3k_4+x_4(k_4+k_6)-x_5k_6-\theta k_6l_1=0\,. \tag{8}$$

Motion of hull – bouncing (9) and angular motion (10):

$$m_5\ddot{x}_5+\dot{x}_5(b_5+b_6)-b_5\dot{x}_2-b_6\dot{x}_4+\dot{\theta}(b_6l_2-b_5l_1)+x_5(k_5+k_6)-k_5x_2-k_6x_4+\theta(k_6l_2-k_5l_1)=0\,; \tag{9}$$

$$I\ddot{\theta}+\dot{x}_5(b_6l_2-b_5l_1)+l_1b_5\dot{x}_2-b_6l_2\dot{x}_4+\dot{\theta}(l_1^2b_5+l_2^2b_6)+x_5(k_6l_2-k_5l_1)+l_1k_5x_2-k_6l_2x_4+\theta(l_1^2k_5+l_2^2k_6)=0\,. \tag{10}$$

Equations of motion mentioned above can be written in matrix form:

$$[\boldsymbol{m}]\{\ddot{\boldsymbol{X}}\}+[\boldsymbol{b}]\{\dot{\boldsymbol{X}}\}+[\boldsymbol{k}]\{\boldsymbol{X}\}=\{\boldsymbol{F}\}\,. \tag{11}$$

Or in the state-space (SS) model form:

$$\left.\begin{aligned}\dot{x}&=Ax(t)+Bu(t)\\ y(t)&=Cx(t)+Du(t)\end{aligned}\right\}, \tag{12}$$

where $x(t)$ is called as a state vector, $y(t)$ as output vector, $u(t)$ as input vector of SS model. There are also four types of matrix: A as a system matrix (matrix of whole subsystem), B as input matrix, C as output matrix and D as feedforward matrix. This type of matrix entry is suitable for large systems.

$$A_{11}=\begin{pmatrix}0&1&0&0&0&0\\ -\frac{(k_1+k_2)}{m_1}&-\frac{(b_1+b_2)}{m_1}&\frac{k_2}{m_1}&\frac{b_2}{m_1}&0&0\\ 0&0&0&1&0&0\\ \frac{k_2}{m_2}&\frac{b_2}{m_2}&-\frac{(k_2+k_5)}{m_2}&-\frac{(b_2+b_5)}{m_2}&0&0\\ 0&0&0&0&0&1\\ 0&0&0&0&-\frac{(k_3+k_4)}{m_3}&-\frac{(b_3+b_4)}{m_3}\end{pmatrix};$$

$$A_{12}=\begin{pmatrix}0&0&0&0&0&0\\ 0&0&0&0&0&0\\ 0&0&0&0&0&0\\ 0&0&\frac{k_5}{m_2}&\frac{b_5}{m_2}&-\frac{k_5l_1}{m_2}&-\frac{b_5l_1}{m_2}\\ 0&0&0&0&0&0\\ \frac{k_4}{m_3}&\frac{b_4}{m_3}&0&0&0&0\end{pmatrix};\quad A_{21}=\begin{pmatrix}0&0&0&0&0&0\\ 0&0&0&0&\frac{k_4}{m_3}&\frac{b_4}{m_3}\\ 0&0&0&0&0&0\\ 0&0&\frac{k_5}{m_5}&\frac{b_5}{m_5}&0&0\\ 0&0&0&0&0&0\\ 0&0&-\frac{k_5l_1}{I}&-\frac{k_5l_1}{I}&0&0\end{pmatrix};$$

$$A_{22}=\begin{pmatrix} 0 & 1 & 0 & 0 & 0 & 0 \\ -\frac{(k_4+k_6)}{m_4} & -\frac{(k_4+k_6)}{m_4} & \frac{k_6}{m_4} & \frac{b_6}{m_4} & \frac{k_6 l_2}{m_4} & \frac{b_6 l_2}{m_4} \\ 0 & 0 & 0 & 1 & 0 & 0 \\ \frac{k_6}{m_5} & \frac{b_6}{m_5} & -\frac{(k_5+k_6)}{m_5} & -\frac{(b_5+b_6)}{m_5} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ \frac{k_6 l_2}{I} & \frac{b_6 l_2}{I} & -\frac{(k_6 l_2 - k_5 l_1)}{I} & -\frac{(b_6 l_2 - b_5 l_1)}{I} & -\frac{(k_6 l_2^2 + k_5 l_1^2)}{I} & -\frac{(b_6 l_2^2 + b_5 l_1^2)}{I} \end{pmatrix}.$$

The resulting system matrix: $A=\begin{pmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{pmatrix}$.

The resulting input matrix: $B=\begin{pmatrix} B_{11} \\ B_{21} \end{pmatrix}$.

$$B_{11}=\begin{pmatrix} 0 & 0 & 0 & 0 \\ \frac{k_1}{m_1} & \frac{b_1}{m_1} & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{k_3}{m_3} & \frac{b_3}{m_3} \\ 0 & 0 & 0 & 0 \end{pmatrix};\ B_{21}=\begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}.$$

The resulting output and feedforward matrix for calculation of hull bouncing x_5 and angular motion θ :

$$C=\begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \end{pmatrix};\qquad D=\begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}.$$

Each ground wheel of vehicle crosses an obstacle at a different time. Delay between wheels crossing of obstacle is given by inter-axis distance L and vehicle speed v_v. Time delay can be defined by the equation as:

$$t_d=\frac{L}{v_v}=\frac{(l_1+l_2)}{v_v}\ \text{[s]} \tag{13}$$

Areas of frequent movement of tracked vehicles (tank terrain) can be compared to sinusoidal profile (Fig. 2). Characteristic dimension of terrain sinusoidal profile are wavelength (λ) 5-8 m and value from peak to peak (A) 0.1 ± 0.2 m [3].

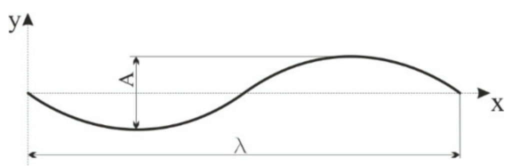

Fig. 2 Terrain profile

The resulting tank terrain profile is characterized by sinusoidal equation and by using vehicle velocity and wavelength can be formulated by equation:

$$u_1(t)=\frac{A}{2}\cdot sin\left(2\pi\frac{v_v}{\lambda}t\right). \tag{14}$$

And crossing of second wheel with time delay:

$$u_2(t)=u_1(\Delta t), \tag{15}$$

where $\Delta t=t-t_d$.

Table 2

Values of terrain according to equation (14), for wavelength λ = 5 m and axial distance L = 0.667 m

Vehicle speed, km/h	Vehicle speed, m/s	Period of sin, s	Frequency, Hz	Frequency, rad/s	Crossing delay, s
15	4.167	1.2	0.833	5.236	0.160
25	6.944	0.72	1.389	8.727	0.096
35	9.722	0.514	1.944	12.217	0.069
45	12.5	0.4	2.5	15.708	0.053

MATLAB Simulink

MATLAB Simulink has been used for calculation of equations mentioned above. Typical obstacle (convex obstacle) for area of motion of tracked vehicle has been made. Obstacle is created by merging a different types of classic signals. Main signal is represented by Eq. (14). The signal is subsequently cropped by two types of step signals into convex obstacle (Fig. 3). The designed obstacle is used for subsequent calculation of oscillation of tracked vehicle, which crossing over the obstacle in different velocity. Time delay of wheel crossing is directly dependent on vehicle velocity.

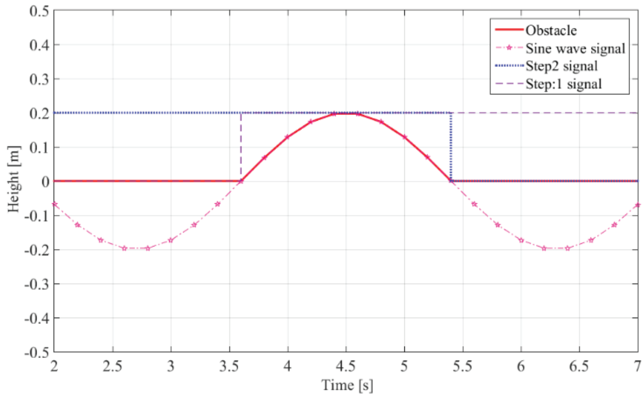

Fig. 3 Convex obstacle – signal merging

Block implementation of solved problem in Simulink is very complex. Subsystems, which simplifies the whole scheme, are used for this reason. Every subsystem is equipped with a mask. The mask provides users better handling with variables of calculation right in the Simulink blocks. Block diagram is shown in Fig. 4, including the detail of one subsystem.

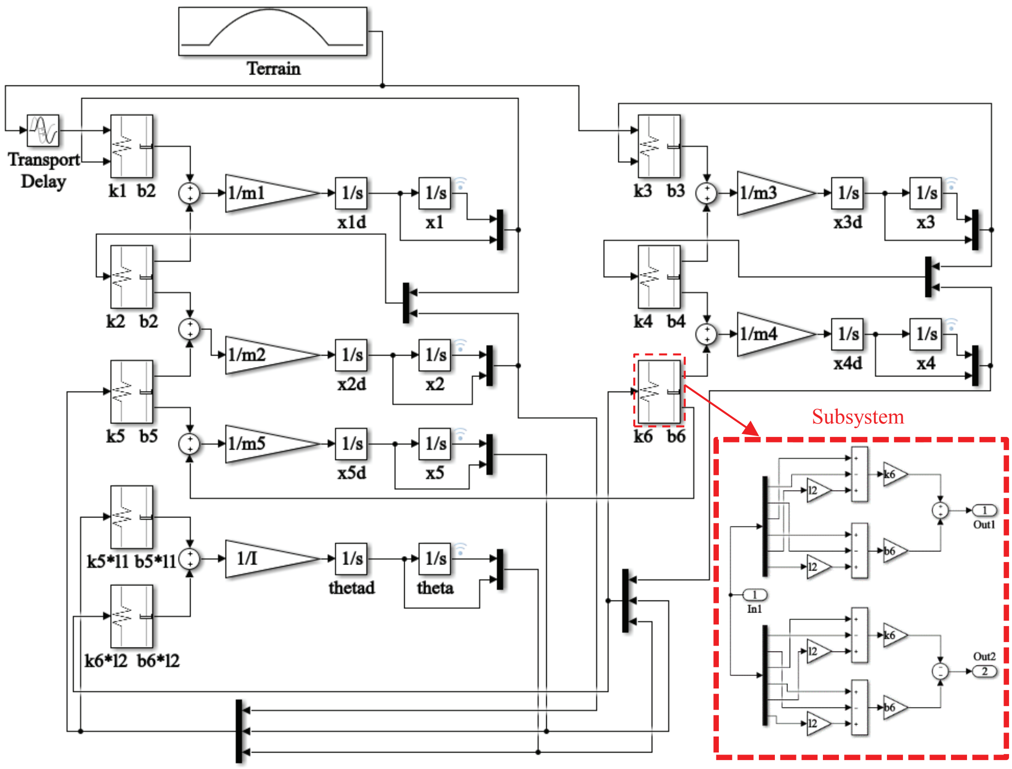

Fig. 4 Block implementation of differential equation in Simulink

Ode45 algorithm has been used for numerical calculation by Simulink. This algorithm operates on fourth order Runge-Kutta method for calculation of differential equations. Graphs express the acceleration of hull of tracked vehicle are outcomes of calculation (Fig. 5 and Fig. 6). Outcomes of time domain have been transformed to frequency domain (Fig. 7) by fast Fourier transformation for results evaluation.

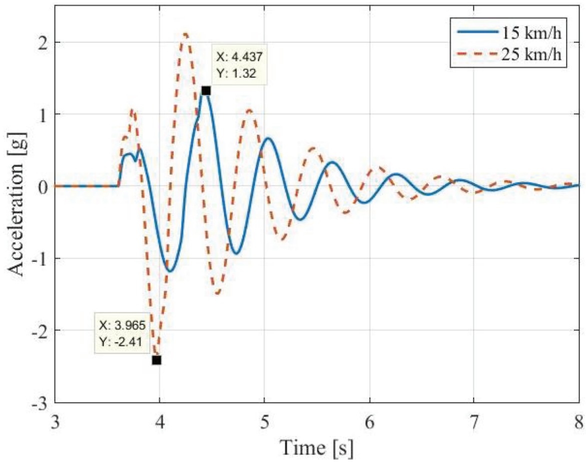

Fig. 5 Acceleration of hull – 15 and 25 km/h

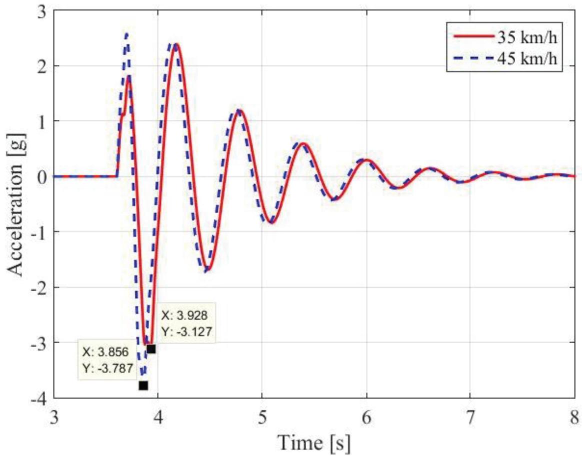

Fig. 6 Acceleration of hull – 35 and 45 km/h

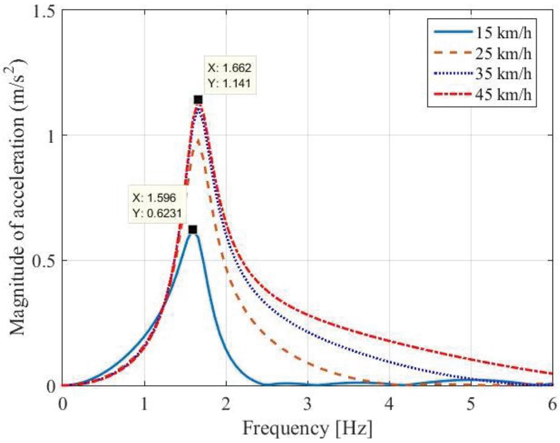

Fig. 7 Frequency domain of acceleration

5. Conclusion

Human body is very sensitive to effect of all types of vibration. These vibrations are also health hazardous. Therefore, it is necessary to take into account the effects of oscillation already at beginning of vehicle design. Mathematical model of tracked vehicle in view of centroid and obstacle has been suggested. The outcomes show that the moving vehicle by speed from 15 and 25 km/h has frequency of oscillation approx. 1.6 Hz and maximal acceleration values 1.31 and 2.41 g. Acceleration on this frequency value will not have a major impact on human health. The acceleration limit for frequency mentioned above is approximately 2.5 g. At vehicle speed of 35 km/h, the oscillation is already in area of rapid body fatigue, and at 45 km/h the values approximate to limit of disturbance in organisms. Problem could arise in the case of couple of obstacles with a height of 0.2 m, which follow behind, and vehicle speed will be from 35 to 45 km/h. Increased fatigue of crew will occurs - human body is going to try to prevent acceleration by alternating muscle stretching.

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Experiences with the Formal Modeling of the Geographical and Tabular Principles of Interlocking Systems

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Abstract

The development of safety-critical, embedded microcomputer-controlled railway interlocking systems has seen an increasing interest in the use of formal modeling, due to its ability to specify the behavior using mathematically precise logical rules. These model-checked formal specifications increase the likelihood that the design of the interlocking system will be complete and correct.
This paper describes experiences with the formal modeling of the railway interlocking principles (i.e. geographical and tabular approaches) using an example of a simplified terminal area. In this paper we show two well-known modeling techniques (i.e. Petri nets and nondeterministic automata) and we compare the tools employed for the modeling and simulation (PetriDotNet and UPPAAL).
Our long-term goal is to prepare the automatic transformation of the non-formal specifications created by domain engineers into appropriate formal models which can be verified by existing model-checking tools.
KEY WORDS: *safety-critical systems, railway, interlocking, formal methods, transition system, Petri net, automaton*

1. Introduction

The application of formal methods in the railway industry has a long history. Many publications have been written in this area, but the theoretical results of transposition in the daily practice have not yet come to realization. The backgrounds of these are for example the extra work needs, which should be used as background knowledge, or the distrust, which accepts the prepared formal descriptions and analyses.

In this paper we explained a case study (a simplified station interlocking with geographical and tabular approaches) and we describe it with two formal methods, (Petri nets [1] and nondeterministic finite automata [2]). Through the examples of case study we would like to introduce that with proper construction we can create well-used models. We use PetriDotNet [3] (in the following PDN) and UPPAAL [4] tools to realize the interlocking principles. Based on this work we compared and evaluated our experiences with the tools from the point of view of usability in the railway interlocking systems.

2. Formal Methods

The formal methods are techniques that we use primarily in the area of information technology. These methods are based on discrete mathematics and mathematical logic. These techniques can be used in the system development including the software and hardware development as well [2]. The semantics and syntax of formal models are well specified, clear and complete, so they do not have equivocal or not defined parts. The cooperation between the participants in the development process does not mean misunderstandings or uncertainty using formal models and specifications instead of textual and ad hoc marking systems which characterize the current engineering practice.

The formal methods support the identification of errors in the early life cycle phases. The executable models can be tested early in their production. Using a suitable analytical tool we can apply model checking allowing full control of the models. When a qualified code generator generates the code, then the proof of the correctness of the models will remain valid as a correctness proof of code in the scope of the verified properties.

The application of formal methods in the railway interlocking systems development is also prescribed by standards (e.g. EN 50128 or EN 50129). These standards [5, 6] classify these techniques as highly recommended requirements.

3. The Railway Interlocking Principles and the Case Study

Based on constructional structure and the route logics imaging the railway interlocking systems can be classified into two essential groups: geographical and tabular interlocking [7]. In a tabular interlocking system the locking between signals and switches is achieved in form of a locking table that contains all locking conditions for all train routes. Tabular interlocking can be effected by cascade locking or by route-related locking. Cascade locking is not discussed in this article. In a geographical interlocking system the track elements are represented by logical objects connected to each other in form of the track layout.

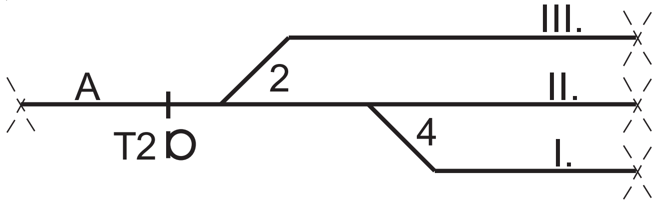

Fig. 1 Case study: the topology

The topology of the case study is shown in Fig. 1. The topology introduces a simple part (start point) of a station whit three tracks (I., II., III.) and one shunt signal (T2). Our goal was to select (artificially construct) a topology which allows to set several train route. This is done with two switches (2, 4). Trains can be traversed from the open line (A) to one of the tracks (I., II., III.) on the station. The open line is marked with A section, which is not part of the models.

The realization of the route-related locking principle is summarized in the Table 1. The first part of the table gives the exclusions between the routes; the second part of the table gives the state of elements (e.g. switches, signals) which are required to lock the route.

Table 1
Case study: Route matrix

	A-I.	A-II.	A-III.	Points	
				2	4
A-I.	–	|	|	+	-
A-II.	|	–	|	+	+
A-III.	|	|	–	-	

Notation:
| : conflicting routes locked by plain locking
|| : conflicting routes locked by special locking
– : main diagonal in route matrix
+ : points locked in normal position
- : points locked in reverse position

Note. We only provided the notation what is necessary for the understanding the case study.

The realization of the geographical principle is summarized in the Fig. 2 and Fig. 3. The case study contains nine objects, one start point, three target points (which are virtual targets), three tracks and two switches (see Fig. 2). Instead of the route-related locking principle the switches do not have predefined end positions. The necessary end position of switches always depends on the current route. The simplified operation of geographical principle is shown in Fig. 3. First we have to choose a Start and a Target point, after that the interlocking system executes the route search between the chosen Start and Target points. If the correct route is selected (designated), then all affected elements perform the relevant operations (e.g. locking). If all of this has been completed successfully (all relevant preconditions are true) then there is no further condition for the setting of the signal and the shunting movement of train (Fig. 3 Occupancy).

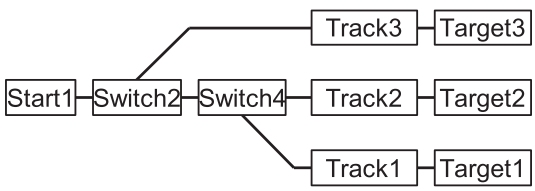

Fig. 2 Case study: The logical object and their connections

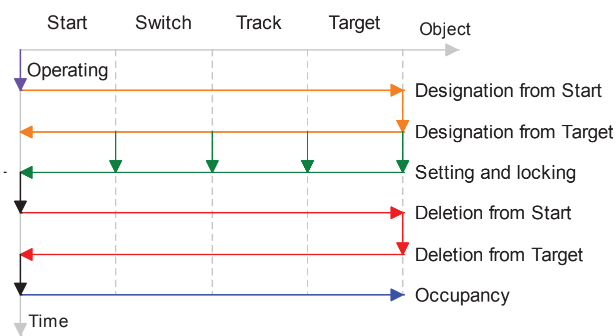

Fig. 3 Case study: The logical objects and their functions depending on time

We provide a simplified notation (see Fig. 4 and Fig. 5) to understand the models. This will be used consistently in the descriptions of the models.

Fig. 4 Case study: The switch notation in the route-related locking principle

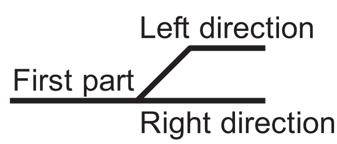

Fig. 5 Case study: The switch notation in the geographical principle

4. Modeling of the railway interlocking principles

In this Chapter we summarize the modeled functions, the constraints and simplifications of modeling. Finally, we briefly describe the basic operation of the models.

4.1. The Modeled Interlocking Functions

The primary purpose of delimiting features was to show all the basic functions in the simplest form in the models. We modeled the selected functions for both railway interlocking principles:

1. route selection/designation;
2. setting and locking of track elements (e.g. switches, tracks);
3. locking of the route;
4. deletion the designation of the locked route;
5. setting the signal clear;
6. movement of a shunting train;
7. unlocking of the route (and the possibility of setting a new route).

Note that this Chapter is also a modeling constraint as well (see Chapter 4.2.).

4.2. Constraints and Limitations of Modeling

Our constraint comes from the specialties of the case study and they are partly our own requirements which are provisions against the complexity. All of these constraints and limitations can be resolved, and the models can be extended with them.

1. We did not use timings because our goal was to model the process. (The PDN and UPPAAL tool support the timings, too.)
2. Only one direction can be set routes: from starting point (Fig. 1 A) to one of three tracks (Fig. 1. I., II. or III.) The models are not handling the opposite direction movements.
3. We only modeled the shunting movements (we did not model the normal train movements). This makes the simplification that we do not have to model the occupancies to the locking of the track elements. We just modeled the occupancy information which is necessary for unlocking (track elements, route).
4. We did not model slip routes because the topology (Fig. 1) does not allow this.
5. We did not model flank protections because the topology (Fig. 1) does not contain the necessary elements.
6. We did not model the function of route storing.
7. We did not model the operating of interlocking (exception is the selection of start and target points).
8. We neglected some checks of real railway interlocking systems which refer to the route closing and locking.
9. We neglected all malfunctions and wrong operations (e.g. false occupancy).
10. We have modeled the movement of short train because of unlocking (taking into account the features of the PDN and UPPAAL tools).

4.3. Modeling the Route-Related Locking Interlocking Principle

In this Chapter we give a short, general description about the modeling of route-related locking principle which is the same for the two tools (PDN and UPPAAL). There is a well defined initial state in the models. The first step is choosing the desired route which is implemented randomly in the models. The following parts of the model check the rules of route matrix (see Table 1) and adjust them. The route matrix can be mapped one in one into a Petri net or automata taking into account some simple rules. The modeling of routes (see Fig. 1 and Table 1) is very similar so we write about them in general. First the models set the switch(es), lock them and lock the tracks, too. Finally the models lock the selected route. Then the T2 shunt signal shows clear aspect and the shunting train movement can be performed. The unlocking of the locked route happens with the help of the dissolving sections. The models must perform the following sequence on the section: clear – occupied – clear. If the sequence is correct the track element and the route will be unlocked. After that it is possible to choose and set a new route.

4.4. Modeling the Geographical Interlocking Principle

In this Chapter we give a short, general description about the modeling of geographical principle which is the same for the two tools (PDN and UPPAAL). In this case the focus is on the connection of the track elements between which communication is involved. The track elements themselves are able to do the interlocking functions (see Chapter 4.1). The first step is choosing the start and target points which process is implemented randomly in the models (see Fig. 3). In the next step a designation link moves all the way from start point to target point and after that from target point to start point (see Fig. 3). If a switch gets the designation from the two directions, it can change its position (when it is needed) and then it can be locked. If a track element gets the designation from the two directions, it can be closed. In the next step a locking link moves all the way from target point to start point (see Fig. 3). If the route is locked the designation is no longer necessary, so it can be deleted. Thereafter the T2 shunt signal shows clear aspect and the shunting train movement can be performed. As the train moves it unlocks all track elements one by one. After all elements are unlocked it is possible to choose and set a new route.

5. Experiences with the Petri nets

During the modeling, we avoided the use of extended Petri nets (e.g. inhibitor edge, test edge etc.) to ensure that the models can be automatically verified. Because of the complexity of the case study we use hierarchical Petri nets to provide a transparency of the models. Further advantage of the hierarchical Petri nets is that we can separately and independently edit the subnets. We use coarse transition to ensure the relationships of the subnets. The coarse transitions are always part of the main net and hide the functionality that we implemented in the subnet.

In the next section we will only describe the switch subnets (only an instance of the switch) because of the large size of the models. We will show and compare the switch subnets using the route-related locking and geographical principles, too.

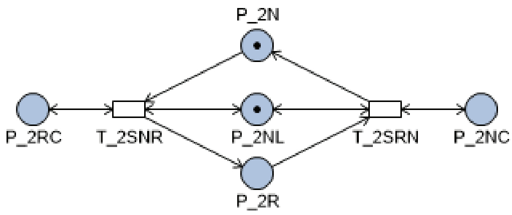

Fig. 6 Case study: The PDN model of the switch (switch subnet, route-related locking principle)

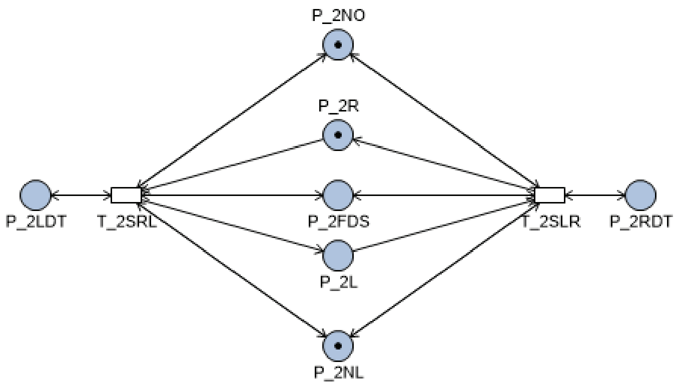

Fig. 7 Case study: The PDN model of the switch (switch subnet, geographical principle)

The initial state of the switch according to route-related locking principle (see Fig. 6) is that it is not locked (token on the P_2NL place) and it is in the normal position (token on the P_2N place). Note that other starting states are also possible, e.g. token on the P_2NL and P_2R places say the switch is in the reverse position. The position of the switch is adjusted by the two transitions (T_2SNR and T_2SRN).

The precondition of T_2SNR (Set from Normal to Reverse position) transition firing are P_2RC (Reverse Command) and P2_NL. If these preconditions are true (there is a token on the P_2RC and P_2NL places) and the switch is in the normal position (a token on the P_2N place) then the switch can change its position.

The precondition of T_2SRN (Set from Reverse to Normal position) transition firing are P_2NC (Normal Command) and P2_NL. If these preconditions are true (there is a token on the P_2NC and P_2NL places) and the switch is in the reverse position (a token on the P_2R place) then the switch can change its position.

Note that we did not model the occupancy of switch.

The initial state of the switch according to geographical principle (see Fig. 7) is that it is not locked (token on the P_2NL place), it is not occupied (token on the P_2NO place) and it is in the right direction (token on the P_2R place). Note that other starting states are also possible, e.g. token on the P_2NL, P_2NO and P_2L places say the switch is in the left direction. The position of the switch is adjusted by the two transitions (T_2SRL and T_2SLR).

The precondition of T_2SRL (Set from Right to Left direction) transition firing are P_2LDT (the Left direction is Designated from Target), P_2FDS (the First part of switch is Designated from Start), P2_NL and P_2NO. If these preconditions are true (there is a token on the P_2LDT, P_2FDS, P_2NL and P_2NO places) and the switch is in the right direction (a token on the P_2R place) then the switch can change its position.

The precondition of T_2SLR (Set from Left to Right position) transition firing are P_2RDT (the Right direction is Designated from Target), P_2FDS (the First part of switch is Designated from Start), P2_NL and P_2NO. If these preconditions are true (there is a token on the P_2RDT, P_2FDS, P_2NL and P_2NO places) and the switch is in the left direction (a token on the P_2L place) then the switch can change its position.

Note that there may be such a case that the switch is not need setting but also can be locked immediately.

6. Experiences with the UPPAAL Specific Finite Nondeterministic Automata

The UPPAAL specific finite nondeterministic automata (in the following FNA) are composed from states and state transitions. The state transitions may be the actions by the system (internal events) or external events from the environment. In the simplest case the modeling of the FNA consists of modeling of the states (circles) and states transitions (directed edges), which makes the model easy to read. During the modeling, we avoided the use of simple FNAs (e.g. we did not use parameterized FNAs).

With one FNA you can model only one system element or process. To describe the entire system we have to model the links between the elements. The communication between the FNAs can be done in several ways. The most basic communication form is the synchronization which is based on the principle of handshake.

In the next section we will only describe the function of the switch (the setting of the switch) because of the large size of the models. We will show and compare the switch FNAs using the route-related locking and geographical principles, too. The notation is similar as in Chapter 5.

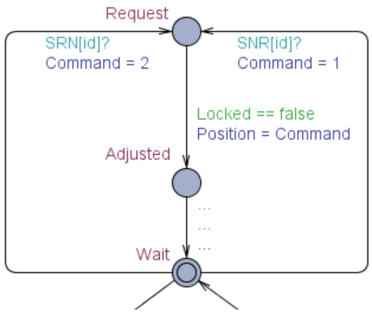

Fig. 8 Case study: The UPPAAL model of the switch (switch FNA, route-related locking principle)

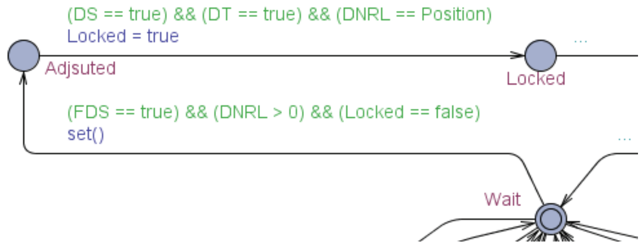

Fig. 9 Case study: The UPPAAL model of the switch (switch FNA, geographical principle)

The setting of the switch according to route-related locking principle starts from a Wait state which is an initial state (see Fig. 8). The initial state is represented by a double circle in the UPPAAL. This FNA is in the waiting state as long as one of the two synchronization (SRN[id]? or SNR[id]?) will not apply. If the SRN[id]? synchronization is applies then the value of the Command variable is update (Command = 2) which means (see Fig. 10) that the switch must be set in a straight position. Note that the SNR[id]? synchronization works same.

```
bool Locked = false;    // locked state of switch (false: not locked, true: locked)
int Route = 0;          // route in which the switch is locked
int [0,2] Command = 0;  // command of setting (0: No command 1: Reverse command, 2: Normal Command)
int [1,2] Position = 2; // position of the switch (1: Reverse, 2: Normal)
```

Fig. 10 Case study: Definition of the variables (switch FNA, route-related locking principle)

If the FNA is in the Request state and the precondition (the guard) is fulfilled (Locked == false) the position of the switch is updated according to the given Command (Position = Command). After that the switch is set to the Adjusted state. Note that on the Fig. 8 we did not detailed the closing and locking of the switch.

The setting of the switch according to geographical principle starts from a Wait state (see Fig. 9). If the guard ((FDS == true) && (DNRL > 0) && Locked == false) becomes true then the set() function does the setting of switch (see Fig. 11 to understand the abbreviations and the set() function). After that the switch is set to the Adjusted state. Note that we can see the locking process of the switch on the Fig. 9, too.

```
bool DS = false;        // Designated from Start (true: designated, false: not designated)
bool DT = false;        // Designated from Target (true: designated, false: not designated)
bool Locked = false;    // switch is Locked (true: locked, false: not locked)
bool Occupied = false;  // switch is Occupied (true: occupied, false: not occupied)
bool FDS = false;       // First part of switch is Designated form Start (true: designated, false: not designated)
int [0,2] DNRL = 0;     // one direction is Designated from target (0: Not designated, 1: Left, 2: Right)
int [1,2] Position = 2; // Position of switch (1: Left, 2: Right)

void set()              // setting the switch
{
  if ((Occupied == false) && (Closed == false) && (FDS == true) && (DNRL > 0)) Position = DNRL;
}
```

Fig. 11 Case study: Definition of the variables and functions (switch FNA, geographical principle)

7. A Summary of the Experiences

The Petri net and the finite nondeterministic automata are suitable for modeling railway interlocking systems. Utilizing their extensions we can make even more robust models, but these models cannot be automatically analyzed for all the tools.

The tool selected for the modeling of Petri nets (PDN) and FNAs (UPPAAL) is suitable for modeling and simulation operation of the route-related locking and geographical principles. The modeling of the geographical principle for both tools was much more complicated and resource intensive than the modeling of route-related locking principle.

We have experienced both advantages and disadvantages with the tools (PDN and UPPAAL). Without the necessity of completeness, we list some examples:

Advantages:

- Both tools are the same in the aspect of learnability, interpretability, utility.
- Built-in model checker and easy-use editing interface is available for both tools alike.
- etc.

Disadvantages:

- Help is not available in the used version of the PDN tool which makes it more difficult to answer the issues that came up during the editing of the models.
- etc.

In this paragraph we briefly summarize our experiences with the modeling of the interlocking principles. In the geographical models all information is at the track elements. The track elements communicate with their neighbors and transfer the locally stored information. In contrast, the route-related locking models have a central logic which can verify the status of each track elements and give commands to the track elements to change their status.

Our models and their detailed presentation can be downloading from [8].

8. Conclusions

The challenges of the modeling in the practical life are usually very large, difficult and various. To solve these problems, it is essential to choose the corresponding tool or tools. During the work we started to collect and categorize those aspects which can be affected the outcome of the selecting tools. We give a not complete shortlist about the aspects without the category and weight: built-in model checker, manageability of the editing interface, simulations skills, etc. This area may be the subject of further research.

Another aspect of the problem in the previous paragraph is a design question: Is it possible to decompose the system and model? How can we decompose the system and models? The large systems are confusing for the people, but the formal methods – i.e. modeling and model checking – support the understanding of the system, the clarification of the specification and the creation of a proper decomposition.

The modeling that we discussed in this article will allow covering additional research areas. It is possible to analyze explicit properties of the Petri nets (e.g. boundedness, deadlock freedom, reversibility, pureness) or model checking is available for both tools (PDN and UPPAAL) so we are able to verify the fulfillment of the functional and safety requirements on the models.

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Driver's Strategy and Braking Distance in Winter

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Abstract
During winter time there is a likelihood of compacted snow on the surface of the road. In such road conditions the essential part of safety is the possibility of stopping a vehicle within the shortest possible distance. The factors influencing the ability, intensity of braking process are as follows: kind of tyres, surface condition and driver's behavior. Using winter tyres and driving the vehicle at set environmental and road conditions the driver's behavior is the main factor of vehicle safety. Braking process strategy that the driver chooses contributes to a shorter or longer braking distance. This article presents experimental research results with the use of winter tyres with and without anti-skid chains in reference to choice of strategy in the braking process
KEY WORDS: *tyre, road, braking process, slalom, coefficient of friction, snow*

1. Introduction

Experimental research of tyre traction to snow-covered surface were conducted by many authors, [1, 4, 6-8]. These analyses more and more often pay attention to environmental factors influencing the conditions of tyre – surface interaction [2, 3, 9-10]. These features, tyre and road surface properties are given additionally which leads to a more precise ranges of obtained decelerations and accelerations. The exemplary values of braking decelerations for certain surfaces in winter conditions are given in Table 1 (values in brackets refer to temperature values that lineary influence braking intensity.

Table 1

Summary of the deceleration according to [3]

Description	Deceleration, m/s^2
Ice not destroyed by chains or spikes that looked like glass	0.53-1.86 (t_0-t_{-25})
Thick layer of black ice, not destroyed by blocked tyres, sliding hard to notice by an average driver	1.18-2.55 (t_{-5}-t_{-40})
A thin layer of black ice, partially destroyed by blocked slipping tyres, hard to notice by an average driver	1.67-4.81 (t_{-3}-t_{-30})
A continuous layer of snow compacted to form an icy surface	1.18-3.83
Packed snow and ice covered with a layer of fresh snow and frozen fog 3-100 mm thick, not ridden by vehicles	1.77-4.41 (t_{-10}-t_{-40})
Packed snow and ice covered with a layer of old, rough, crusty snow with thickness of 100-200 mm, not ridden by vehicles	4.22-4.41 (t_{-15}-t_{-40})
The snow which fell directly into the street, compacted by vehicles, but not forming a dense layer of snow and ice	2.35-3.63 (low temperature effect)
The snow which fell directly into the street, not affected by vehicles	1.47-4.12 (t_0-t_{-10})

Many articles, especially the ones concerning road safety, do not fully present data about the influence of driver's strategy on the vehicle's total braking distance. In case of rectilinear movement apart from using the ABS system it is also possible to use the hand brake, which in case of a snow-covered surface may enhance the braking process. When the vehicle moves in a winding course it seems possible to shorten the braking distance compared to rectilinear movement. In order to verify the above mentioned driver's behavior strategies it was necessary to perform road test to determine the braking distance. The additional assumption was the driver's willingness to stop the vehicle in front of theoretical obstacle.

This article shows the results of experimental research of the influence of driver's behavior strategies on the length of braking distance.

2. Methodology and Course of Investigations

The aim of the research was to determine a mean fully developed deceleration (MFDD) of test vehicles on the road surface covered with compacted snow. The vehicles were equipped in winter tyres and the test were performed with and without the use of anti-skid chains. During the road test braking was performed in the following ways: driving straight with the use of ABS system, driving straight with the use of ABS system and hand brake, only hand brake and driving in a slalom way. Due to safety matters tests with switched off ABS system were not performed.

The vehicles were equipped with measuring system Analog Devices ADIS 16385, that consisted of triaxial gyroscope and triaxial acceleration meter. Also portable computer was used with sensor software to obtain and store results. The measurement inaccuracy for the measurement equipment was 2%.

The test was to accelerate the vehicle dynamically to a given speed (about 50 km/h) and brake it intensively until the car is stopped. During the tests the environmental conditions were measured as well (Fig. 1).

Fig. 1 View of the road surface during the test

The study was conducted during the ongoing snowfall, on a surface covered with a thick, uniform snow layer, which was previously compacted as a result of traffic. was -3.0 °C. Geometric characteristics of the surface were determined using geodetic instrument – TPS. Results of geodetic measurements are shown in Fig. 2.

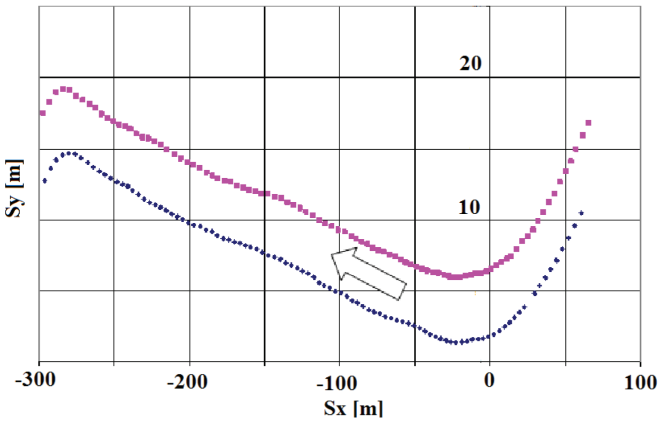

Fig. 2 Viewpoints that lie on the edges of the test section in plain view, whose coordinates were measured using TPS, the arrow shows the direction of movement of the car at the time of experiments [2]

During the experiments the car was moving slightly uphill. On the basis of the shape of vertical alignment and equation of its linear approximation, it can be concluded that the angle of inclination of the surface on the entire segment length was virtually constant, and the average value was about 1.45° (or about 2.53%), as calculated (1)

$$\left.\begin{aligned} &\alpha = a\ tan\left(0,0253\right) \cong 1,45^{o};\\ &y_{x=0} = 0,0253 \cdot 0 - 7,3892 \cong -7,39;\\ &y_{x=356} = 0,0253 \cdot 356 - 7,3892 \cong 1,62;\\ &\frac{y_{x=356} - y_{x=0}}{356} \cdot 100 \cong 2,53\%. \end{aligned}\right\} \tag{1}$$

Acceleration values obtained in the tests were adjusted by the designated angle of the test section, based on formula (2).

$$a_{kor\_\alpha} = a_{pom} \cdot cos\,\alpha + g \cdot sin\,\alpha\ , \tag{2}$$

where a_{pom} – measured acceleration value; g = 9,81 [m/s^2] – gravitational acceleration.

3. Vehicles Characteristics

Two vehicles were used for the road tests. The first one was Skoda Octavia II Tour with front Wheel drive , equipped with tyres sized 195/65 R15. The second vehicle was also Skoda Octavia with four Wheel drive 4 × 4 and tyres 205/55 R16. Both test vehicles are presented in Fig. 3.

Fig. 3 Skoda Octavia II Tour [left] and Skoda Octavia 4 × 4 with test equipment [right]

4. Characteristics of Environment

Road tests were done on the section of the Sudeten road near Borowice (Poland). The results of environment investigations are presented in Table 2.

Table 2

The measurement results of the environmental conditions before and after drive trials

	Skoda Octavia II Tour		Skoda Octavia 4 × 4	
	before	after	before	after
Ambient temperature	-2,6°C	-3,4°C	-3,2°C	-3,4°C
Humidity	90,7%	95,6%	82,4%	84,6%
Atmospheric pressure	934 hPa	934,2 hPa	946,3 hPa	946,0 hPa
Temperature of saturation point	-3,9°C	-3,6°C	-5,4°C	-5,6°C
Temperature of road surface	-4,6°C	-3,6°C	-6,8°C	-5,4°C

5. Measurement Results and Kinematic Analysis of Vehicle Motion

The measurement results of acceleration intensity and braking process for different driver's behavior strategies are shown in Tables 3- 5. Data in brackets show the value of standard deviation for single measurement for the obtained results. Examples of longitudinal accelerations are presented in Fig. 4.

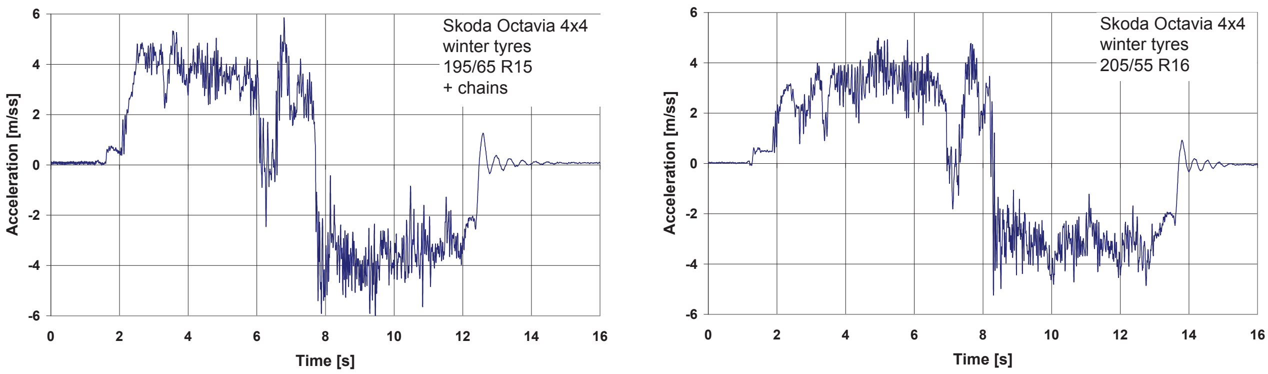

Fig. 4 Examples of longitudinal accelerations

Table 3

Test results for Skoda Octavia II Tour equipped with winter tyres 195/65 R15

Braking	Acceleration [m/s^2]		MFDD [m/s^2]	Starting speed of braking process, V [km/h]	Braking distance s [m]
	I gear	II gear			
Without anti-skid chains	1,141 (0,156)	1,081 (0,170)	-2,939 (0,118)	51,573 (3,250)	42,546 (3,421)
With chains	1,892 (0,169)	1,629 (0,267)	-2,850 (0,185)	55,964 (2,008)	37,314 (1,927)
chains + hand brake	1,933 (0,054)	1,449 (0,068)	-3,200 (0,337)	55,286 (1,101)	32,829 (1,245)
With chains Only hand brake	1,787 (0,013)	1,268 (0,140)	-1,416 (0,068)	55,249 (2,698)	67,221 (7,137)

Table 4

Test results for Skoda 4 × 4 equipped with winter tyres 195/65 R15

Braking	Acceleration [m/s²]		MFDD [m/s²]	Starting speed of braking process V [km/h]	Braking distance s [m]
	I gear	II gear			
Without anti-skid chains	3,191 (0,186)	2,926 (0,105)	-3,208 (0,186)	58,208 (2,046)	37,160 (2,787)
Without anti-skid chains /slalom	3,545 (0,023)	2,816 (0,105)	-2,186 (0,181)	59,315 (1,601)	55,826 (6,473)
With chains	3,645 (0,105)	3,109 (0,100)	-3,294 (0,136)	62,245 (0,965)	33,328 (1,749)
With chains + hand brake	3,580 (0,117)	2,960 (0,114)	-3,678 (0,117)	60,665 (0,043)	33,030 (1,482)
With chains slalom	3,676 (0,187)	3,136 (0,033)	-2,404 (0,281)	63,826 (1,250)	46,781 (1,039)

Table 5

Test results for Skoda 4 × 4 equipped with winter tyres 205/55 R16

Braking	Acceleration [m/s²]		MFDD [m/s²]	Starting speed of braking process V [km/h]	Braking distance s [m]
	I gear	II gear			
Without anti-skid chains	3,262 (0,265)	2,991 (0,123)	-3,294 (0,120)	61,040 (3,398)	34.717 (2,033)
Without anti-skid chains slalom	3,393 (0,426)	3,024 (0,097)	-2,517 (0,172)	63,498 (2,248)	42,487 (1,728)
Without chains Only hand brake	3,029 (0,054)	2,955 (0,088)	-1,337 (0,018)	63,871 (0,718)	57,634 (12,699)
With chains	3,524 (0,049)	2,581 (0,089)	-3,684 (0,251)	59,128 (1,497)	34,836 (4,636)

6. Test Results Analysis

The results of experimental research show in Tables 3-5 concerning the intensity of braking process for a passenger vehicle are presented in a form of a diagram in Fig. 5.

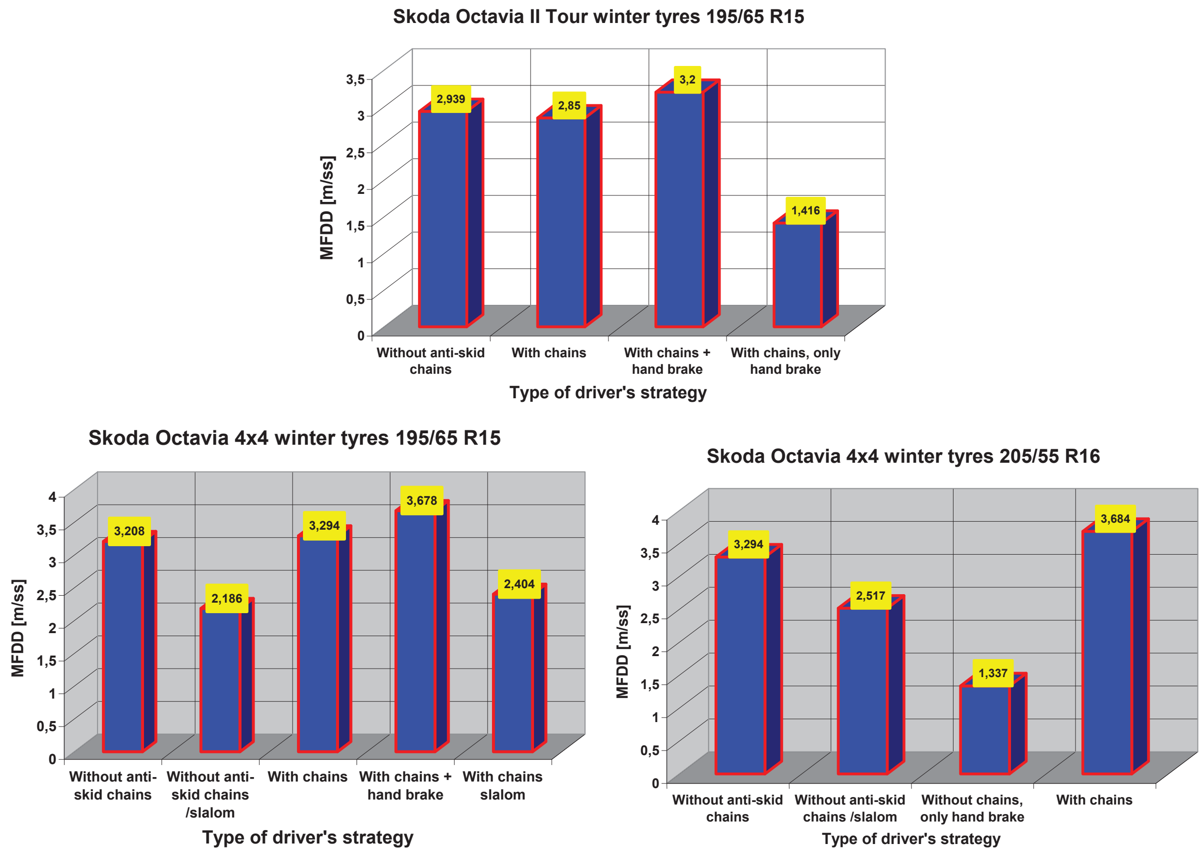

Fig. 5 The comparison of values of mean fully developed deceleration MFDD for different driver's behavior strategies

The obtained values of MFDD for a vehicle equipped with winter tyres and with or without anti-skid chains are similar. The observed differences in one case are about 10% whereas in other cases do not exceed 4%. The substantial rise in deceleration values, over 11,5% was obtained during intensive braking with the use of hand brake. The use of hand brake only allows to obtain decelerations under 1,5m/s^2.

Using ABS system and simultaneously changing the direction of movement (slalom) as a driver's behavior strategy seems to be the most optimal. However, the obtained results give evidence that the capability of tyre to transfer forces onto road surface decreases and the coefficient of traction is not fully used. In all the cases the of the vehicle motion, winding course - slalom, the obtained value of MFDD was significantly lower than in case of moving straight and in the weakest observed point was 68% compared to rectilinear movement.

7. Conclusions

Measurement results for acceleration and braking process for test without anti-skid chains show in Tables 3 – 5 have similar values for longitudinal accelerations both for tyre sizes 195/65 R15 and 205/55 R16. It may suggest that the test vehicles, regardless of tyre size, represent similar capability of force and torque distribution onto snow-covered surface. The obtained longitudinal accelerations for measurement tests with the use of anti-skid chains have higher values of mean fully developed deceleration (MFDD) when compared to tests without chains. Similar differences in results may be observed in the average acceleration values obtained in the first gear. The use of anti-skid chains significantly increases wheel traction on a snow-covered surface. The difference between the values of deceleration while braking was noticeable. Using the hand brake in order to assist braking process resulted in higher deceleration values than when not used. It was caused by blocking the vehicle wheels and by tearing away snow layer generating higher friction.

Moving in a winding course – slalom, despite covering a longer distance by a vehicle, does not provide satisfying results. In case of a way measured as rectilinear distance it is significantly longer than braking in a straight line. The choice of driver's behavior strategy determines the range of possibly obtained safety in a given road conditions, and the obtained MFDD values give evidence, that the best braking strategy when moving along rectilinear distance is braking straight with a simultaneous use of hand brake.

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The Change of Driving Self-Efficacy during and after Driving Training: Relations to Driving Behaviour

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Abstract

Researchers agree that driving self-efficacy might be one of the most important factors that contribute to high crash rates among novice drivers. Thus this paper aims to evaluate the change of driving self-efficacy during driving training and independent driving and to investigate its relation to later driving behaviour in the group of novice drivers. 173 learner drivers (39.3 percent males; age M = 20.75, SD = 5.9111; all licensed to drive vehicle) participated in the longitudinal study. Driving self-efficacy was measured three times using Adelaide Driving Self-Efficacy Scale: the first assessment was made on the first or second day of driving training; the second assessment took place after training course and just before taking driving exam; and the third assessment was made by telephone in one year after completing driving training. Additionally, questions about driving behaviour and outcomes were asked during the third assessment. Study results revealed that driving self-efficacy of novice drivers increased during driving training and independent driving, even regardless their initial level of self-confidence in own driving. Novice drivers with different profiles of driving self-efficacy did not differ according negative outcomes of driving. Still, females with low driving self-efficacy reported rarer independent driving and rarer passing the driving exam from the first time.
KEY WORDS: *driving self-efficacy, passing the driving exam, driving consequences, learner drivers, novice drivers*

1. Introduction

Traffic accidents are serious health issue of novice drivers [20, 21]. According to statistics, novice drivers were at fault of approx. 44 percent of all traffic accidents in Lithuania during past five years [19,]. Such vulnerability of novice drivers might be related to insufficient driving experience and poor driving skills [10, 17], still this explanation is insufficient. Different psychological characteristics, such as personality traits, attitudes towards risk, motives to drive in risky manner, peer influence, or emotions have been identified as correlates of risky driving in young adulthood [3, 12, 15]. Also some researchers reported the extreme importance of driving self-efficacy in traffic casualties among novice drivers [16, 18]. However, the research on driving self-efficacy in the group of novice drivers and especially driver learners is scarce. Thus, this paper aims (1) to evaluate the change of driving self-efficacy during driving training and independent driving and (2) to investigate its relation to later driving behaviour of novice drivers.

Driving self-efficacy could be defined as confidence in one's own driving skills and expectations about the level of his / her ability to successfully drive [1, 2, 4, 9, 11]. These beliefs about one's own competency mediate the relation among social experience, individual way of thinking, and actual behaviour [2]. According to Reeve, self-efficacy beliefs arise mainly from "one's personal experience in trying to execute the particular behaviour in the past and from vicarious experience of observing others performing the same behaviour" [8, p. 235]. Therefore, we hypothesize that driving self-efficacy should consistently increase during driving training and later independent driving.

Many studies reported that novice drivers tend to overestimate their driving skills and this tendency has been viewed as a factor, related to risky driving and high accident involvement [9, 11, 13, 14]. But Victoir and colleagues indicated that novice drivers with high self-efficacy performed better and were more motivated to develop safe driving skills [16]. On the other hand, low driving self-efficacy may hinder the development of driving skills of novice drivers [1, 4] and increase the probability of failures while driving which lead to higher vulnerability too. However, summarizing these contradictions we assume that novice drivers with higher driving self-efficacy would report more negative outcomes of their driving as they engage in risky driving and drive more frequently (thus, have more possibilities to experience any accident or other event on the road).

2. Method

Participants and research procedure. 173 learner drivers (68 males, 111 females) participated in the longitudinal study. For the first assessment participants were approached on the first or second day of their driving training in driving schools and filled in self-report questionnaires. Their age ranged from 17 to 53 years (M = 20.75, SD = 5.9; no difference between males and females: Mann-Whitney Z = -1.857, p = .063). Even though all participants started their driver licensing training for B category (the first licence to drive a vehicle), 66.9 percent of participants reported having prior experience of driving. More males compared to females reported having experience of independent driving without supervision of any instructor or other driver (respectively 37.7 percent of males and 13.9 percent of females; $\chi^2 = 18.707$, p = .001). All participants signed the informed consent at this stage of the study and were introduced with the explanation for the necessity of non-anonymous data collection.

In one or two months (after training course and just before taking driving exam) the second assessment using the same self-report questionnaires was carried out. And for the last assessment all participants were telephoned in one year after completing their driving training. All participants reported already being licenced to drive a vehicle at this stage of the study: 78 percent reported passing the theoretical driving exam and 48.6 percent passing the practical driving exam from the first time.

Instruments. Driving self-efficacy at each stage of the study was measured using Adelaide Driving Self-Efficacy Scale (ADSES) [4]. The scale consists of 12 items which were translated to Lithuanian language using back – forward translation procedure. Participants were asked to rate their confidence levels about different driving situations on the scale from 1 (no confidence) to 10 (full confidence). Previous studies have reported that ADSES is a reliable and valid measure of driving self-efficacy [4, 11]. The internal consistency of the scale in this study was also high (the first assessment Cronbach alpha = .89; the second assessment Cronbach alpha =.93; the third assessment Cronbach alpha = .92). Higher score of the scale indicated higher confidence in own driving skills.

All participants were asked socio-demographics as well as questions about their prior driving experience and driving frequency at each stage of assessment. Additionally, at the third stage novice drivers were asked how many times they had been passing the driving exam until were licenced and how many negative outcomes while independent driving (accidents and fines for violations of any traffic rules) they had already experienced.

3. Results and Discussion

First of all, the differences in driving self-efficacy among learner drivers and pathways of its change during driving training courses and independent driving were analysed. Result analysis revealed that men scored higher on driving self-efficacy compared to women at each stage of the study (Mann Whitney $Z_{1assessment} = -4.38$, $p < .001$; Mann Whitney $Z_{2assessment} = -3.62$, $p < .001$; Mann Whitney $Z_{3assessment} = -3.49$, $p < .001$). Therefore two step cluster analysis using all three scores of driving self-efficacy were conducted separately in male and female groups. The analysis resulted in 2 cluster solution for male participants and 3 cluster solution for female participants (see Fig. 1). Even though drivers tend to overestimate their driving skills and usually report high scores of ADSES [9, 11], learner drivers both males and females could be described by high driving self-efficacy profile or moderate driving self-efficacy profile, and low driving self-efficacy profile was found only in female group. The differences between means of driving self-efficacy scores at all three assessments were significant among all three clusters (p < .05). Meanwhile only one difference between male and female driving self-efficacy scores in the same cluster was found: in the group of high driving self-efficacy males scored higher compared to females (Mann Whitney Z = -2.23, p = .026).

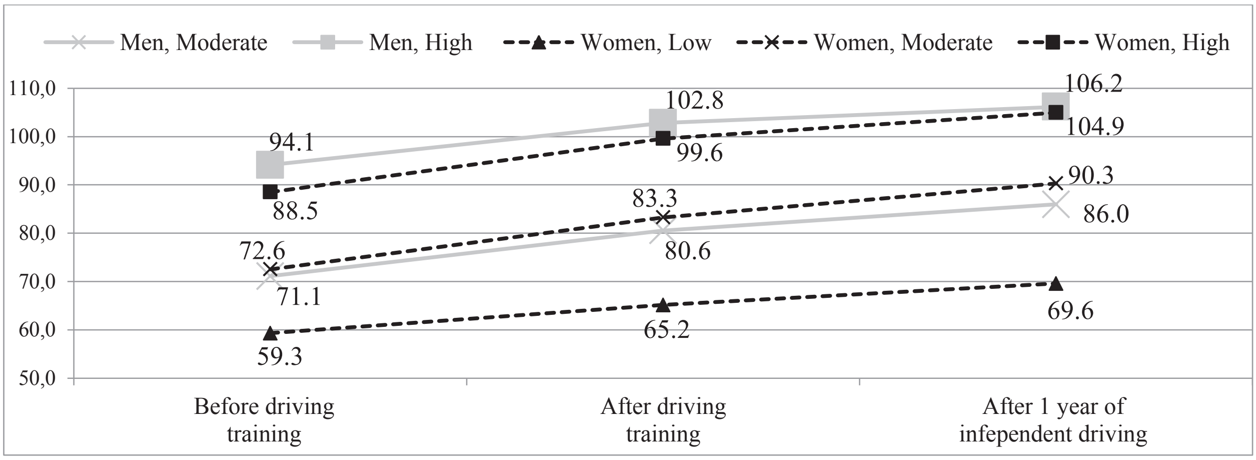

Fig. 1 Profiles of driving self-efficacy and its change during driving training and independent driving in learner drivers

Further analysis revealed that 66.1 percent (N = 41) of male and 34.3 percent (N = 38) of female learner drivers could be characterized as having high driving self-efficacy profile, 33.9 percent (N = 21) men and 47.7 percent women reported moderate driving self-efficacy before and after training or independent driving, and 18 percent (N = 20) of female participants scored pretty low on driving self-efficacy at all three stages of the study. Furthermore, more males than females could be characterized as having high driving self-efficacy profile, and more women tend to belong to the groups of participants with moderate or low driving self-efficacy ($\chi^2 = 21.824$, $p < .001$). These results are in line with previous research and support the idea that males are more confident in their driving especially at early stages of driving [5, 6]. However we don't know whether males tended to overestimate their driving self-efficacy and females were more accurate about their driving [5, 6] or men were actually more skilled drivers as they reported more independent or supervised driving prior official driving training.

Also, the comparison of driving self-efficacy at different stages of the study was made. It was found that driving self-efficacy of all study participants increased between 1st and 3rd assessment ($p < .05$). Thus, the results confirmed the underlying assumption that experience of driving help to increase the confidence in one's driving skills and strengthen feeling of competency. However, driving training courses were effective only for those learner drivers who reported high either moderate confidence in their driving skills at the beginning of their training (both males (Mann Whitney $Z_{HighProfile} = -3.79$, $p < .001$; Mann Whitney $Z_{ModerateProfile} = -2.00$, $p = .046$) and females (Mann Whitney $Z_{HighProfile} = -4.54$, $p < .001$; Mann Whitney $Z_{ModerateProfile} = -4.26$, $p < .001$)). During period of independent driving (between 2nd and 3rd assessments) self-efficacy increased only in the group of high driving self-efficacy novice drivers (males: Mann Whitney $Z_{HighProfile} = -2.09$, $p = .037$; females: Mann Whitney $Z_{HighProfile} = -2.93$, $p = .003$) and for the females with moderate driving self-efficacy profile (Mann Whitney $Z_{ModerateProfile} = -3.16$, $p = .002$).

Study participants with different pathways of driving self-efficacy change were compared according their success in driving exam and experience of independent driving after being licenced. It has to be noted that 78 percent of learner drivers passed the theoretical driving exam from the first time, while success of passing the practical driving exam from the first time reported only 48.6 percent of participants. There was no difference between men and women found (theoretical exam: $\chi^2 = 1.006$, $p = .345$; practical exam: $\chi^2 = .844$, $p = .428$). Very similar results were obtained when comparing the success in driving exam according driving self-efficacy profile of study participants: the majority of males and females with high or moderate profile successfully passed the theoretical exam from the first time and approximately half of them experienced the same success in practical driving exam. But significantly more women with low driving self-efficacy profile reported being licenced only after the second or more attempts to pass the practical driving exam (see Table). Even though all study participants finally were licenced to drive a vehicle, these results confirm that low confidence in own competence to drive reduces likelihood of successful driving [9, 16] and these learner drivers need more time and perhaps more practice for the development of sufficient driving skills.

Table

Driving behaviour differences among novice drivers with different driving self-efficacy profiles

Variable		**Driving self-efficacy profile**			χ^2	**p**
		High	**Moderate**	**Low**		
Males						
Theoretical exam passing	passed from the 1st time	33 (80.5%)	18 (85.7%)	–	.026	.610
	passed from the 2nd time or more	8 (19.5%)	3 (14.3%)			
Practical driving exam passing	passed from the 1st time	23 (56.1%)	10 (47.6%)		.101	.527
	passed from the 2nd time or more	18 (43.9%)	11 (52.4%)			
Driving frequency	often	35 (85.5%)	15 (71.4%)		1.728	.308
	rare	6 (14.6%)	6 (28.6%)			
Negative outcomes while driving	no outcome	31 (75.6%)	15 (71.4%)		.127	.765
	at least 1 negative outcome	10 (24.4%)	6 (28.6%)			
Females						
Theoretical exam passing	passed from the 1st time	28 (73.7%)	40 (75.5%)	16 (80%)	.286	.867
	passed from the 2nd time or more	10 (26.3%)	13 (24.5%)	4 (20%)		
Practical driving exam passing	passed from the 1st time	20 (52.6%)	27 (50.9%)	4 (20%)	**6.638**	**.036**
	passed from the 2nd time or more	18 (47.4%)	26 (49.1%)	16 (80%)		
Driving frequency	often	33 (86.8%)	44 (83.0%)	5 (26.3%)	**28.32**	**< .001**
	rare	5 (13.2%)	9 (17.0%)	14 (73.7%)		
Negative outcomes while driving	no outcome	30 (78.9%)	43 (82.7%)	16 (80%)	.212	.899
	at least 1 negative outcome	8 (21.1%)	9 (17.3%)	4 (20%)		

Also the majority of women with low driving self-efficacy profile reported rare driving after being licenced, while significantly more males and females with high or moderate driving self-efficacy profile drove a vehicle pretty often – at least once a week (see Table). Thus, it might be that low self-efficacy is related not only to poorer actual driving skills, but also to higher fear of driving or other factors and that's why people with low sell-efficacy do not engage in driving even after they are licenced and thereby do not develop their driving skills nor confidence in own driving [8, 16].

Finally, all study participants were divided into two groups according their experience of negative outcomes while independent driving. 78.5 percent of novice drivers ($N = 135$) reported no involvement in any kind of car crash and never were fined while driving. The other 21.5 percent experienced at least one negative outcome while independent driving: 31 participants were involved into at least one car crash and 6 participants were fined by police (no gender differences were observed; $\chi^2 = 1.059$, $p = .337$). Contrary to expectations novice drivers with different profiles of driving self-efficacy did not differ according accident or traffic rules' violation involvement (see Table). Of course, the period of independent driving for study participants (approx. one year) might be too short in order to reveal the real driving style of novice drivers that leads to higher involvement in any negative events on the road. On the other hand, such result may confirm previous findings that novice drivers are relatively accurate in assessing their own driving skills [7] and because of such realistic view to the demands of traffic do not risk too much. Also self-report bias of social desirability or self-selection bias may be the limitations of this study that did not allow establishing significant results.

4. Conclusions

Study results showed that people with different levels of self-confidence about their driving enter driving training and the experience of successes and failures during driving practice help to increase driving self-efficacy of novice drivers, even regardless of their initial skill level. Still, novice drivers with low self-efficacy limit their practice of independent driving and do not develop their skills further. Thus, interventions targeting mastery experiences of novice drivers could motivate them for safer driving behaviour [17].

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Modeling and Prediction of Air Quality in Vehicles and Impact on Driver´s Fatigue

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Abstract

This paper deals with a mathematical model that assesses the impact of CO_2 in the cab of vehicle and the influence of variables in relation to the occupants in vehicle. These parameters are then verified by using modelling in Matlab. The aim of paper is to verify the mathematical model and an evaluation of dependence of individual parameters used in the mathematical model.
KEY WORDS:*microclimate of vehicles, CO_2 concentration, mathematical model, variables, modelling*

1. Introduction

The crew in the vehicle is under the constant influence of the external and internal environment. In this article, we describe possible internal environmental influences that may have an impact on crew and driver fatigue. Significant parameters are intake of air into the vehicle cabin, exhaled air from the crew and the driver, and, in the case of combat vehicles, harmful exhaust fumes.

In the Table 1 of effects of CO_2 on the human organism, it is possible to monitor the human values of the boundary values. It is clear from the table that CO_2 has a significant effect on human organisms at a higher concentration.

Table 1

Effects of carbon dioxide on human organism [6]

Values	Effects of carbon dioxide on human organism
approx. 350 ppm	Level of outdoor environment
do 1000 ppm	The recommended indoor CO_2 level
1200-1500 ppm	The recommended maximum level ofCO_2 in indoor areas
1000-2000 ppm	Possible headaches occur
2000-5000 ppm	Possible headaches occur
5000 ppm	Maximum safe concentration without health risks
> 5000 ppm	Nausea and increased heartbeat
> 15000 ppm	Breathing problems
> 40000 ppm	A possible loss of consciousness

2. Model for the Carbon Dioxide Content

The unsteady state process of the change in the carbon dioxide (CO_2) content inside the examined system is determined by the change in molar amount$n$ of CO_2. The molar balance of CO_2 in the control volume can be expressed in the differential rate form with respect to a time-lag dτ as the summation for influence of all the inlets, sources, and exits by:

$$\left(\frac{dn}{d\tau}\right)_{CO_2} = \sum_j \left(\frac{dn_j}{d\tau}\right)_{CO_2} . \quad (1)$$

According to the Avogadro's law stating that the equal volumes of ideal gases, at the same temperature and pressure, contain the same number of molecules and the Amagat's law of partial volumes [1], the number of moles can be substituted by the product of the CO_2 molar fraction x and the volume V of a gas mixture. Applying this principle on the system of a vehicle cabin, the schematic of which is shown in Fig. 1, we can obtain:

$$\frac{d(Vx)}{d\tau}=\frac{dV_{\mathrm{vent}}}{d\tau}x_{air}+\frac{dV_{breath}}{d\tau}x_{breath}+\frac{dV_{\mathrm{comb}}}{d\tau}x_{\mathrm{comb}}-\frac{dV_{out}}{d\tau}x\,, \tag{2}$$

where the inlet volumetric flow rates ($dV_j/d\tau=\dot{V}_j$) have the positive sign and the outgoing flow rate is negative.

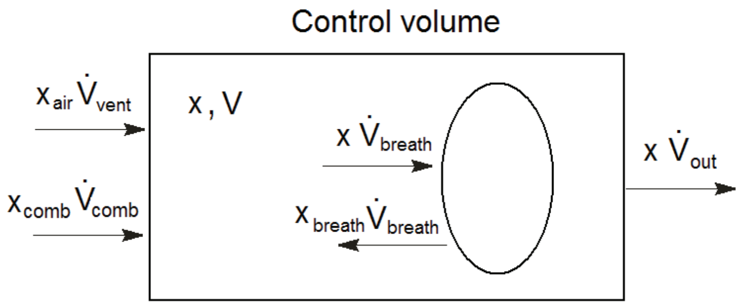

Fig. 1 Schematic of a vehicle cabin system

If the pressure within the vehicle cabin is constant, the mass balance of the control volume (Fig. 1) can be expressed by volumetric flow rates of all inlets and exits as

$$\sum_j \frac{dV_j}{d\tau}=0\,. \tag{3}$$

For the incoming air by ventilation, products of combustion due to guns' fire, and outgoing air from vehicle cabin, ityields

$$\dot{V}_{vent}+\dot{V}_{comb}-\dot{V}_{out}=0\,. \tag{4}$$

The terms appearing in the above equations are as follows: $\dot{V}_{vent}$ is the volumetric flow rate of incoming air by ventilation; $\dot{V}_{comb}$ is the volumetric flow rate of products of combustion due to guns' fire; $\dot{V}_{out}$ is the volumetric flow rate of outgoing air from vehicle cabin; $\dot{V}_{breath}=i\,f\,V_t$ is the respiratory volumetric flow rate as the product of the number of persons in a vehicle cabin *I*, the respiratory rate per time unit *f*, and the tidal volume V_t; x_{air}, x_{comb}, x_{breath} and x are the – in ambient air, in products of combustion due to guns' fire, in exhaled air, and in vehicle cabin air.

If the net volume of vehicle cabin *V* is constant, the change in the volumetric fraction$x$ of CO_2 in the vehicle cabin can be obtained from Eqs. (2) and (4)as

$$\frac{dx}{d\tau}=\frac{x_{air}\,\dot{V}_{vent}+x_{breath}\,i\,f\,V_t+x_{comb}\,\dot{V}_{comb}-x\left(\dot{V}_{vent}+\dot{V}_{comb}\right)}{V}\,. \tag{5}$$

This differential equation will be solved by using the MATLAB because the boundary conditions may be varied during the time duration of the investigated process of increasing the CO_2 content within a vehicle cabin.

3. Initial and Boundary Conditions for the Solution

By using the Eq. (5), we can predict the time dependence of the carbon dioxide content in a vehicle cabin for various vehicle's configurations and operating conditions. Initial and boundary conditions for the above described solution are as follows.

The volumetric flow rate of incoming air by ventilation can be expressed by the product of the airflow velocity v_{vent} in the ventilation duct of the flow cross section A_{vent}:

$$\dot{V}_{vent}=v_{vent}\,A_{vent}\,. \tag{6}$$

Most vehicles have the ability to adjust the airflow intensity (see Fig. 2), with the vehicle being measured being set to 0 to IV. When determining the flow rate of exhaust ventilation, it is necessary to measure the velocity of airflow, in our case testo 410-2 and testo 415, in the pipeline and the area of the ventilation exhaled. From these two variables, it is possible to obtain the volume of intake of gas in litters per minute (see Fig. 3).

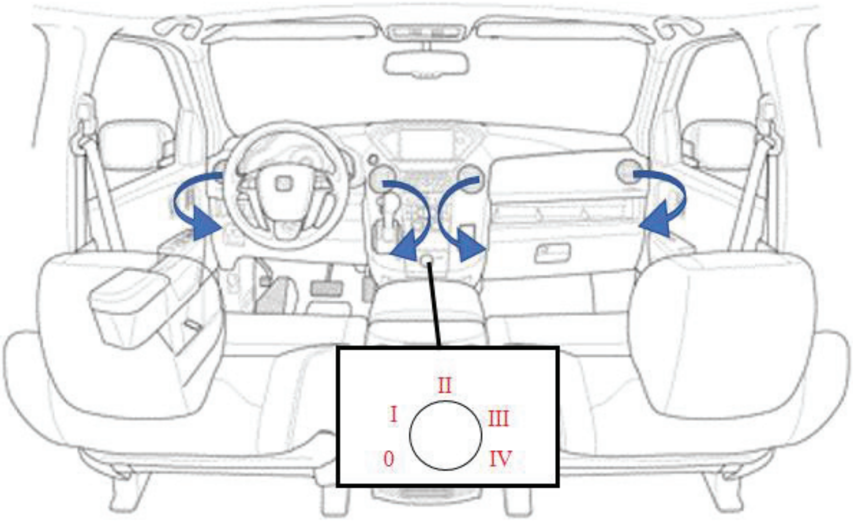

Fig. 2 An illustration of how to adjust the airflow intensity in the vehicle cabin

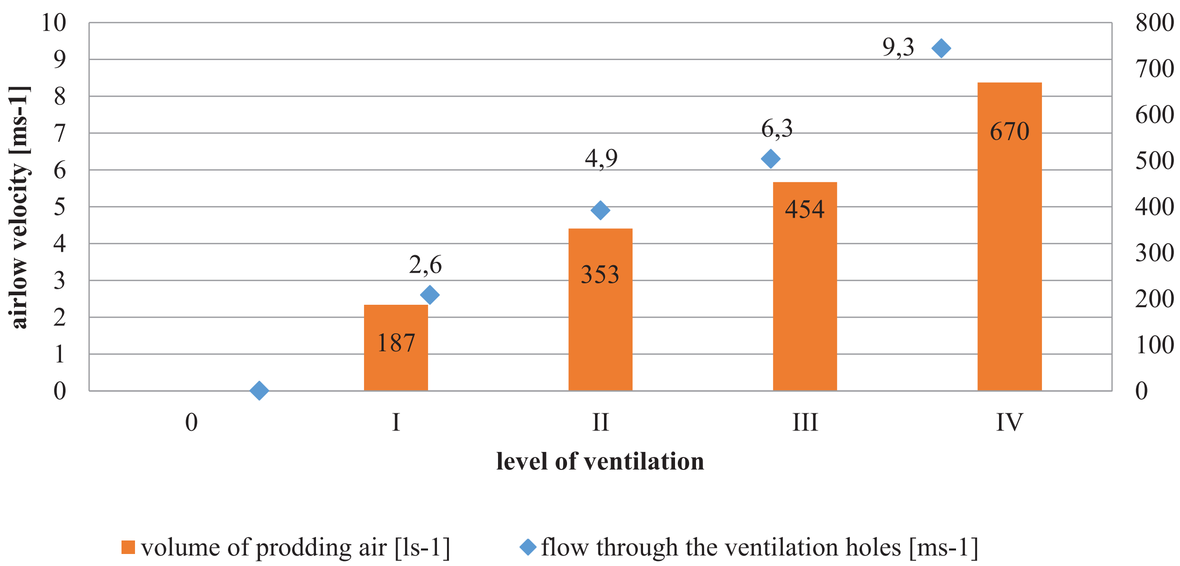

Fig. 3 Output of air intake into the vehicle cabin of the category of small cars

The volumetric (molar) fractions of CO_2 in ambient air depends on the local level ofair pollution. Mean values of CO_2 concentrations are: $x_{air} = 0.0003$ (i.e. 300 ppm) for fresh air in nature, $x_{air} = 0.0005$ for air in urbanareas and $x_{air} = 0.0008$ for air in heavy trafficareas [2].

Determination of the volume of the empty vehicle V. This value is stated by the producer if the value is not known; the volume can be expressed by measuring the lengths a, b, c (see Fig. 4) [5] .

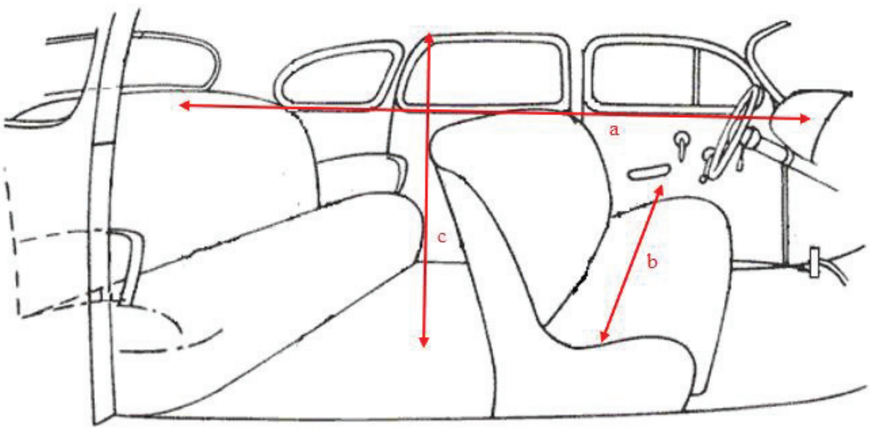

Fig. 4 Determination of vehicle cabin volume

Human respiration rate$f$ is usually measured in breaths per minute. The typical respiratory rate for a healthy adult at rest is 16 breaths per minute [3]. But breathing rates may increase up to 40 breaths per minute under a physical load. The average tidal volume V_t at rest is 0.5 litres.While, during a deep breath, this can be as high as 2,5 litres. From here, it resumes that a normal respiratory volumetric flow rate $\dot{V}_{breath}$ of one person while resting is about 5-8 litres per minute, but during a moderatephysical load this may be between 40-50 litres per minute.For trained people, maximum values can be increased up to 180 liters per minute. A function approximating the dependence of the respiratory volumetric flow rate on a person (driver) age, sex, physical and psychical load should be developed.

The carbon dioxide content in the exhaled air is nearly constant, about 3.8% (i.e. 38000 ppm). It could be assumed that the same growth in CO_2 content will be produced due to metabolic processes of breathing the vehicle cabin air with increased CO_2 content.It yields the volumetric fraction of CO_2 in exhaled air [4, 7]:

$$x_{breath} = x + 0.038 \,. \tag{7}$$

This hypothesis should be verified experimentally in future.

The volumetric flow rate and CO_2 content in products of combustion due to guns' fire are given by type and location of weapons. The volumetric flow rate can be expressed by the ratio of released combustion products of volume V_{comb} and the corresponding exposition time $\Delta\tau_{comb}$, which is given by the gas distribution to the vehicle cabin by:

$$\dot{V}_{comb} = \frac{V_{comb}}{\Delta\tau_{comb}} \,. \tag{8}$$

Values of all volumetric flow rates are connected with the systemoperation timing. The MATLAB program has to be able to vary any of the above described conditions in time τ.

When combusting from vehicles, gun powder explosive products are released, in nitro-glycerine explosives and nitrocellulose gun powder, carbon dioxide is also occurred (details of percentage share of substances in gun power see in Table 2).

Table 2

Table of released gun powder - generated products

substance	share[%]
NO	1
NO_2	7
CO_2	17
CO	28
H_2	8
CH_4	2
N_2	37

If the vehicle has an external lafetation, the crew is not in direct contact with the resulting products, the products of combustion screen after shooting is in the vicinity of the combat vehicle, which makes it possible to penetrate the vehicle into the cab through the vehicle's exhaust ventilation. This situation is illustrated in the Fig. 5. In the interior lafetation, the risk of contact with the resulting products is considerably higher.

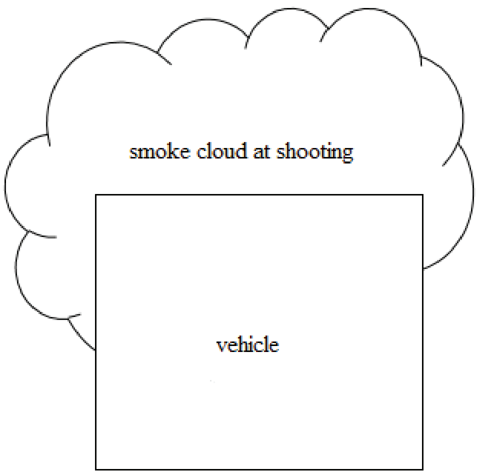

Fig. 5 products of combustion screen scheme when firing from a combat vehicle

4. Mathematics Model Application (Discussion and Conclusion)

The resulting solution is a model for CO_2 modelling in the vehicle cabin. For the simulation, one can observe the evolution of CO_2 in the vehicle cabin per person in the vehicle.

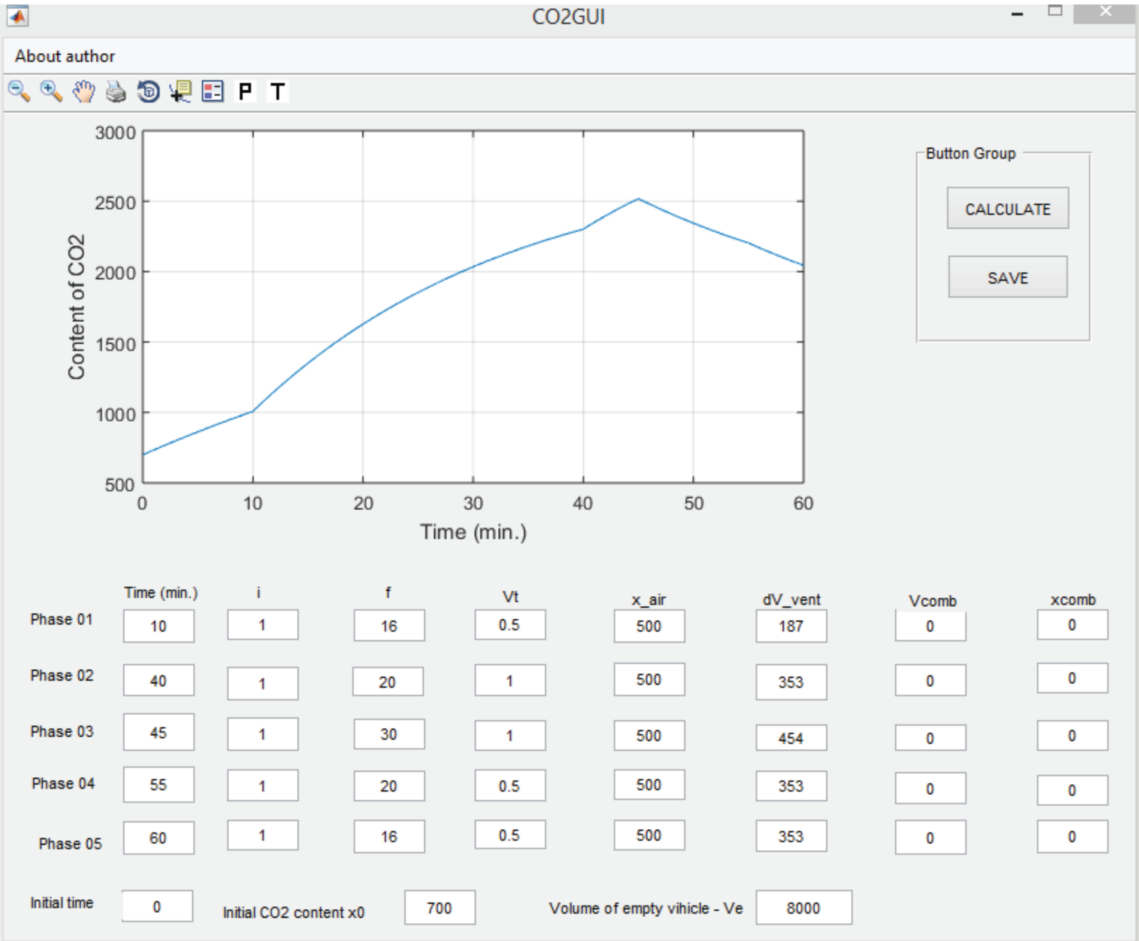

Fig. 6 Sample modelling of CO_2 concentration in vehicle cabin

Fig. 6: CO_2 percentage content x versus time τ (in minutes) is characterized as following (description of Fig. 5):
The solution is divided into several phases:

- Defined number of time phases (1-5)

Basic initial inputs, define:

- The volume of empty vehicle V_e in liters
- The initial CO_2 content in ppm

Phase inputs for given phases, define:

- Duration of the phase in minutes $\Delta\tau$.
- Number of persons in a vehicle cabin i,

The respiratory rate f per minute

- The tidal volume V_t per person in liters
- The volumetric flow rate of incoming air by ventilation $\dot{V}_{vent}$ in liters per minute

Content of CO_2 in the ambient air x_{air} in ppm

Amount of products of combustion due to guns' fire V_{comb} in liters

Content of CO_2 in products of combustion due to guns' fire x_{comb} in ppm

Fig. 6 illustrates the simulation of a vehicle with one person. The cabin volume is 8,000 m^3, the initial CO_2 level in the cab is 700ppm. It is assumed that in the first ten minutes the vehicle moves under conditions without significant load, ventilation in the vehicle is at level I. Within thirty minutes, a milder stress occurs, the driver starts to breathe faster, given that he is a trained individual, the volume of exhaled air increases as well, the driver increases ventilation to level II. In the next five minutes, the driver's maximum load is reached; the driver's breathing speed is increased to thirty exhales while retaining the previous volume of exhaled air, ventilation in the vehicle cabin is level III. In the rest of the minutes, the driver relaxes, the respiration rate and volume of the exhaled air volume returns to baseline, the level of ventilation gradually returns to level I.

5. Discussion and Conclusion

The proposed model of the CO_2 simulation in the vehicle cab simulates different types of vehicle occupancy in different situations. Based on this model, it is possible to observe the possible evolution of CO_2 concentration, which can then be verified by real measurements in normal operation. The prediction allows editing all selected values.

From the Fig. 6, we can see that in the event of stress or increased physical exertion, the limits of CO_2 concentration in the vehicle may be exceeded. Using this model, it is possible to design sufficient fan power for vehicle development or to provide other space ventilation options. Concentration of CO_2 has an impact on driver fatigue and thanks to the proposed model, it is possible to properly plan the safety of the driver's break.

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Using of the Incoterms ® 2010 Rules in the Maritime Transport

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Abstract

Incoterms rules have traditionally been used in international sale contracts where goods pass across national borders. In various areas of the world, however, trade blocs, like the European Union, have made border formalities between different countries less significant. Consequently, the subtitle of the Incoterms® 2010 rules formally recognizes that they are available for application to both international and domestic sale contracts. A result the Incoterms® 2010 rules clearly state in a number of places that the obligation to comply with export/import formalities exists only where applicable.
KEY WORDS: *incoterms rules, transport, seller, buyer*

1. Introduction

On January 1st, 2010, Incoterms® 2000 (6th revision) were replaced by Incoterms® 2010 (7th revision). The Incoterms® 2010 rules (International Commercial Terms) were developed by the International Chamber of Commerce (ICC) as a uniform set of rules to clarify the costs, risks and obligations of buyers and sellers in international commercial transactions. Because they address issues relating to import and export, Incoterms® 2010 rules are most appropriate for use in international shipping. It is a common misunderstanding that the Incoterms rules represent nothing more than standard contract terms that could be revised at any time. In fact, the value of the Incoterms rules as an expression of international commercial practice would be endangered by frequent changes for some purpose or other, such as to make them more reader-friendly or to clarify a few points of minor importance. A revision of the Incoterms rules therefore requires that something important has taken place in commercial practice. [1]

What are Incoterms? First, it is an acronym for International Commercial Terms. These are International Chamber of Commerce terms that can be incorporated into a contract for the sale of physical goods, which stipulate which party (i.e. seller or buyer) has the obligation to make carriage or insurance arrangements, when the seller delivers the goods to the buyer, and the allocation of costs between each party. Incoterms are only part of the transactional clauses between the parties: other terms negotiated determine price, method of payment, and transfer of ownership. Ownership of goods („title") transfers, often upon actual payment, or some specific contractual agreement. It can be retained specifically by the seller until a specified point-in-time which includes the receipt of a final payment. Risk, however, transfers as per the Incoterms. Risk has a specific meaning: the risk of physical loss of or physical damage to the goods. Note that a buyer can have contracted to have had this risk transferred to them but as yet they have not acquired title. They are therefore contractually obliged to pay for the goods even after they have been destroyed. This is why marine transit insurance is so important. The risk of loss of or damage of the goods is generally transferred when the seller has fulfilled its delivery obligations in accordance with the particular Incoterms rule. Delivery has multiple meanings in trade law and practice, but in the Incoterms® 2010 rules, the term is used to indicate where the risk of loss of or damage to the cargo passes from seller to buyer. The separate risk of loss of or damage caused by the goods is not part of the Incoterms. This is a separate matter of the seller´s products liability and products liability insurance in the contract of sale. Incoterms® 2010 provide harmonized interpretation rules for eleven common trade terms. From these eleven common terms, a trader has to choose the Incoterm that is most appropriate for the specific transaction he wishes to engage in. [4]

Four categories can be distinguished:

• E-terms (only EXW): the goods are placed at the disposal of the buyer at the seller's premises – come to collect the goods;

• F-terms: the buyer is responsible for the cost and risk of the main international carriage – goods are 'sent from';

• C-terms: the seller pays for the main international carriage, but does not bear the risks thereof – goods are 'sent to, freight prepaid';

• D-terms: the seller bears all costs and risks up to the delivery point in the country of destination – goods are 'delivered at'.

Rules for any mode(s) of transport:

EXW Ex Works - At the disposal of the buyer at a named place, usually the seller´s premises but not loaded on any collecting vehicle, nor does it need to clear the goods for export, where such clearance is applicable.

FCA Free Carrier - On delivery at the named place (usually the seller´s premises) to the carrier or other party nominated by the buyer. The parties are well advised to specify as clearly as possible the point within named place of delivery, as the risk passes to the buyer at that point.

CPT Carriage Paid To - On delivery at the named place by the seller to the carrier, with the seller then paying for carriage to destination. CPT has two critical points, because risk passes and costs are transferred at different places. The parties are well advised to identify as precisely as possible in the contract both the place of delivery, where the risk passes to the buyer, and the named place of destination to which the seller must contract for the carriage.

CIP Carriage and Insurance Paid To - On delivery at the named place by the seller to the carrier with the seller then paying for carriage and (minimum) insurance to destination. CIP has two critical points, because risk passes and costs are transferred at different places. The parties are well advised to identify as precisely as possible in the contract both the place of delivery, where the risk passes to the buyer, and the named place of destination to which the seller must contract for the carriage.

DAT Delivered At - Terminal Once the goods have been delivered and unloaded at the buyer´s disposal at the named port or place of destination. Terminal includes any place, whether covered or not, such as quay, warehouse, container yard or road, rail or air cargo terminal. If the intention is that the seller bear the risks and costs from the terminal to another place, then the DAP or DDP terms should be used.

DAP Delivered At Place - Risk transfers once the seller has delivered the goods to the named place at the disposal of the buyer: the goods are „on the arriving means of transport ready for unloading.‟ The seller bears all risks involved in bringing the goods to the named place.

DDP Delivered Duty Paid - Risk transfers when the seller has delivered the goods at the buyer´s disposal at the named place, cleared for import on the arriving means of transport, ready for unloading. DDP represents the maximum obligation for the seller. The seller not only has to clear the goods for export and for import, and to pay any of the associated customs duties and formalities

It is important to note that these rules above can be used where a ship is used as part of the carriage.

Rules only for sea and inland waterway transport:

FAS Free Alongside Ship - The seller delivers and risk transfers when the goods are placed alongside the vessel (e.g. on a quay or barge) at a named port of shipment. The risk of loss of damage to the goods passes when the goods are alongside the ship, and the buyer bears all costs from that moment onwards. FAS is not well suited to containerised cargo, as they are typically delivered at a terminal. In such situations, FCA should be used.

FOB Free On Board - Risk transfers when the goods are „on board the vessel nominated by the buyer at the named port of shipment.‟ The risk of loss of or damage to the goods passes when the goods are on board the vessel, and the buyer bears all costs from that moment onwards. FOB is not well suited to containerised cargo, as they are typically delivered at a terminal. In such situations, FCA should be used.

CFR Cost and Freight - The seller delivers the goods on board the vessel or procures the goods already so delivered. The risk of loss of or damage transfers when the goods are on board the vessel at the port of shipment. However, the seller pays for the costs and freight necessary to take the goods to the named port of destination. Like CPT, CFR has two critical points where risk and costs are transferred at different places. Like FOB, CFR is not well suited to containerised goods. CPT should be used instead.

CIF Cost Insurance and Freight - Risk of loss of or damage transfers when the goods are placed on board the vessel at the port of shipment. The seller must also contract for and pay the costs and freight necessary to bring the goods to the named port of destination. CIF is not well suited to containerised cargo, as they are typically delivered at a terminal. In such situations, CIP should be used in the „Sea and Inland Waterway Only‟ rules, the point of delivery and the place to which the goods are carried to the buyer are both ports.

Therefore the overall number of rules is reduced from 13 to 11, by eliminating four terms (DAF, DES, DEQ and DDU) and adding two (DAP and DAT).

The biggest change for the „Sea and Inland Waterways‟ Incoterms is the time that risk passes from seller to buyer. Previously the transfer of the risk of loss of or damage to the goods passed "from the time they have passed the ship´s rail at the named port of shipment". Now, under FOB and CIF, risk transfers once the seller has delivered the goods on board the vessel at the named port of shipment. [8]

Note that FAS, FOB, CFR and CIF are not recommended for use where containers are used. This is because the practicalities of container handling are not suitable for the chosen risk transfer point. For example, the ICC recommends that FCA be used instead of FOB for goods in a container, as the container is handed over to the carrier at a terminal, which is obviously a point-in-time before they are on board the vessel. Instead of CIF, the ICC recommends CIP for containerised goods. Nevertheless, even though much of NZ´s exports are carried in containers, we´ll no doubt, in the short term, continue with the existing practice of overseas buyers stipulating CIF as a term of trade for containerised shipments. This could give rise to some misunderstandings. Now the risk transfer point is when the entire cargo has been loaded, rather than that theoretical vertical line above the ship´s rail. Buyers will want to insist on shipped on board notations on transport documents. Should a set of documents (including the bill of lading) have a number of containers listed then risk would only transfer when the last of the cargo (i.e. containers) is on board the vessel. „Stowed on board‟, which is not the phrase used in the Incoterms® 2010, carries an implication of the cargo´s final placement on the ship. It will be interesting to see whether there are any difficulties in interpreting what „placing the goods on board the vessel‟ actually means, as this could be less obvious than the stark reality of gravity´s definition of „ship´s rail‟.

Examples of correct formulation of the terms:
CFR landed, Port of Bratislava, Slovakia, Incoterms® 2010
FOB Chennai, TN, INDIA, Incoterms® 2010
DDP Regional Police in Bratislava, Racianska 147, 831 54 Bratislava, Incoterms® 2010

2. Overview of the Transport Modes

The UN/CEFACT distinguishes eight transport modes for international trade can be:
- maritime;
- inland water;
- rail;
- road;
- air;
- fixed installation (e.g. pipelines);
- and multimodal transport.

Multimodal transport occurs when goods are carried by at least two different modes, from a place at which the goods are taken in charge by a transport operator, to a place designated for delivery, on the basis of one transport contract. [7]

2.1. How to Select the Appropriate Mode of Transport

Sellers and buyers seldom reflect on the choice of an Incoterms rule for every transaction. Normally, the choice is determined by their business strategy. As noted, the choice of the maritime terms in most cases depends on the type of the cargo and the buyer's intention to sell the goods in transit. Here, the choice between any of the F-terms rather than the C-terms depends on the ability of sellers and buyers to obtain the most favourable contract of carriage [4] .

In countries where the seller has good possibilities of procuring maritime transport, or where he is induced to use a national shipping line, he may prefer to use CFR or CIF. Where the buyer for the same reasons has good possibilities to procure the transport, he is likely to insist on the choice of FAS or FOB. In the same manner, the choice between CFR and CIF depends on the seller's and the buyer's insurance arrangements and their possibilities to arrange insurance at the most competitive rate [9] .

In principle, the same considerations apply with respect to the sale of manufactured goods. In this case, however, sellers, in order to remain competitive, frequently have to sell on extended terms using either DAT, DAP or DDP. But when a small exporter sells goods to a sizeable wholesaler or department store, these buyers may find it more advantageous to arrange for transport in order to ensure just-in-time deliveries at the most competitive price. In such cases, the buyer may prefer to use EXW or FCA.

CPT or CIP may be appropriate when the buyer prefers that the seller procure carriage (CPT), or carriage as well as insurance (CIP), but nevertheless agrees to bear the risk of loss of or damage to the goods when in transit. It should be added that the term CIP, if unamend is inappropriate with respect to manufactured goods, since the insurance cover is then far too restrictive and additional insurance is required. Normally, the most extended cover available (e.g., Clause A of the Institute Cargo Clauses LMA/IUA) is appropriate.

Several factors have to be considered in order to conduct the trade-off between cost and service requirements, namely:
- operational factors, e.g. law (including liability of the carrier, security requirements, etc.), payment conditions (including the need for a 'title document'), taxation and the basic logistic infrastructure,
- consignment factors, e.g. volume, weight, speed of delivery and distance and,
- transport mode characteristics, e.g. reliability and availability.

Most of these considerations are relatively obvious ones, but the problem lies with the large number of different aspects that need to be taken into account. In most cases, the trader will shift the choice of the mode of transport to a freight forwarder. [8]

The container revolution and the problems with maritime terms

It was mainly because of the container revolution (1960-70) that logistical practices dramatically changed. It became clear that the maritime terms were not suitable for container trade. Containerization opened the door for multimodal transport, because containers can easily be put from one means of transport to another, greatly reducing the risks of damage and theft. It enabled a single transport operator to take charge of a cargo throughout the entire voyage, thereby replacing the "port-to-port" with a "door-to-door" thinking.

It is clear that the terminology in the maritime terms only works when the goods are delivered directly to the sea or inland waterway carrier without passing through a terminal. The maritime terms refer to "alongside the ship", "on board the vessel", "port of shipment/destination", "in the manner customary at the port", etc. As a result, they are in most situations not suitable for other modes of transport or multimodal transport. [10]

Under the Incoterms® 2010 the seller contracting under CFR and CIF has to tender a negotiable on board bill of lading to the buyer. Unless otherwise agreed, it has to be a document of title, i.e. one entitling the buyer to ask the carrier for the goods and enabling him to sell the goods in transit. This will often not be the case in door-to-door transport, where the seller will be tendered a multimodal (combined) bill of lading or other transport or receipt documents that do not meet the documentary obligations established under CFR or CIF. In container trade, the goods are received either at a container freight station (CFS) or at a container yard (CY), for subsequent loading of the containers on board the ship. In other cases, the containers are loaded by the seller and then collected at the seller's premises (often FCL deliveries). The seller thus hands over the goods to the carrier at an inland point, instead of placing them on board the ship. [2]

3. Incoterms Rules in Practice

1) Determine, which Incoterms rules is more appropriate for the seller and which is more appropriate for the buyer. Goods are transported from the warehouse in Presov, Slovakia to the warehouse in Macomer, Sardinia, Italy. (See Fig. 1) Good´s weight is 22t and its worth is € 270 000. The purchase contract considered with the following Incoterms rules:

a) FAS Terminal Crociere, Port of Porto de Livorno, Italy, Incoterms® 2010,

b) CIF Port of Olbia, Sardinia, Italy, Incoterms® 2010.

Route: Presov Livorno Olbia Macomer (See Figure 1)

Main information:

- Presov – Livorno: 1 340 km
- Olbia – Macomer: 120 km
- Ferry Livorno - Olbia: 545 €
- Transport cost from seller: 0,95 € / km
- Transport cost from buyer: 1,15 € / km
- Cost for Import formalities: 76 €
- Cost for Export formalities: 87 €
- Embark: 157 €
- Disembark: 148 €
- ALL risk insurance 4 ‰.

Source: author

Fig. 1 Route Presov - Macomer

a) FAS Terminal Crociere, Port of Porto de Livorno, Italy, Incoterms® 2010

This term can only be used for sea or inland waterway transport. And it means that the seller fulfils his obligation to deliver when the goods have been placed alongside the vessel on the quay or in lighters at the named port of shipment. This means that the buyer has to bear all costs and risks of loss of or damage to the goods from that moment.

Costs of the seller:

- transport cost: 1 340 km · 0,95 € / km = 1 273 €
- cost for export formalities: 87 €

Total costs of the seller:

1 273 € + 87 € = **1 360 €**

Costs of the buyer:

- cost for the Ferry Livorno-Olbia: 545 €
- transport cost: 120 km · 1,15 € / km = 138 €

- cost for import formalities: 76 €
- loading/unloading: 157 € + 148 € = 305 €
- insurance: Freight carrier´s liability under the CMR convention is limited to 8,.33 SDR (Special Drawing Rights) per kilo gross of the damaged and/or lost goods. What in our example means:

1 XDR = 1, 09510 € - for day May 08 / 2017). [3]

8, 33 · 1, 09510 € · 22 000 kg = 200 688, 03 €, what is the value lower than the value of the machine, so it is advisable to cover additional All Risk insurance:

4‰ from (270 000 €) = 1 080 €

Total cost of the buyer:

545 € + 138 € + 76 € + 305 € + 1 080 € + 270 000 € = **272 144 €**

b) CIF Port of Porto of Olbia, Sardinia, Italy, Incoterms® 2010

This term can only be used for sea and inland waterway transport. It means that the seller has the same obligations as under CFR but with the addition that he has to procure marine insurance against the buyer's risk of loss of or damage to the goods during the carriage. The seller contracts for insurance and pays the insurance premium. The buyer should note that under the CIF term the seller is only required to obtain insurance on minimum coverage.

Costs for seller:

- transport cost: 1340 km · 0,95 € / km = 1 273 €
- cost for export formalities: 87 €
- loading: 157 €
- cost for the Ferry Livorno-Olbia: 545 €
- insurance on minimum coverage: 297 000 € (110 % from 270 000 €) is: 1 188 €

Total costs for seller:

1 273 € + 87 € + 157 € + 545 € + 1 188 € = **3 250 €**

Costs for buyer:

- transport cost: 120 km · 1,15 €/km = 138 €
- import formalities: 76 €
- unloading: 148 €

Total cost for buyer:

138 € + 76 € + 148 € + 270 000 € = **270 362 €**

Table 1

Total costs for buyer and seller under the terms FAS and CIF

Term	Total costs for seller	Total costs for buyer
FAS	**1 360 €**	272 144 €
CIF	3 250 €	**270 362 €**

Seller is worth conclude a purchase contract with the term FAS in terms of price. In terms of transfer of risk is a much more advantageous the term CIF, so if he would consider this option, he should raise the purchase price of goods of around € 1 900. Buyer is worth concluding a purchase contract with the term CIF in terms of price [6].

The basis for a proper understanding of Incoterms is to distinguish the moment of transition the cost and risk from the seller to the buyer. In principle, it is possible to define two different situations:

- the moment of transition the cost and risk of shipping - costs and risks associated with shipping has a largely pays the buyer
- the moment of transition the cost and risk on delivery - costs and risks associated with delivery has a largely pays the seller.

4. Conclusion

Transport is the essential link between supplier and receiver, and the aim is to receive the goods in good condition, when and where they are needed. This necessitates close collaboration between procurement staff, the supplier and the transporter. The journey involved, whether over land, sea and/or air, may introduce certain costs and risks that can be mitigated by appropriate methods of dispatch, insurance coverage, suitable packaging instructions, and by considering the roles and responsibilities of the parties involved in the chain of transport events up until final delivery to the client [5].

Incoterms rules do say which party to the sale contract has obligation to make carriage or insurance arrangements, when the seller delivers the goods to the buyer and which costs each party is responsible for. Incoterms rules, however, say nothing about the price to be paid or the method of its payment. Neither do they deal with the transfer of ownership of the goods, or the consequences of a breach of contract. These matters are normally dealt with through express terms in the contract of sale or in the law governing that contract. The parties should be aware that mandatory local law may override any aspect of the sale contract, including the chosen Incoterms rule.

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Simulation Model of Light Controlled Intersection in the Program ExtendSim8

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Abstract

Computer simulation has recently become an important tool for solving transport problems in the context of city logistics. For the realization of a computer simulation, there are currently specialized simulation tools. However, suitable for application in this field are various general simulation programs such as ExtendSim8. ExtendSim8 belongs to the object-oriented simulation programs, which has a wide range of libraries and tools. The paper describes the creation of a simple simulation model of light controlled intersection with the available blocks in the program ExtendSim8 for the needs of quick and operational analysis of traffic situations.
KEY WORDS: *simulation, model, light controlled intersection*

1. Introduction

The present condition of urban agglomerations structuring has a negative impact on mass passenger transport, because the concentration of passenger transport is directed to their centers, resulting in saturation by transport. This is related, for example to the problems with public passenger transport, such as indirect line guiding or unequal use of transport service in one direction [1]. The requirements arising from the settlement of the area and mass passenger transport represent the foundations for the construction and development of the transport infrastructure [2]. Significant elements of the transport infrastructure include junctions [3].

The intersections represent in solving transport tasks and problems the nodes where the traffic flows are parted and the traffic situation changes. Solving a wide range of intersections problems requires the application of different approaches and methods, for example game theory [4]. Intersections play an important role also in terms of transport crisis situations [5].

In general, it can be concluded that the issue of intersections is broad-spectrum [6]. For intersections solutions, it is necessary to take into account various factors and criteria and various methods are used, such as Petri nets [7] or computer simulation.

The computer simulation method has an increasingly dominant position in transport field. Various types of software tools and approaches exist for its implementation. Using them, different types of models can be created that differ one from the other in extent and also in the degree of detail. However, in addition to the traditional specialized programs (PTV Visum/Vissim), other non-traditional simulation programs can be used for the creation of micro-models, such as Tecnomatix Plant Simulation (Fig. 1 and Fig. 2), Simul8 or ExtendSim 8.

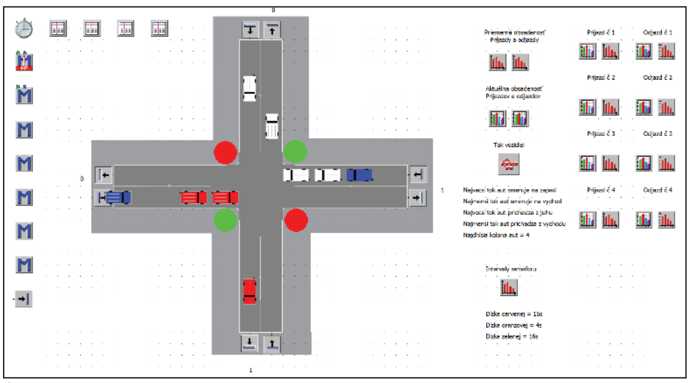

Fig. 1 2D visualization demonstration of the simulation experiment in Tecnomatix Plant Simulation

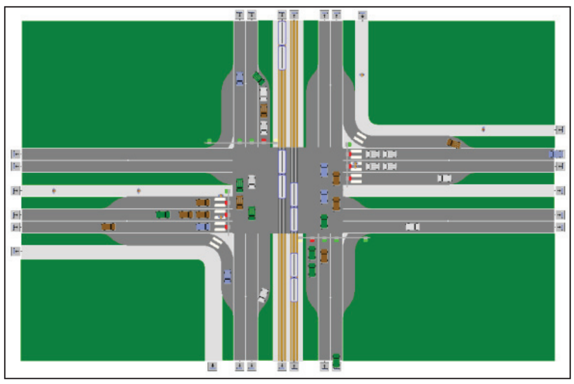

Fig. 2 A view of 2D animation of the complex intersection simulation model

2. Characteristics of ExtendSim8 Program

ExtendSim8 is currently one of the world's foremost computer simulation tools and it is the first tool intended for users from a variety of science branches. It belongs to the category of object-oriented simulation languages. Extend is an iconic simulation environment for creating continuous, discrete and combined simulation models. Models are created by combining and joining blocks from the prepared libraries on the desktop of the program. New blocks can be created by linking existing blocks into hierarchical structures or by modifying the block program code. The program offers animation options and tools for importing and exporting data.

Using this program, we can create dynamic models of real processes in different areas. Creating models from created blocks allow examine complex processes, see how processes relate to each other, and finally find the optimal solution by changing their parameters. It enables easy and fast creation of complex models of different systems, processes and devices. In the program there can be created block diagrams of processes and devices where each block describes part of the process or device.

The methodology of creating a light controlled intersection simulation model in the program ExtendSim8 can be divided into several steps (Fig. 3):

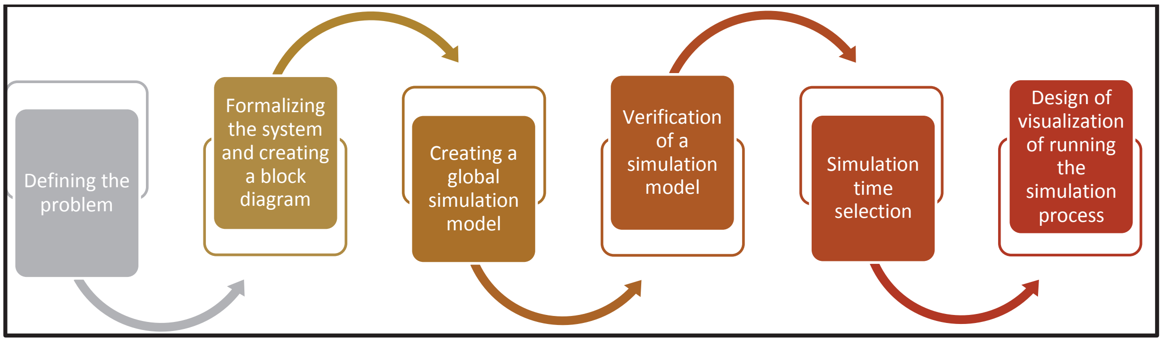

Fig. 3 The methodology of creating a light-controlled intersection simulation model in the ExtendSim8 program

The first step is to formulate the problem, especially range of issues that will be analyzed and solved by a simulation experiment. The Extend simulation program is particularly suited for application in logistics, transport and manufacturing systems.

In the second step of creating a simulation model, it is necessary to focus on the process under consideration and defining the parameters of its individual elements (permeability, capacity utilization, time, position and capacitance variables). This part is also met in the previous subchapter. An inevitable condition for this step is to formalize the system or process under review using a block diagram. This formalized process is most often analyzed and plotted using block diagram creation tags.

The creation of a global simulation model is the third step in the methodology of creating a simulation model in the Extend program. As part of this step, the created block diagram is directly transformed into a simulation model. This whole step is divided into 2 stages.

In the first stage, individual basic elements (machine, conveyor, buffer etc.) are created. The existing blocks from individual libraries are used to create them. More complex elements can be created by programming or a combination of basic elements. Program Extend allows to combine individual blocks into hierarchical blocks that greatly facilitate modeling, increase clarity, and logical consistency.

In the second stage, the individual elements are joined to the system according to the block diagram. This second step results in the creation of a simulation model. The simulation model after setup needs to be set to the most accurate delays during each operation as needed, and to statistically process intervals and values for random number generators.

In the fourth step of creating the simulation model, it is necessary to focus on verifying the simulation model. It is monitored and verified whether the logic processes run in the simulation model in accordance with the real system, i.e. whether the model faithfully reflects the behavior and functions of the real system. As part of this step, we can create and use reference values for comparison. A model that provides sufficiently accurate results can be used for simulation experiments with variants for the observed system.

The choice of simulation time is the fifth step of consecutions in creating simulation model. This process is very important because it determines the time that will run during the experiment in the model, or how long real-time will be simulated in a given simulation model. The question is how long it is necessary to simulate the real system so that the results (which are always processed statistically) can be considered valid.

The last step in the simulation system creation methodology is to design a visualization of the course of the simulation process and to present the results of the simulation experiment. ExtendSim8 offers a wide range of visualizations. The simplest form is graphical visualization using various images, schemes, photographs or drawings created by a simple graphical tool that is implemented in the simulation program (Fig. 4).

A higher form of visualization is to create animation of a simulated process using a basic range of animation elements or using own animation compositions. For simulation process animation, the program also includes a special library. The program also offers the possibility of 3D animation (Fig. 5).

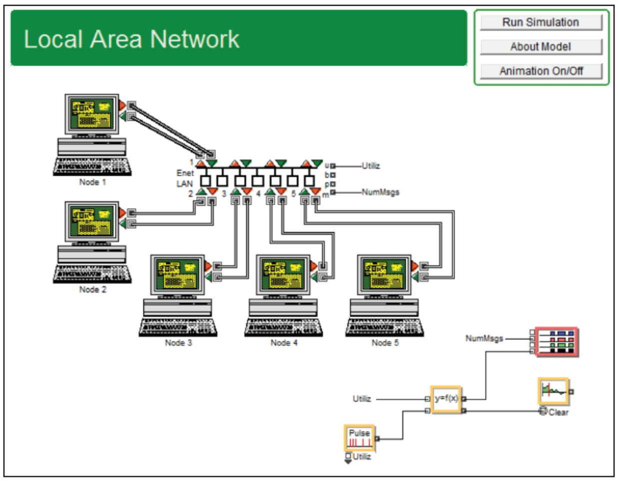

Fig. 4 2D visualization demonstration of the simulation experiment in ExtendSim8 program

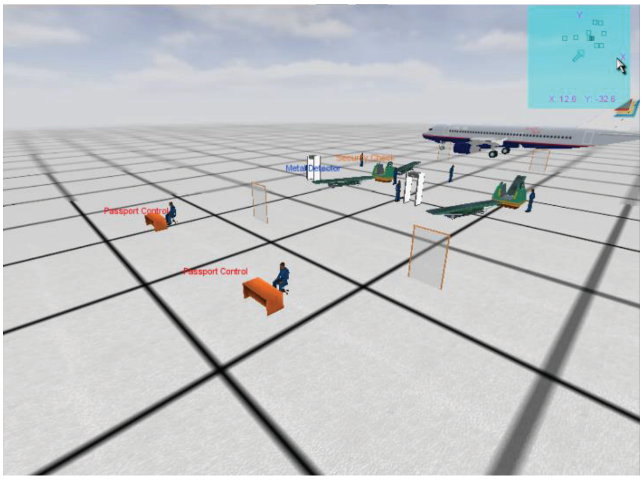

Fig. 5 A view of 3D visualization of simulation experiment in ExtendSim8

3. Simulation Model of Light Controlled Intersection

Based on the characteristics of the ExtendSim8 simulation program, an attempt was made to create a simulation intersections model that is controlled by light signaling. The aim was to verify whether a model of the transport node could be designed to be used for simple simulation experiments.

To create the simulation model, blocks from two base libraries of the Item and Value blocks (Fig. 6) were used. These are blocks that serve to create discrete simulation models.

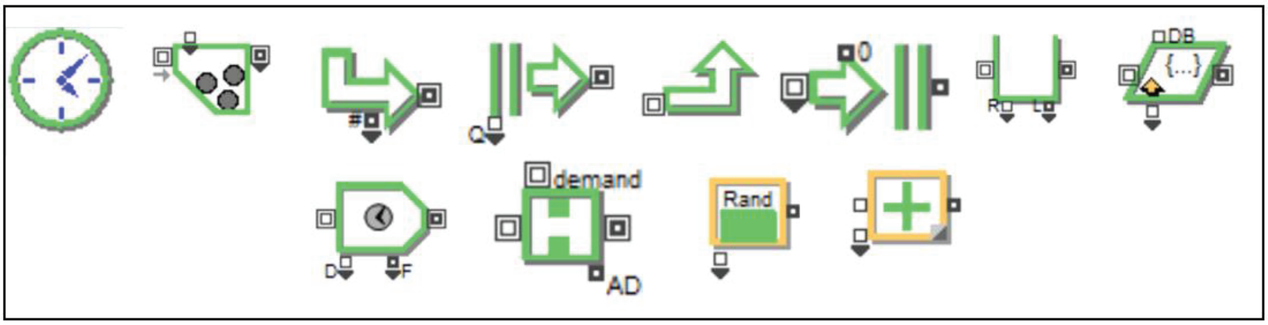

Fig. 6 ExtendSim8 program blocks used to create the simulation model

The simulation model creation process was divided into two phases. In the first phase a model representing the movement of transport means was created. In the second phase a model of a light signaling device was created. The traffic flow model (Fig. 7) was designed as a universal one so it could be used for any traffic direction.

The principle of the vehicle movement simulation model consists in generating time intervals using the Create block, which is then fed into the Unbatch block. Inside the block, it is transformed the time interval to the number of vehicles that pass through the junction within the time interval. The number of vehicles is generated randomly through the Random block. In the Random block, the appropriate random number generator is used to generate the number of passing vehicles. The boundaries for generating the number of vehicles are obtained on the basis of a traffic survey. Subsequently, each generated vehicle passes through the Queue block that performs a temporary traffic lane feature.

Furthermore, the direction of travel is defined for the individual means of transport. This requirement is executed via the Set block. In the Set block, a numeric attribute is defined for each vehicle. Its range is bounded by the number of possibilities offered by the modeled junction. After defining the directional attribute, the transport mean is again placed on the road and is preparing for the process of joining the appropriate direction and then the traffic lane.

The distribution of the means of transport into individual traffic flows is realized through the Throw and Catch pairing blocks. The Throw block ensures that each vehicle reads the numeric attribute value. Based on this, the individual transport means are assigned to the respective Catch block. The number of Catch blocks depends on the number of choices to select the direction of travel at the appropriate junction.

After passing the vehicles through the Catch block, they get to the next Queue block, which represents the corresponding road traffic direction. Consequently, the means of transport from the intersection are removed according to any additional requirements.

The mentioned principle of vehicle movement simulation is universal and can be applied to any type of junction.

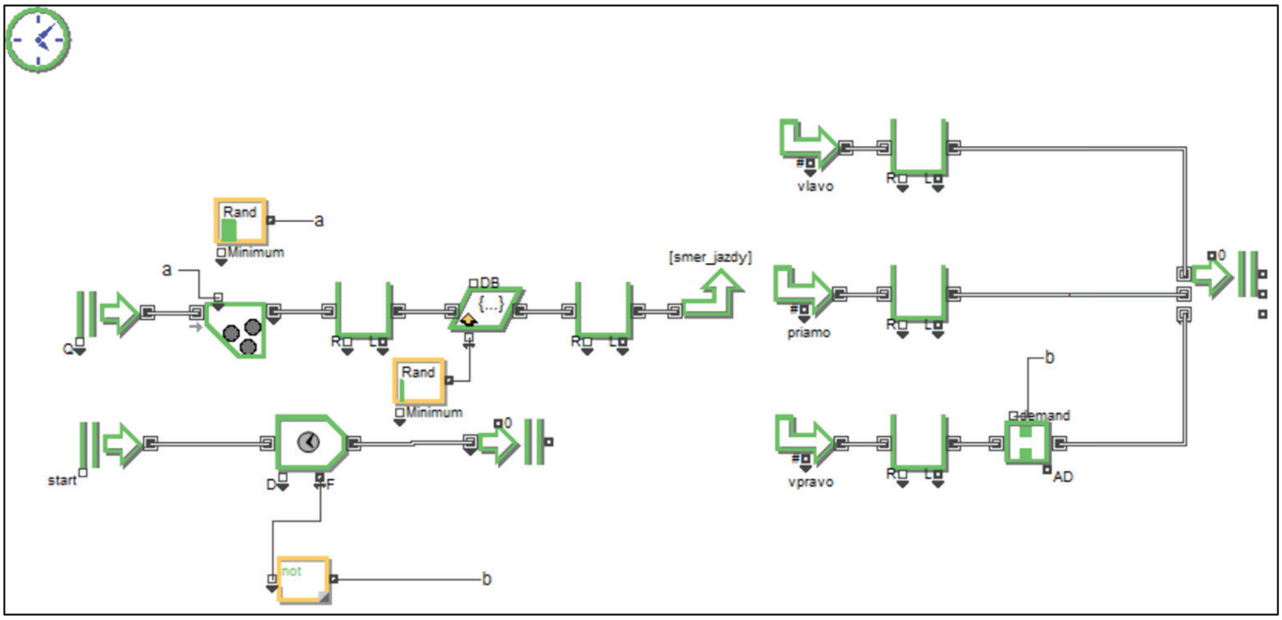

Fig. 7 The overall concept of the simulated traffic flow model and the light signaling device

The light-signaling system in the simulation model was implemented via the Gate block. This is a block that works in two modes. In the first mode, the block is open and allows the passage of individual entities. In the second mode, the block is closed for the change and the entities do not pass through it. The Gate block, in the presented simulation model, represents a light control signalization that allows the passage of vehicles through crossroad or not. For simplicity, it was not considered with the three color control /red, yellow and green / in the simulation model but with only two colors /red and green/.

Changing modes in the Gate block is accomplished by using another five blocks. The first block, the Create block, generates time moments as entities when the red traffic light is on. The duration of the red signal is secured by the Activity block which holds the time entity for the desired time. During the time that the entity is held in the Activity block, a value of 1 is transmitted to the F connector on the Activity block. This is then sent to the Math block where the logic function is set to NOT. As a result, a value of 0 is generated at the output of the block, which is applied to the Demand connector on the Gate block. Consequently, the Gate block is in the entity impassability mode. Otherwise a value of 1 is input to this connector and the Gate block is in possibility mode for entities - vehicles.

The results obtained from the model created in program ExtendSim8 can be visualized as follows, the traffic flow intensity (Fig. 8), and information on the number of vehicles passing through the intersection, the duration of the light signal (Fig. 9).

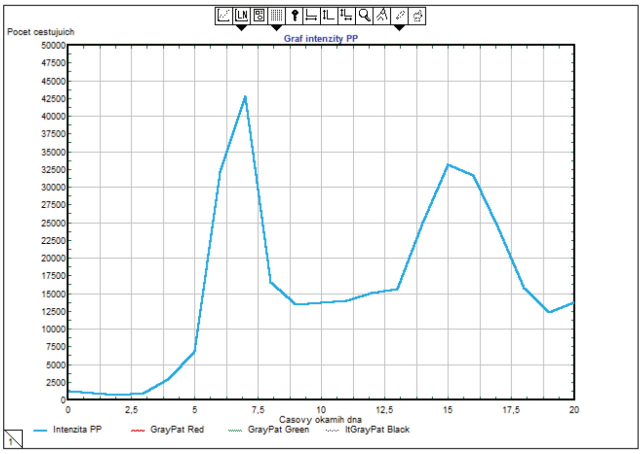

Fig. 8 Presentation of the results of the simulation experiment on the intensity of the transport flow at the light-controlled intersection in ExtendSim8

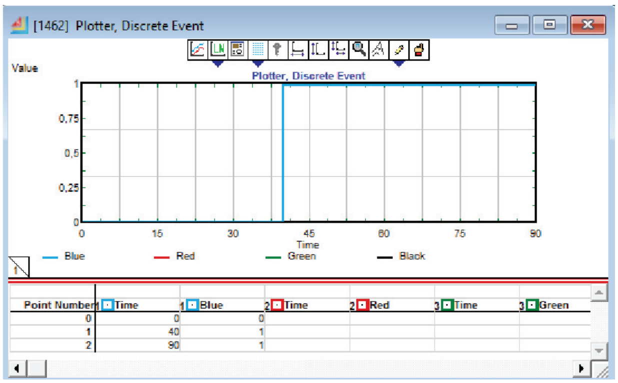

Fig. 9 A view of red light signal visualization during the simulation experiment of light-controlled intersection in ExtendSim8

Other simulation experiment results can be presented in the following form using MS Excel and the obtained data can be further processed for various needs (Fig. 10 and Fig. 11).

VÝSTUP														
Čas [h.]	min.	max.	Čas [h.]	min.	max.	Čas [h.]	min.	max.	Čas [h.]	min.	max.	Čas [h.]	min.	max.
5:20	1	3	8:40	1	3	12:00	1	3	15:20	1	3	18:40	1	3
5:40	1	3	9:00	1	3	12:20	1	3	15:40	1	3	19:00	1	3
6:00	1	3	9:20	1	3	12:40	1	3	16:00	1	3	19:20	1	3
6:20	1	3	9:40	1	3	13:00	1	3	16:20	1	3	19:50	1	3
6:40	1	3	10:00	1	3	13:20	1	3	16:40	1	3	20:20	1	3
7:00	1	3	10:20	1	3	13:40	1	3	17:00	1	3	20:50	1	3
7:20	1	3	10:40	1	3	14:00	1	3	17:20	1	3	21:40	1	3
7:40	1	3	11:00	1	3	14:20	1	3	17:40	1	3	-	1	3
8:00	1	3	11:20	1	3	14:40	1	3	18:00	1	3	-	1	3
8:20	1	3	11:40	1	3	15:00	1	3	18:20	1	3	-	-	-

Fig. 10 Presentation of the results of the light-controlled intersection simulation experiment by exporting to MS Excel 2016

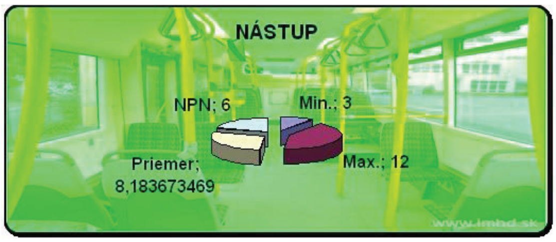

Fig. 11 Demonstration of the results processing of the light-controlled intersection simulation experiment by export in MS Excel 2016

4. Conclusions

The solution to traffic problems associated with different types of crossroads and their management systems is currently experiencing a huge increase. This is due to the fact that the continuous progress of transport on individual transport junctions in urban areas and rural zones is unstoppable. With issues that in the past only concerned large cities, we are now meeting even in smaller towns. For this reason, various City Logistics tools are being implemented here. Its key and the most powerful tools include computer modeling and computer simulation.

To solve transport problems and problems, there is currently a range of different software tools. Using them, it is possible to create a wide portfolio of simulation models and then simulation experiments. The development of transport models and the subsequent solution is associated with large specialized software packages for many transport experts. It is only possible to agree with this, but it should be noted that these tools are mostly time-consuming for the creation of individual models. Their use for operative and fast traffic analyzes is mostly demanding and sometimes not feasible.

For these cases, it is very efficient to use general simulation software. This is a group of programs that is much more accessible and allows quick and flexible work with simulation models. These softwares are known enough and more of professionals handle work with them. Among these types of software we also include the ExtendSim8 program.

ExtendSim8, as has been confirmed, allows the fast creation of simple transport models, such as a model of a light-controlled intersection. Consequently it provides to obtain sufficient information. A certain disadvantage of such a model of a light-controlled intersection can be visualization and animation of the results of individual simulation experiments compared to special simulation tools designed specifically for the transport domain. However, this mentioned handicap can be fully accepted with regard to speed and operability of this tool. Additional benefits include the option to apply ExtendSim8 software in exporting the results of simulation experiments to external programs, such as MS Excel and their subsequent processing.

Finally, it can be concluded that general simulation tools are as well suited as specialized transport tools for modeling and simulating of traffic tasks and problems.

Acknowledgements

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Layered Safety System Models – Evolution of the Concept

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Abstract

Process of designing and implementing the safety systems in different areas of people's presence and activity leads to creation of systems with complex relations among their elements (risk reduction measures) and among the elements of the domains, for which the systems are created. Understanding how such systems work is impossible without a proper model, e.g. with application of the layer concept. Recent reports on the layered model use indicate on the significant potential of this kind of modelling. In this paper, we showed the results of a literature review, which allowed us to discuss the development of related definitions and understandings of layers in different application domains.
KEY WORDS: *safety systems, safety system models, protection layers*

1. Introduction

Process of designing and implementing the safety systems in different areas of people's presence and activity relies on the seriousness of hazards identified there. In reference to the currently available and significant technological and scientific potential, this active approach leads practically to the creation the complex safety systems with complex relations among the elements of those systems (risk reduction measures) and among the elements of the domains (elements of super systems – people, artefacts, natural environment), for which the systems are destined. As Cempel [1] points out, the potential for forming the increasingly complicated systems seems to be bottomless, but a shallow knowledge about their operation poses a problem. The majority of the complex systems that are seen in science, technology and economy lacks the complete and unambiguous information about their structure and behaviour [2].

It needs to be said that it is very hard and sometimes, due to the human factor, even formally impossible to research such systems as the real objects. A solution is the creation of safety system models. This enables to do many research tasks referring to the operation of those systems (see e.g. works [3, 4]). However, in the relatively distant development history of the issues connected with safety systems, very few examples of safety system models can be found, and practically only one of them (LOPA) has been formally developed. On the other hand, the applications of the layered models indicate on the significant relevance of this kind of modelling. Thus, through the present article, we aim to briefly present the development of safety system modelling with the use of layered models and to stimulate its next applications.

2. Layered Models

The essence of layered models is the division of their elements on some groups (usually independent groups), which are called the layers. Many criteria are applied for identify the layers, but usually they are not explicitly defined. A typical way is using the properties of the layers, like: technical and non-technical i.e. logical or organizational. For example, Ni et al. [5] uses this criterion in the model for flow availability in two-layer networks. He distinguishes the logical layer (IP layer) and physical layer (optical layer). Gill et al. [6] present the concept of identification of layers through classification of risk reduction measures. Cheng et al. [7] proposed a three-layered model to analyse and recognise the activities of a group of people. The inherent interactions within the group are the criterions of identify the layers. Each layer can be flexibly described with multiple cues and expresses higher level semantics for understanding the group action. Birch et al. [8] presented a model for structuring automotive safety arguments comprising four different, yet interrelated, layers of safety claims. In their work, the layered model was structured based on the rationale behind safety requirements, their relationship to corresponding physical artefacts and hazardous events, the means used in their development, and the environment in which safety activities are undertaken. Hankin et al. [9] present a shallow layer model for heavy gas dispersion. Other examples of references to the layered models can be found e.g. in work [10] of Khan et al.

In the view of creating the layered safety system models, the criteria to be met by the layers are crucial. According to the IEC61511 standards, these are:

- specificity: a layer is designed solely to prevent or to mitigate the consequences of one potentially hazardous event;
- efficiency: a layer must on its own be capable to prevent the concern outcome when all other measures have completely failed;

– independence: a layer is independent of the other layers associated with the identified hazardous event;

– dependability: a layer counted on to do what it was designed to do. Both random and systematic failure modes are addressed in the design;

– auditability: a layer is designed to facilitate regular validation of the protective functions.

Sometimes, the criteria are also used to decide if a device, a system, or an action could be considered as an *independent protection layer* (IPL). For example, in the methodology of LOPA (see chapter 3) some questions are proposed to guide the team or the analyst in making the appropriate judgment. For example, it should be tested whether the safeguard detects the condition that requires it to act; the strength of the IPL is adequate to the required action, etc. The efficiency of an IPL is quantified in terms of its probability of failure on demand (PFD) which is defined as the probability that a system (in this case the IPL) will fail to perform a specified function on demand [11]. An example of the layered safety system model interpretation is shown in Fig. 1.

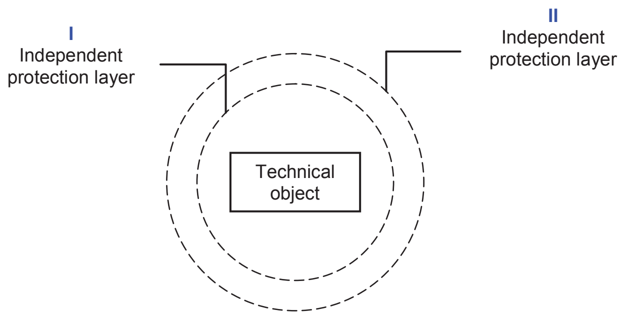

Fig. 1 An example the layered safety system model interpretation

It could be concluded that the safety system layer is a functional, notionally separated fragment of the system activated to realize the one or more specific safety functions. The realisation of the safety function involves the interaction of the safety system components with the specific factors (so called risk sources or hazard sources [12]) or the interaction on the hazardous event. The interaction is carried out in different manners, and can be either technical or organisational. Its effect is to reduce the value of one or two components of risk: the probability and/or the consequences of accidents and other unwanted events in a system [13]. Such safety system components which participate in reducing risk are referred to as risk reduction measures (RRM) or barriers. The structure of a safety system layer does not possess a real, physical counterpart. It is the result of a certain procedure completed for the needs of the modelling process.

3. Evolution of the Layered Safety System Models

To present the evolution of the layered safety system models, it is proper to use definitions of terms such as: *barrier/safety barrier* (SB), *defence*, *defence in depth*, *protection layer*, *safeguard*. Initially, this kind of modelling was used in the nuclear industry for the presentation of safety systems with multiple protection layers [14]. It is noticeable that the safety system used to be organized in the multiple barriers or a chain of safeguards – 'if one level of protection or barrier could fail, the subsequent level or barrier should be available'[15]. It is so called *defence-in-depth* principle (see e.g. work [16–18]). The concept, the history and a review of the published definitions of defence-in-depth was presented by Fleming et al. [9]. Necessary part of this principle is 'the independent efficiency of the different levels of defence'.

According to [42], the concept of a defence-in-depth constitutes the basis for the discussion about the safety barriers (layers are often identified with barriers). A comprehensive review by Sklet [14] found that there is no universal and commonly accepted definition of the terms, either in literature, or in the regulations, or in the standards. However, it can be point out that, the concept of the safety barriers is often related to an accident or energy model [14]. Barriers may than occur in different forms: technical as well as organizational [13] and in different types of activation i.e. passive and active barriers [19]. The term can also be used more generally to encompass the organizational aspects [20]. Currently, according to e.g. the Commission Implementing Regulation (EU) 2015/1136, a barrier means: 'technical, operational or organizational risk control measure outside the system under assessment that either reduces the frequency of occurrence of a hazard or mitigates the severity of the potential consequence of that hazard'. In the problems solved by e.g. [21] mainly the definition of a safety barrier proposed by Sklet is used [14]: safety barriers are physical and/or non-physical means planned to prevent, control, or mitigate undesirable events or accidents.

Another term which should be considered in the creation of the layered model is *protection layers*. Probably it was implemented in connection with the development of the defence-in-depth in the process industry or the chemical industry: 'The concept of defence in depth was developed within the nuclear industry, but is also used in other high risk industries e.g. the process industry, where the term multiple protection layers is also used' [14]. Whereas Harms-Ringdahl says that [15]: 'Protection layer is a fundamental term employed in chemical industry, although this is not explicitly defined. It typically involves special process designs, process equipment, administrative procedures, the basic process control system and/or planned responses to imminent adverse process conditions; and these responses may be either automated or initiated by human actions'.

The use of a safety barriers and the defence in depth for modelling the safety systems in the chemical industry, led to the formulation and introduction of the related terms such as, e.g. *independent protection layer* (IPL). The term is used in the method of Layer of Protection Analysis (LOPA), among others. The description of LOPA can be found in CCPS (American Institute of Chemical Engineers) research paper [11]. LOPA is a semi-quantitative methodology that can be used for assessing the operation of the safety systems and to identify the safeguards that meet IPL criteria established by the Centre for Chemical Process Safety (CCPS) in 1993 [20]. Its concept is connected with the defence in depth principle. Thus, the defence in depth concept and layered models are applied to the risk control in the industrial systems of the chemistry process as well as in managing the functional safety. LOPA consists of a few steps. Among LOPA algorithms presented by various authors, no fundamental differences occur; they usually refer to the number of algorithm steps.

The authors of LOPA indicate that 'the distinction between an IPL and a safeguard is important' but they have not pointed out the important differences and stated only that: 'A safeguard is any device, system, or action that would likely interrupt the chain of events following an initiating event. However, the efficiency of some safeguards cannot be quantified due to the lack of data, uncertainty as to independence or efficiency, or other factors'.

Numerous applications of layered models are also reported in recent papers. Sun et.al. [22] propose an evaluation model of cyber-attacks based on four layers of vulnerability, asset, service and mission. Ni et.al. [5] as well as Ratnam et.al. [23] use layered models for designing protection measures in networks. Cheng et.al. [7] propose a layered model to analyse and recognize the activities of a group of people. They develop the model to cope with the varying number of participants and the inherent interactions within the group.

The layered models can also be helpful in modelling systems in transportation sciences, although there are only few such examples. One of them is the paper of Birch et.al [8], which was mentioned before in this paper. The idea of identification of the layers in safety system models for the technical transport objects was also proposed by Gill et al. in works: [6, 24]. The first works on the development of the concept and the application of the layered models in transport were presented by Gill and Kadziński in 2006. The next year, a dissertation 'Decision procedures in technical systems maintenance with risk analysis' (Gill 2007) was presented, where a simple layered safety system model in the decision-making procedures referring to the operation at the technical facilities, was developed. The range of the research issues related to the layered safety system models early appeared is vast. They ranged from the idea of creating the models for systems that are already in operation through ones that are being designed, to the selection of safety measures. Some of these problems were solved for example by [25].

4. Discussion

Layered models usually consist of several layers and their structure depends on the layer definition. To help to decide if a device, a system, or an action could be considered as a layer, in LOPA some criterions are provided. Unfortunately to meet these criteria is not always possible. Bridges [26] even pointed out, that the 'one of the biggest problems with LOPA is that its users do not always follow the rules of LOPA'. It mostly refers to the layer independence understood as a lack of a susceptibility to the other layers influence. That is, there must be no failure that can deactivate two or more layers [27]. Fleming [28] focused on this problem for the barriers in nuclear power reactor (barriers are usually identified as the layers). He gives, among others, the example of radionuclide barriers that are not independent. Similarly, Ni et al. in work [5], takes into account correlations by tracing logical/IP layer failures to physical/optical layer root causes.

If we are modelling the protection system or safety system, layer and barrier can be identified as the same elements due to realized functions. Then, among the layers, just like among the barriers, various types of the dependencies occur. Guldenmund et al. [29] clearly presents some of these relationship, which are between the hardware barriers and their behavioural elements. The graphic interpretation of the known layered safety system models with the use of a protection layer and the dependencies among the safety system components is presented in Fig. 2.

Another aspect that is omitted in various methods (e.g. LOPA), we call the partial fulfilment of a safety function. It means that limitation of the hazard potential is realized only to some extent. Layers are not always working in zero-one logic. If one layer limited the hazard potential then the next one could not fully work. Some kind of this problem was noticed by Ratnam et al. [21]. He divides the layers according to the degree of protection demand. They adopts a multi-layer protection approach consists of dedicated lightpath protection, shared lightpath protection, and shared label switched path protection methods.

The next problem is a simultaneous, joint action of layers. In LOPA layers should act in a certain order. This is of course related to the fact that LOPA is based on defence in depth concept, where the following principle is using: 'if one level of protection or barrier could fail, the subsequent level or barrier should be available'. In our approach to the layers, there are common elements of these layers (e.g. a pump restores the state of a fluid while a person – an operator helps to pump the fluid out and he acts as an executive element in the system) or observes the state of the fluid (acts in the system as e.g. a sensor).

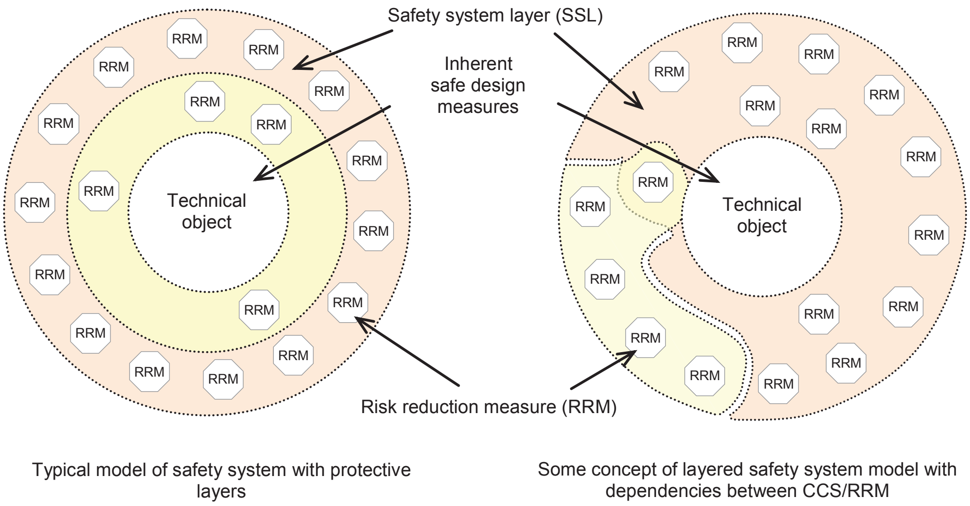

Fig. 2 The example of some layered safety system model concept with the dependencies between the components of a safety system

5. Conclusions

Safety system models can be used in a variety of ways. Firstly, they provide an indication of the system behaviour under different conditions, allowing estimating its efficiency in reaction to predicted undesirable events. Secondly, the results of such prediction can be used for redesigning of existing safety systems or creating new ones. The potential, however, highly depends on how the model describes the reality. In this paper, we presented the evolution of layered safety system models. The literature review indicates that layered models are used very often for safety system modelling, although there are noticeable differences in definitions and understanding of the layer concept.

This kind of modelling helps to understand relationships among safety system elements, safety functions, as well as hazards and their sources. It is also supporting the design of the safety systems, configuring/modifying and identifying an existing safety system. We believe that the awareness of these issues will contribute to stimulating next applications of the layered models.

Acknowledgements

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Pumps and Piping Systems in a Vessel Operation and Crisis Situations

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Abstract

A ship operates on various types of fluids moving inside different machinery and systems for the purpose of cooling, heating, lubrication, balancing and as fuels. These liquids are circulated by different types of pumps, which can be independently driven by ship power supply or attached to the machinery itself. All the systems on board ship require proper operational and compatible pump and pumping system so that ship can run on its voyage smoothly. The selection of a type of pump for a system depends on the characteristics of the fluid to be pumped or circulated. Characteristics such as viscosity, density, surface tension and compressibility, along with characteristics of the system such as require rate of fluid, head to which the fluid is to be pumped, temperature encountered in the system, and pressure tackled by the fluid in the system, are taken into account. Pumps and piping system contributes to safety [1] at sea and on a river and to a prevention of accidents, casualties and pollution [2].
KEY WORDS: *pump, vessel, fluid, valves, dynamic pressure*

1. Introduction

Pumps are used extensively throughout the maritime industry. Vessels and shore installations utilize a wide range of pumps and pumping techniques to transfer and distribute fluids and slurries of all types. Aboard ship, pumps, valves, and piping are used for a number of essential services. They supply water to the boilers, draw condensate from the condensers, supply seawater to the fire main, circulate cooling water for coolers and condensers, pump out bilges, transfer fuel oil, supply sea water to the distilling plants, and are used for many other purposes. The operation of the ship's propulsion plant and of almost all the auxiliary machinery depends on the proper operation of pumps. Although most plants have two pumps ,a main pump and a standby pump, pump failure may cause failure of an entire power plant.

2. Main Types of Pumps Being Used on a Vessel

All common types of pumps use a source of energy [3] to move a liquid through a confined space [4]. The energy may be applied by mechanical force directly on the liquid or by using an energy carrier like compressed air [5]. Pumps for general applications are mostly direct mechanical pumps. Specialized pumps use a variety of techniques to appropriately handle whatever material is being transferred. Liquids that are highly viscous or flammable need special equipment to be transferred quickly and safely [6].

Main types of pumps being used on a vessel are divided in two main groups:

Positive displacement pumps

Positive displacement pumps are self priming pumps and are normally used as priming devices.

- They consist of one or more chamber, depending upon the construction, and the chambers are alternatively filled and emptied.
- The positive displacement pumps are normally used where the discharge rate is small to medium.
- They are popularly used where the viscosity of the fluid is high.
- They are generally used to produce high pressure in the pumping system.

Dynamic Pressure or Roto-Dynamic Pump [7]

- In dynamic pressure pump, during pumping action, tangential force is imparted which accelerates the fluid normally by rotation of impeller.
- Some systems which contain dynamic pump may require positive displacement pump for priming.
- They are normally used for moderate to high discharge rate.
- The pressure differential range for this type of pumps is in a range of low to moderate.
- They are popularly used in a system where low viscosity fluids are used.

This broad classification of pumps are further differentiated in Table 1 by their constructional properties and popularity of usage onboard ship.

Table 1

Main types of pumps being used on a vessel

1. Positive displacement pumps	2. Nonpositive displacement (dynamic)	
• Positive displacement pumps • Rotary • -Multirotor • -Single rotor Reciprocating pumps 1.1.2 Piston pumps 1.l.3 Diaphragm pumps 1.1.4 Piston/plunger 1.1.5.Rotary pumps 1.1.6. Screw pumps 1.1.7.Gear pumps 1.1.8.Eccentric helical rotor pumps 1.1.9.Lobe pumps 1.1.10Vane pumps	• Centrifugal pumps (Fig. 1) 1.2.1 Diffuser type pumps 1.2.2 Volute pumps 1.2.3 Hand pumps 1.2.4.Motor driven pumps 1.2.5 Electrical motor driven pumps / electro-pumps 1.2.6 Motor pump unit 1.2.7 Turbine driven pump/ turbo-pump	1.3.1.Axial flow pumps • 1.3.2 Submersible pump • 1.3.3 Centrifugal-axial (mixed) pump. • 1.3.4 Jet pumps

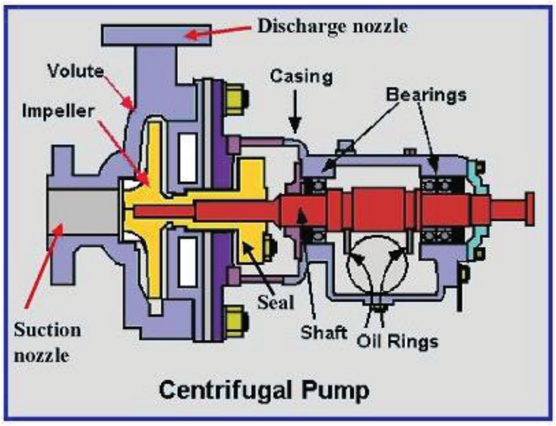

Fig. 1 Centrifugal pump

3. Pumps Run for Several Piping Systems on a Vessel

3.1. Bilge System

The bilge system is used to remove small quantities of fluid that have leaked [8] or condensed into a dry space. The system serves the machinery spaces, cargo holds, cofferdams, voids, stores, tunnels and pump rooms. Each space has its own piping but the pump is likely to be shared.

The capacity of a bilge system is defined by the diameter of the bilge main and pump (Fig.2) capacity for the volume of the enclosed space.

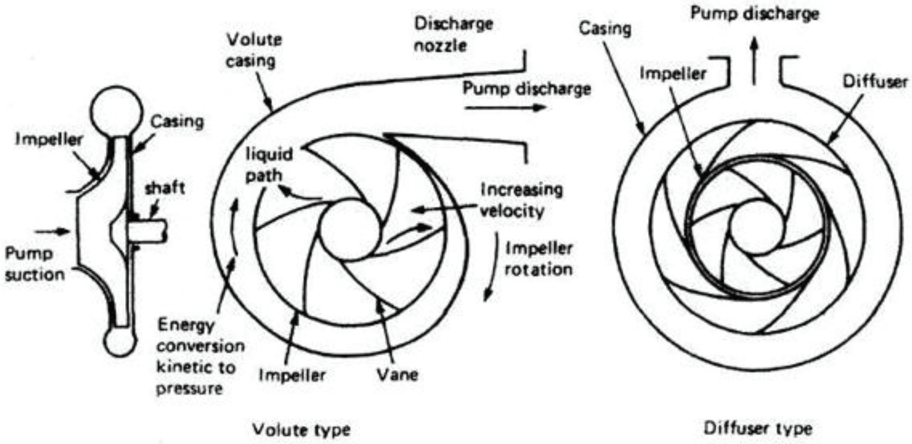

Fig. 2 Operation of a bilge pump

Cargo ships are required to have two bilge pumps with non-return valves fitted to prevent back-flow or cross-flow.

The pumping system in a passenger ship must be able to drain water from any dry space when one or more of the ship´s other compartments are flooded. However, the system is not required to empty the flooded space. A flooded passenger ship is required to have at least one bilge pump, with its own power supply, available for pumping. Bilge suction must have remotely operated suction valves. The minimum number of pumps [9] required is three or more, depending on the ship´s design.

Mud boxes and strum boxes (line filters) are fitted at the ends and in bilge lines to stop debris being drawn into the pipe.

The requirements for bilge systems on ships carrying dangerous goods are basically the same as those for general cargo ships. However, systems drawing fluids from gas-dangerous spaces are kept segregated with their own pumps and pipes, where appropriate, from systems serving gas-safe spaces [10].

3.2. Ballast System

Ballast system contains ballasts tanks i.e. compartments on a vessel that hold water in order to balance the ship (Fig. 3) and ensure its stability. Older vessels used to use stone or iron to provide balance, however this has now been replaced by water as it can more easily be adjusted. Ballast pumps are designed to efficiently transfer vast amount of sea water into the marine vessels' ballast tanks or to empty if necessary i.e. when entering more shallow waters. As our range of ballast water pumps reflect, they are often centrifugal pumps due to their ability to handle water efficiently.

Ballast is taken to increase a ship´s draught, particularly the stern draught when sailing without cargo.

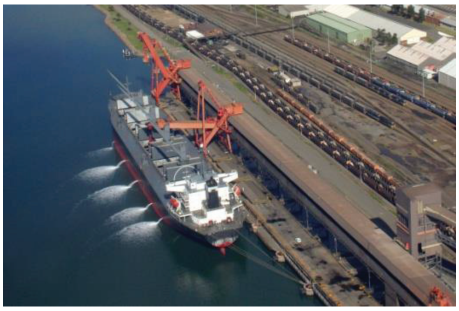

Fig. 3 A vessel discharging ballast water [11]

On a dry cargo or passenger ship, the ballast system is commonly operated from the engine room. On a tanker, the entire ballast system is commonly located in the cargo area and is operated from a pump room and cargo control room.

Ballast piping is usually made from ordinary mild steel which corrodes. Some ships have ballast piping manufactured from glass reinforces epoxy (GRE), which does not corrode, but care is needed with clamping arrangements to ensure that the pipe is secure and does not move along its axis; this may cause coupling joints to fail. Spare sections of GRE piping should be carried, along with joining couplings and gaskets. A ship´s size determines the capacity of its ballast system.

3.3. Firefighting Systems

Piping is used extensively throughout a ship for fire control (Fig. 4) purposes. The specific features of ship´s firefighting equipment are governed by the International Convention for the Safety of Life at Sea (SOLAS).

Fig. 4 Firefighting on a vessel [11]

They include:

3.3.1. Fire Main

Mild steel piping fitted with hydrants for hoses where saltwater is used for manual firefighting. The fire main is designed for a typical working pressure of 10 bar. Pipes in the fire main are affected by corrosion both externally and internally. Pipes are joined with flanged connections.

In passenger and cargo ships where the engine room provides bilge pumping, the whole ship is the enclosed space. The diameter of the bilge main is:

$$d = 25 + 1{,}68\sqrt{L}\left(B + D\right), \tag{1}$$

where d - internal diameter of bilge main, in millimeters; L - ength between the ship´s perpendiculars, in meters; B - extreme breadth, in meters; D - moulded depth, in meters.

In a tanker with a separate cargo pumping and piping system, the enclosed space is the engine room and the diameter of the bilge main is:

$$d = 35 + 3\sqrt{Lo}\left(B + D\right) \tag{2}$$

where Lo - length of the engine room, in metres.

3.4. Sprinkler Systems

Small-bore pipes kept permanently charged with freshwater at 10 bar pressure. A sprinkler system is arranged to release automatically at temperatures of about 70^{o}C, so the system can react and extinguish a fire. The system uses saltwater after the freshwater [14]. After use, it must be flushed with freshwater to minimize corrosion.

Some systems operate at higher pressures and produce a fine high pressure mist or fog. These systems are used in oil purifier compartments and above diesel engines to protect the high fire risk areas in engine rooms. It has been proven that rapid operation of this system can quickly contain and extinguish pressure-fed oil fires.

Water spray systems usually have small-bore piping, which is dry when not in use. A water spray system is operated manually and looks similar to a sprinkler system.

Inert gas system is fitted on all tankers over 20.000 dwt (Fig. 5) and on all tankers with crude oil washing systems. Inert gas piping is usually large diameter low-pressure mild steel, with smaller diameter branch lines.

Fig. 5 Pipelines on a tanker [11]

The internal surface of inert gas piping does not usually corrode. The water wash pipework of an inert gas system is usually lined with a corrosion resistant coating, as the wash water from the inert gas scrubbing tower is highly corrosive.

4. Conclusions

Development of ships with an increasing transportation of cargoes requires higher outputs and failure free operation of all types of pumps being used on the board. Some of them share the power, some need to be independent. However the efficiency of pumps is not the unique important feature. For health reasons some of them cannot be used for a different purpose, for emergency situation they must be redundant. However, the pumps should match not only a ship specialization, but also its size. They need to be connected sometime to special equipment, for example, water treatment plant, that make the pump a single-purpose equipment.

The kinds of ship pumps and their operational parameters are so different, that due to their role on a ship, they should be well calculated and tailored to the particular circumstances on the vessel board. Minor failure in pumps may result in massive damages on a vessel and cargo. For efficient operation, it is important to ensure that leakage from a whole system is kept to a minimum that is crucial in vibrating and unstable environs of a pump on a board.

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Experimental and Numerical Studies of Residual Stresses in Railway Turnout

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Abstract

The residual stresses in steel railway superstructure components may in some cases result in unforeseen structure behaviour. The stresses may occur in the course of a production process of railway superstructure steel components, and combined with residual stresses, may affect rail traffic safety. The tests of levels and distribution of residual stress in rails in the course of a production process show that currently used rolling and cooling technologies are not a source of unacceptable residual stress values. Depending on cooling time, internal tensile stresses in non-straightened rails does not exceed 100 MPa for the rail head and rail foot axis. A rail straightening process is an operation causing significant longitudinal residual stresses. For rails straightened on roller straighteners, as a result of variable strain of surfaces in contact and not in contact with the rollers, 150÷300 MPa residual stresses over the rolling surface of a head and at the bottom of a rail foot and -100÷-200 MPa compressive stresses of a rail web are recorded. The danger lays in an increase of stresses in the areas subject to service load, i.e. in the area of rail head, and in case of a crossover, in points where vehicle wheel contacts the frog (actual frog point with bent component of a wing rail).
KEY WORDS: *railway turnout, FEM, residual stress, ultrasonic instrument*

1. Introduction

The residual stress arises in the case of heterogeneous plastic deformation caused by:

- bending and cold rolling;
- thermal stresses;
- heterogeneous phase transitions.

For steel railway superstructure components, occurrence and change in residual stresses are due to thermal stresses and plastic strain resulting from bending and cold rolling. Thermal stresses are a result of non-uniform phase transitions due to thermal treatment, including surface hardening, used for shaping the steel turnout components. The treatment aims to increase hardness of the surface layer of a wing rail or a switch blade. The effect of generating residual stresses in this case is more complex compared to heterogeneous cold strain. It is affected by a temperature gradient and resulting thermal stresses, including phase change processes, recrystallization, relaxation, and dependence of material properties on temperature. For steel railway superstructure components, occurrence and change in residual stresses are due to thermal stresses and plastic strain resulting from bending and cold rolling. Thermal stresses are a result of non-uniform phase transitions due to thermal treatment, including surface hardening, used for shaping the steel junction components. The treatment aims to increase hardness of the surface layer of a wing rail or a switch blade. Residual stresses in hardened steel components are due to a martensitic transformation at lower temperatures, where an overcooled austenite transforms into a martensite – a phase with lower density or other structures depending on requirements and thermal processes (hardening) [3].

2. Tests and Analyses – Object Research

2.1. Experimental Studies

Residual stress values can be obtained by experiments and theoretical analysis. The methods of theoretical determination of residual stresses involve solving complex thermal, elastic, and plastic relations. It is a complex solution, due to lack of accurate data on actual loads exerted on an object. The theoretical analysis of residual stresses is bound up with the elastic theory and elastic properties, plastic flow and material hardening, heat transfer, phase transitions, thermal expansion, structure, and thickness of surface layer. The complexity of processes that occur in the material during process treatment means that the results of the theoretical analysis are based on simplified models and cannot be used to evaluate the residual stress state even in components with straight geometry and require use of the experimental method. The residual stresses have been the topic of interest for the researchers and scientist for several decades. Thus, various methods and techniques for measuring the residual stresses were developed. Generally, residual stress measurement methods in steel components can be divided into two categories: destructive and non-destructive methods. Destructive methods do not allow to determine the quality of tested objects without damage, whereas non-destructive methods allow multiple tests on the same object.

Ultrasonic method used by the author to determine the residual stresses is based on the relation between ultrasonic wave velocity and stress. Ultrasonic wave velocity is determined with an accuracy of a fraction of a meter per second to measure the residual stresses with required precision. To measure the absolute values, the effects of temperature and non-uniform distribution of elastic properties and material texture on the wave velocity must be allowed for. A relatively easy and simple method is the ultrasonic measurement with DeBro-35 instrument (Fig. 1) [2].

Fig. 1 Measurement of residual stress with DEBRO instrument

Measurements of residual stresses with DEBRO meter were carried out for rail and switch point samples before and after bending and the surface hardening processes. The measurements places at the circumference of rail 60E1 and I60 shown in Fig. 2.

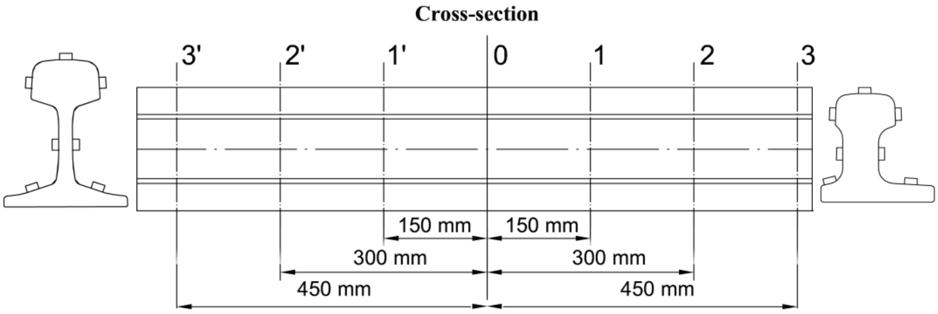
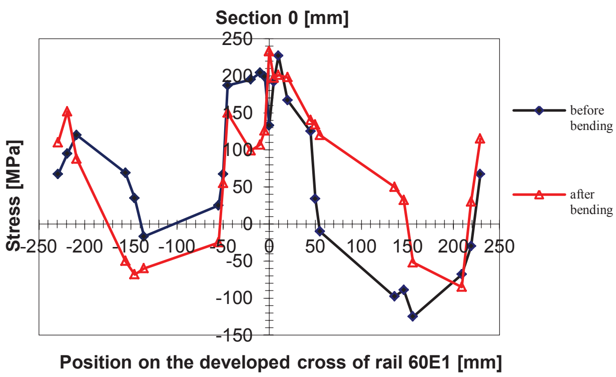


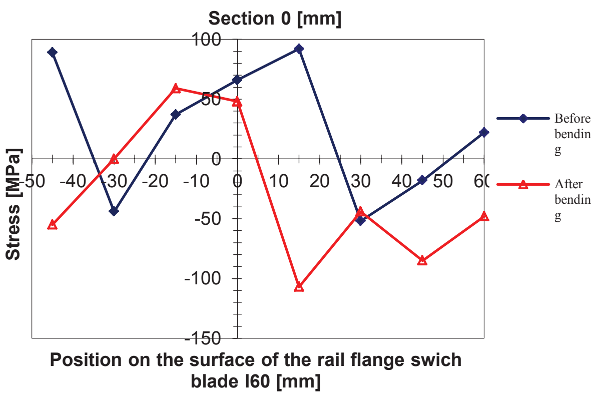
Fig. 2 Measurement places at the circumference of rail 60E1 and I60

2.2. Results of Residual Stress Measurement

The diagrams (Figs. 3-4) show example of longitudinal stress changes at the circumference of rail and switch blades after bending processes and after hardening of selected sections. A horizontal axis represents a distance from the centre of a head rolling surface (measured at the rail and switch point surface), and vertical axis represents the longitudinal component of a residual stress.



a



b

Fig. 3 Longitudinal stress changes at the circumference of rail 60E1 (a), and I60 (b) before and after three point bending processes (section 0 mm).

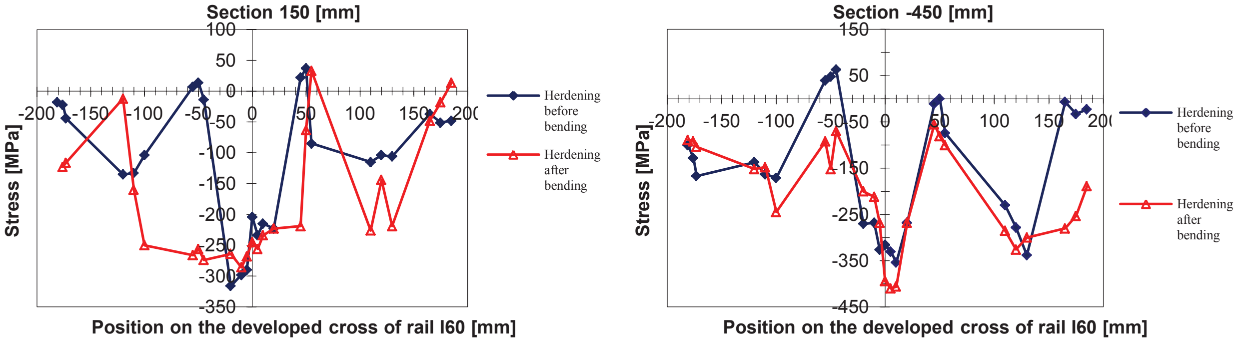


Fig. 4 Longitudinal stress changes at the circumference of rail I60 after heat treatment and after bending processes (section 150 and – 450 mm)

Bending processes increase both compressive and tensile stresses. The highest residual stress values were recorded at the head and foot, since most of the elastic strain energy remains in the head and foot after value of the force applied during the bending is reduced.

The comparison of results measurement of residual stress after three and four point cold bending processes bending shown in Fig. 5.

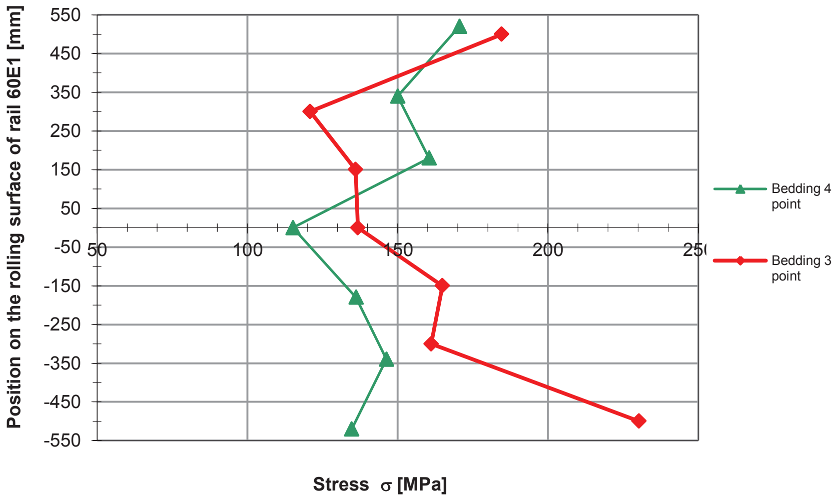


Fig. 5 The comparision of results measurement of residual stress after three and four point cold bending processes bending (f = 18-22 mm)

It the results of measurements for residual stresses obtained with ultrasonic testing shows after the bending tests that in case of four-point bending the distribution and size of residual stresses is more favourable and uniform, compared to the three-point bending case. A surface hardening process introduces for rolling surfaces of rail 60E1 and I60 the compressive strength up to -400 MPa (Fig. 4). Compressive stresses prevent microcracks at the rolling surfaces. It may extend life of turnout, reduce wear of its elements the and eliminate material flow.

2.3. Simulation Studies

Tests of residual stresses in the steel components of track superstructure are expensive and time-consuming, even when using non-destructive testing methods. If possible then, measurements shall be limited to the most essential while the simulation methods and numerical calculations shall be used instead. Such calculations allow to determine the influence of dimensional and material parameters on the stress distribution. The subject of the numerical analysis in this paper is simulation of three and four-point bending and surface hardening processes of the section samples of 60E1 rail and I60 switch point. The analysis concerns strains and stresses generated in the course of the above mentioned technological operations. The main purpose of the numerical calculations is to determine residual stresses in the rail after the relief that happens after bending and/or hardening process. It is also to define the influence of different test parameters on the size and distribution of stresses.

2.3.1. Model Geometry - Finite Element Grid Railway Track

Models and numerical calculations of a railway track with and without reinforcement were performed using

Abaqus software version 6.11. A geometry of a numerical model is defined as a grid of nodes indicating position and size of finite elements. Due to the complex shape of modelled structures, apart from cuboids with six walls, also an additional three dimensional components were included, solids with a triangular base (with five walls).

Square components are considered the most relevant for the description of the issues with bending as a prevailing treatment to better describe stress concentration and allow better approximation of curved shapes with lower number of elements. The way of support was defined by reduction of the specific degrees of freedom in the nodes, which correspond to the experiment are present in the support sections (Fig. 6).

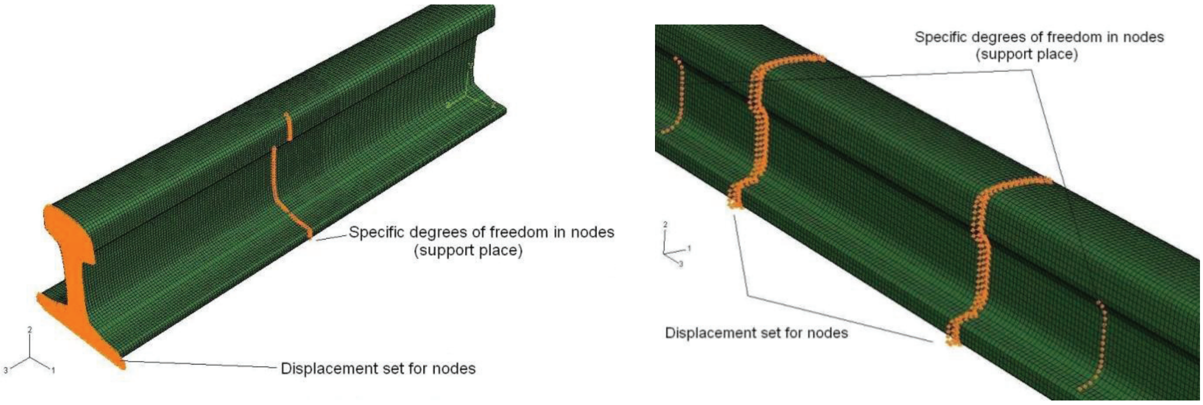


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Fig. 6 Finite element models of 60E1 (a) and I60 (b) rail with boundary conditions and loading—three and four point transverse bending

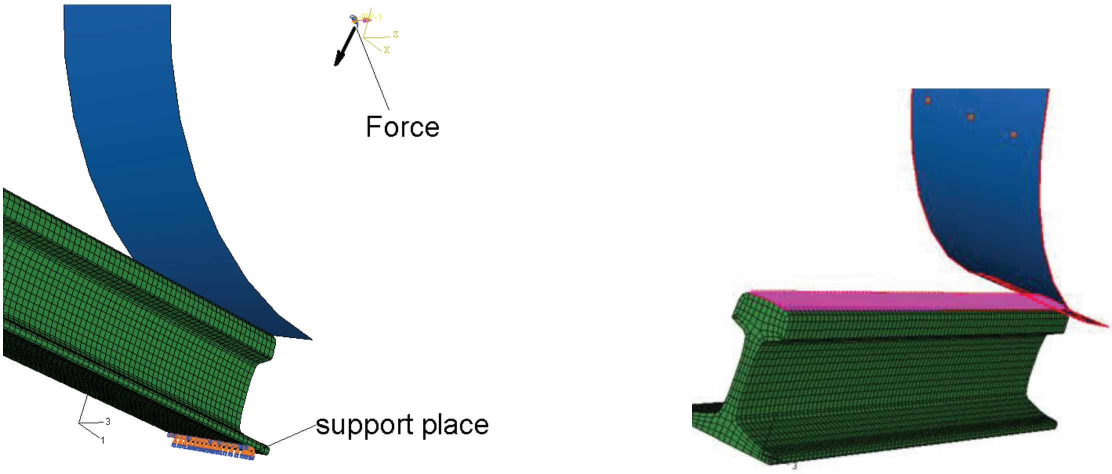

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Fig. 7 Finite element models of UIC 60 rail with boundary conditions and loading – the rolling process (a), and rail / wheel interface (b)

2.3.2. Material Model

Approximate stress σ strain ε curves were plotted for numerical calculations. Table 1 shows material ductility (relation $\sigma - \varepsilon$, for axial tension of steel) results obtained in the course of empirical tests. Values shown in table were defined using a software.

Table 1

Stress σ, MPa	Plastic strain ε, %
0.0	0,0
629.7 (A)	0,4
900.0 (B)	2,6
1066.0 (C)	6,0
1069.0 (D)	16,0

Besides, stress and strain values for the approximation curves (red line) were determined for each temperatures represented in Fig. 8.

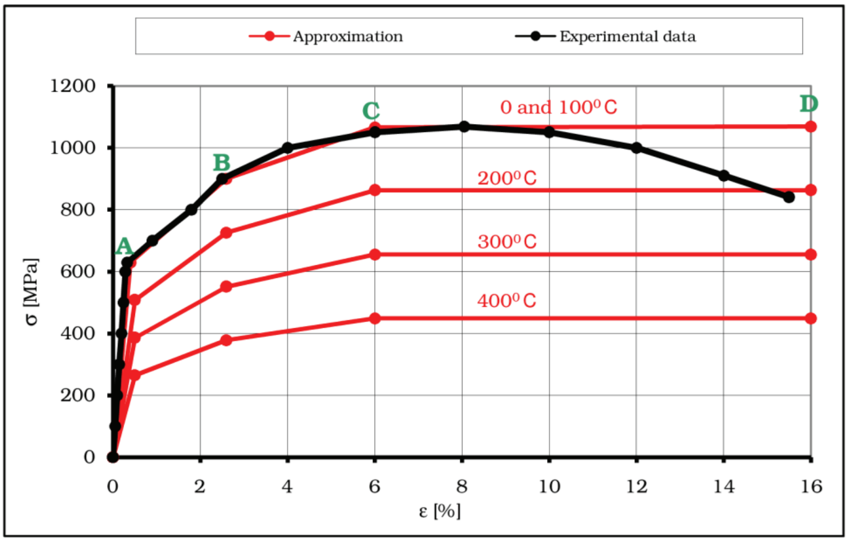

Fig. 8 Experimental material curve and its approximation $\sigma - \varepsilon$ depending on the heating temperature [1]

2.3.3. Results of Simulation Calculation

Several simulation calculations covering different variants of section bending, surface hardening, and rolling process were performed. Figs. 9-11 show the results of computer simulation for 60E1 rail and I60 switch blade models. The figures show contours of the of residual stress σ_{11} after relief.

Numerical calculation results shown in Figs. 9-11 provided a number of interesting data in addition to the experimental tests. A location of extreme stresses around the periphery of analyzed objects may be determined based on the results obtained.

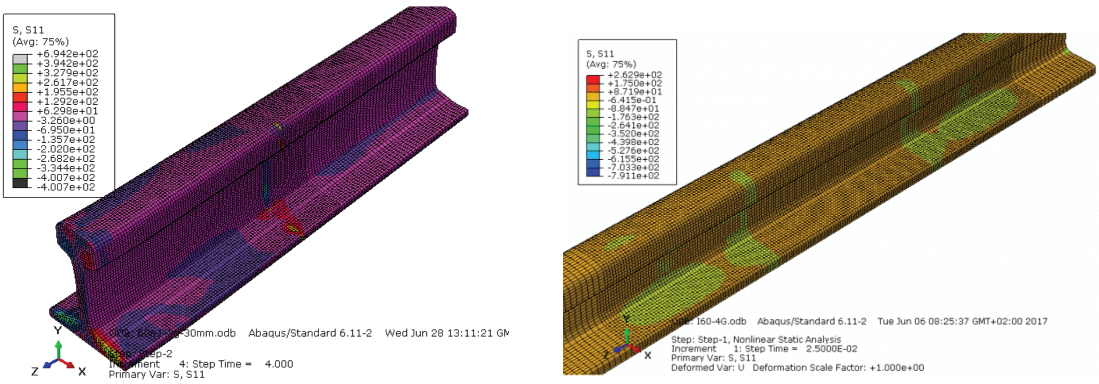

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Fig. 9 Contours of residual stress σ_{11} of the rail 60E1 and I60 switch blade section after three (a) and four (b) point bending

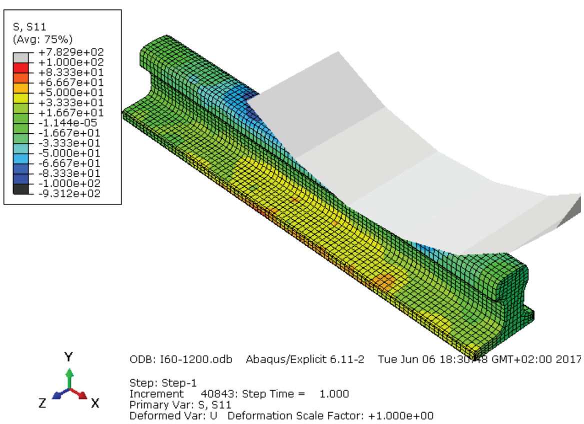

Fig. 10 Contours of residual stress σ_{11} of rail 60E1 after rolling process

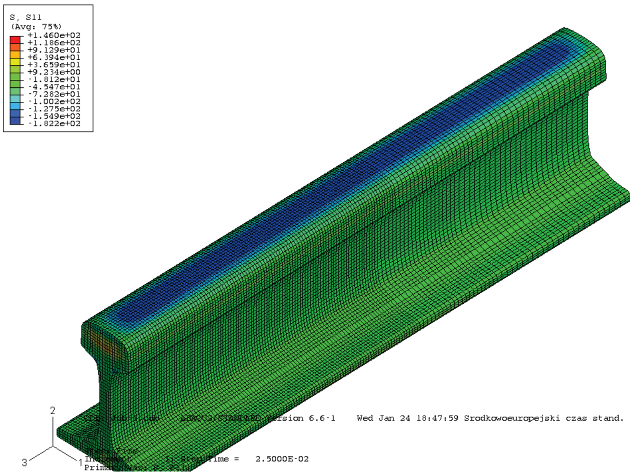

Fig. 11 Contours of residual stress σ_{11} on the head of rail 60 E1 after heat treatment.

3. Conclusions

The discussed issues are a subject of interest of both the manufacturers and the experts responsible for condition of the track superstructure. Stress may affect the energy state, phase changes and corrosion. It may reduce fatigue strength and cause damage and cracks of the rails. It is one of the causes of accelerated development of standard rail head defects. Presented method of residual stresses evaluation diagnosing with ultrasonic testing and numerical analysis in the course of the manufacturing process, provides control of size and distribution of residual stresses during bending and hardening processes. Proper selection of e.g. bending process parameters provides uniform distribution and level of residual stresses in the bent components.

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Evaluation of the Diesel Engine Parameters after Regeneration of its Fuel Delivery System

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Abstract

This article presents the influence of diesel fuel additive used to clean the injection system on the operating parameters and the concentration of toxic components in the exhaust gas of the compression ignition engine. This additive (agent) was used according to the manufacturer's recommendations to ensure optimum conditions in the experiment. Empirical studies were conducted on a four-cylinder, turbocharged self-ignition Perkins 1104C-E44T engine. The tested engine was characterized by a mileage of 220 hours and most of this time the engine was fueled by alternative fuels such as Fatty acid methyl ester (FAME). The cleaning process took place for the first time. During this study the fuel consumption, engine torque and concentrations of selected toxic components in exhaust gas were measured before and after cleaning the system with the additive. The analysis of the research results was carried out to evaluate the engine's performance right after the process of cleaning its fuel delivery system.

KEY WORDS: *compression ignition engine, injection system, engine performance, fuel additives, regeneration process*

1. Introduction

The concept of operating wear is known for years. Depending on machine aging and amount of operating hours this process deteriorates performance of the machines [1, 2]. In this case, operating wear will be resulted not only in extra mechanical wearing between rubbing parts but also in fuel fractions deposition on the surfaces where diesel fuel flows through the fuel delivery system. As long as mechanical wear requires physical intervention in an engine parts to restore its performance, in the case of reduced efficiency due to contamination, the regeneration process can be performed using chemical additives. The wearing of the injection system in a compression ignition engine has an impact on a number of parameters such as the concentration of harmful substances, fuel consumption, power and torque characteristics, noise and vibrations.

2. Injection Systems Wearing

Fuel delivery systems in compression ignition engines are characterized by accurate design and low clearance between the operating parts. Such demands are important to maintain sufficient impermeability of the components at high fuel pressures that occur during the operation of the engine's fuel supply system. It is known that with time clearances become bigger because of wearing, resulting in leakage and loosing operability [1]. The presence of fine impurities between the operating surfaces and the edges of precision couples may cause their malfunction and even seizure and immobilization or may result in leakage of the injector sealing jacks. The main plunger element in the injector is piston head and this head is exposed by wearing in a maximum rate. The surfaces of the atomizer and injector's valve are mostly exposed by deposits formation because of special conditions initiated by high speed needle motion [5]. Another factor contributing to the wearing of precision assemblies in the injection system is the erosive effect from fuel flowing that occurs at high velocity between the walls of the assembly. Another undesirable phenomena is cavitation occurring in the fuel delivery system under the influence of rapid pressure changes of the fuel [1]. But the most common cases of premature wear of injection systems are caused by improper fuel cleaning. Typical problem is seizure of the needle in the atomizer body, but except for seizures, leakage may occur in the valve housing as well as clogging of the spray holes caused by excessive engine thermal load and deposition of particles of size exceeding spray orifices diameter [6]. To increase the reliable operating time the best possible cleaning of the fuel is needed, that includes the maintaining the cleanliness when filling the fuel tank and using special cleaning additives for fuel delivery system. Fig. 1 shows cross-section of the injector with marked areas of internal and external deposits [1, 3, 5].

For now, empirical data dealing with the subject of present research has assumed the formation of internal deposits in the injectors [3]. The most important factors causing these deposits formation in the injectors were: fuel composition and refining additives presence, quantity and quality of FAME fuel used and engine operating conditions. Lubricants such as unsaturated fatty acids can react with metal ions located as contaminants in the fuel and create soaps and solids as result [6]. Zinc containing acid soaps cause, for example, sediment deposition on the atomizer outlets. The publication [3] proposes to divide the internal deposits of the injectors into three main types:

Type I - metal ionic or "wax" soaps or carboxylic soaps or carboxylic salts.

Type II - viscous, polymer-organic deposits or amides.

Type III - oxidation products of fuel.

It is assumed that Type II comes from detergent additives that include corrosion inhibitors or lubricants and used for diesel fuels, and the third type is produced as an aging product of FAME in diesel fuel [5-12].

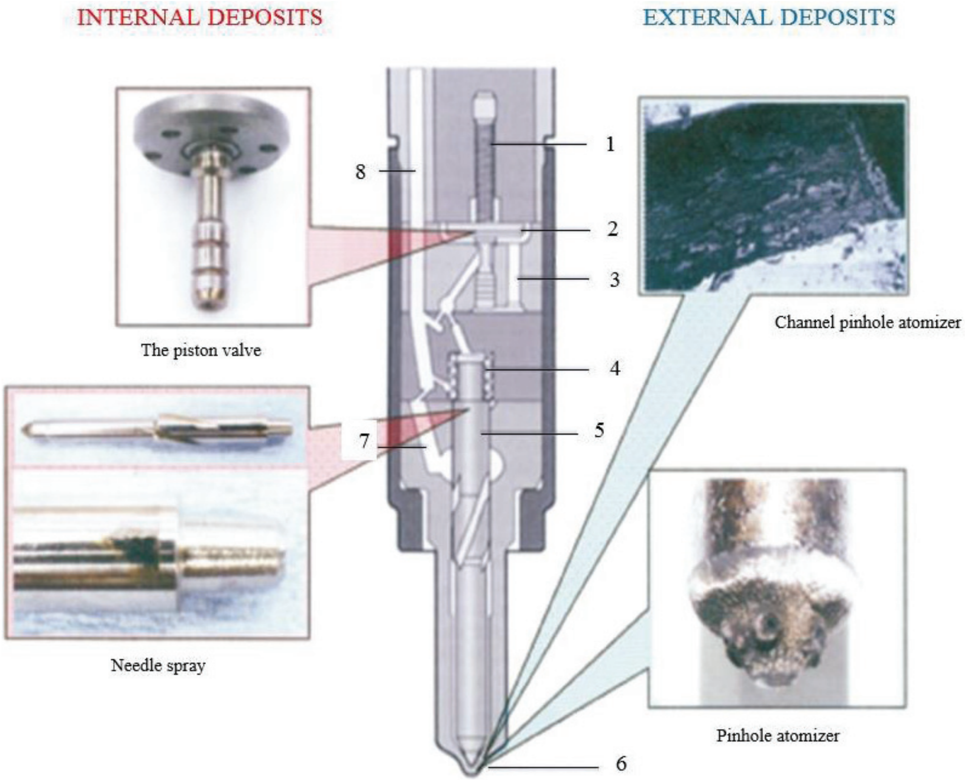


Fig. 1 The cross-section of injector with area where deposits occur on external and internal areas [2]: *1* - spring solenoid valve; *2* - control valve; *3* - fuel drainage channel; *4* - fuel distribution control chamber; *5* - needle spray, *6* - hole spray; *7* - prechamber

3. Additives for Fuels

Many additives are available on the market that improve the physicochemical properties of diesel fuel or gasoline. They increase the cetane number, lower the cold filter blocking temperature, remove carbon deposits and contamination from the injection system or raise the exhaust gas temperature to facilitate the regeneration of the particle filter. In the present study, the influence of the additive of the following composition was analyzed [4]:

– hydrocarbons (C10-C13, n-alkanes, cycloalkanes) in a concentration of 60-80%;
– 2-ethylhexyl nitrate at a concentration of 5-15%;
– 2-ethylhexanol at 1-5% concentration.

The tested additive according to the manufacturer's recommendations is used to remove impurities from the entire fuel delivery system - from the fuel tank, pipes, fuel filter, injection pump to injectors.

4. The Test Bench

The test bench, built according to norms BN74/1340-12 and PN-88/S-02005, was used for testing. Test bench has the dynamometer connected to the turbocharged four-stroke, four - cylinder, in-line directly injected compression ignition engine Perkins 1104C-E44T. The engine meets the emission standards of EU Stage II/U.S. EPA Tier 2. The test stand was equipped with the system for quick-exchange measurements with Schenk instruments and included the devices for recording fuel consumption and the AVL CEB II exhaust-gas analyzer was used as well. Figs. 2 and 3 present the diagram of the test stand and Table 1 presents the parameters of the tested engine [12].

Within the framework of the empirical studies, the measurements of emissions of harmful substances before and after the process of cleaning the injection system using the fuel additive was carried out. The cleaning process was carried out according to the additive manufacturer's instructions, i.e. the engine worked under variable loads until it consumed 50 liters of diesel fuel with additive. After the end of cleaning process, the engine run for one more hour in order to minimize the appearance of the additive residue in the fuel delivery system after the main test was done. During experimental research the measurements were made and collected data allowed to get the load characteristics for two crankshaft rotation speeds namely 1400 and 2200 rpm. The speed characteristic of the engine was also plotted in the range of crankshaft rotation speeds from 1000 to 2400 rpm. Each measurement was done ten times, and resulted plots show their averaged results. The tests were taken in accordance with ISO 15550 standard used for testing on brake test benches.

Table 1

Main engine parameters

Engine type	Perkins 1104C-E44T
Engine capacity	4400 [cm^3]
Cylinder bore	105 [mm]
Piston stroke	127 [mm]
Numer of cylinders	4
Max power	73,47 kW at 2300 rpm
Max torque	415 Nm at 1350 rpm
Specific fuel consumption at max power/max torque	223/219 [g/kWh]
Injection pump	Bosch VP29/30

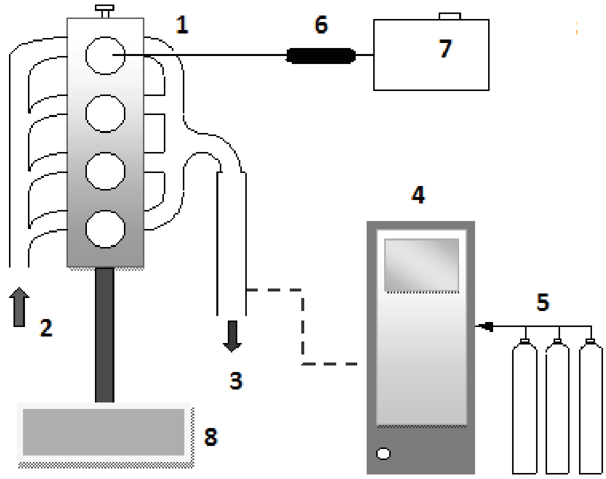


Fig. 2 Block diagram of test bench: *1* - Perkins engine; *2* - air inlet; *3* – exhaust; *4* - AVL CEB II exhaust gas analyzer; *5* - calibration gases set; *6* - fuel flow meter; *7* - fuel tank; *8* - eddy current engine brake

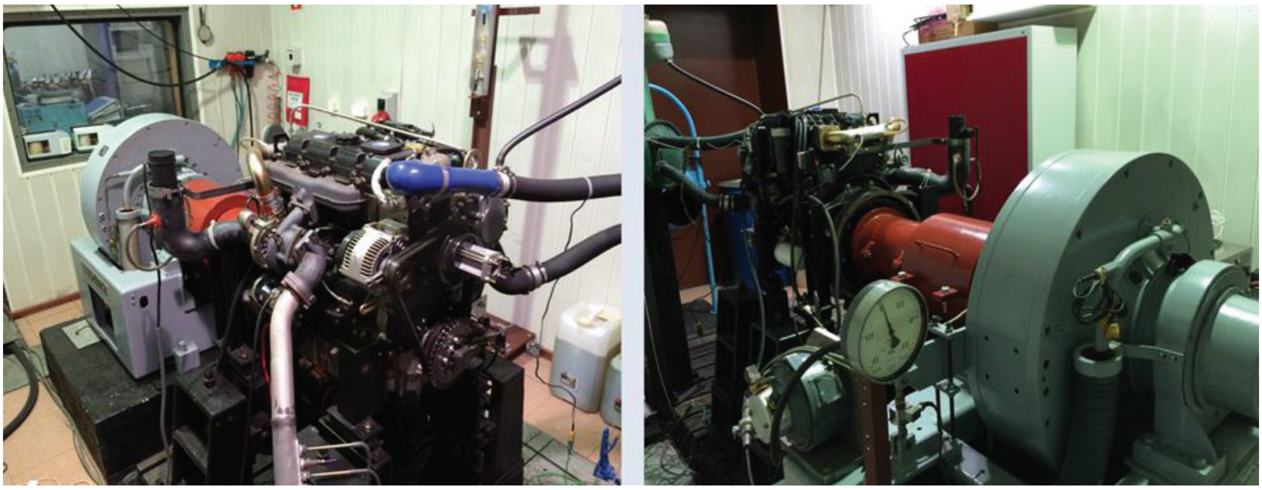


Fig. 3 The test bench

5. Results and Discussions

The main results of the study are shown in Figs. 4-17. Due to homologation and environmental reasons, the focus was primarily made on selected toxic components in exhaust gas [14-17]:

- hydrocarbons (HC) - are easily absorbed through the skin and respiratory tract. These compounds are characterized by very low surface tension and therefore even small amount of them can cover the surface of the skin or the lungs. These are lipophilic compounds characterized by high affinity for adipose tissue. This makes it easier for them to pass through the brain and cell barrier. Hydrocarbons dissolve body lipids, and thus neurons and cell membranes, leading to damage and inhibition of the nervous system, general anesthesia, seizures and coma;

- total nitrogen oxides (NO_x) - cause general weakness, dizziness, numbness of the extremities, cyanosis, weakening of the heart rate, change of blood and skin color and as result the death of the body;

- carbon monoxide (CO) - is absorbed by the body from the respiratory tract in an amount depending on the concentration in the air, exposure time and degree of lung ventilation. The toxic effect of carbon monoxide is in its ability to bind to blood hemoglobin and, in addition, to increase the stability of hemoglobin to oxygen connection;

- particulate matters (PM) - causing chronic respiratory disorders, also showing carcinogenic effects. In the case of high concentrations PM become irritating to the mucous membranes of the eyes and respiratory tract; also they can cause pain, dizziness and fatigue.

The torque curve and the fuel consumption dependences for the experimental engine running according to speed characteristic are shown in Fig. 4 and Fig. 5, respectively.

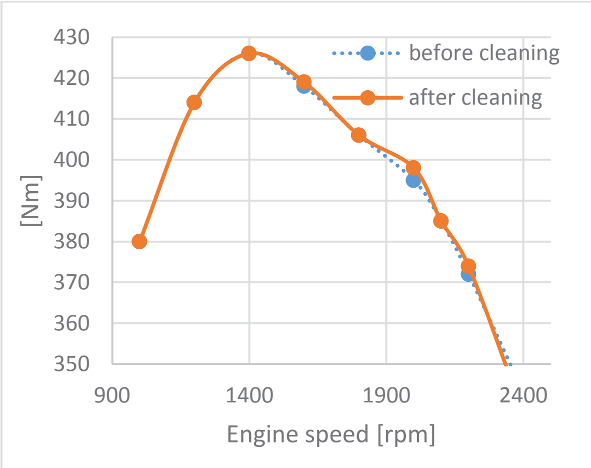


Fig. 4 Torque curves

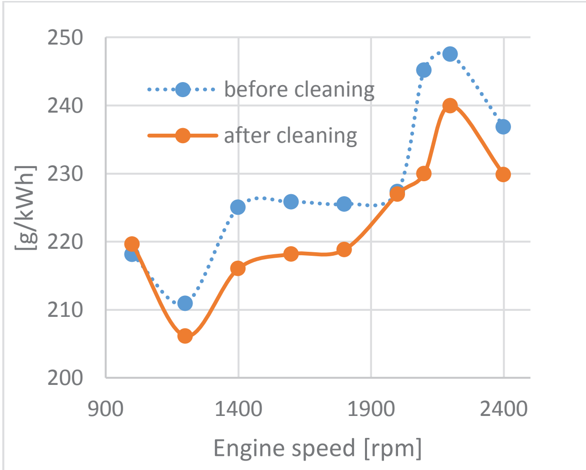


Fig. 5 Brake specific fuel consumption as function of crankshaft rotation speed – speed characteristic

The concentrations of nitrogen oxides NOx in exhaust gas are shown in Figs. 6-8 respectively. Concentrations of hydrocarbons and PM are shown in Figs. 9-11.

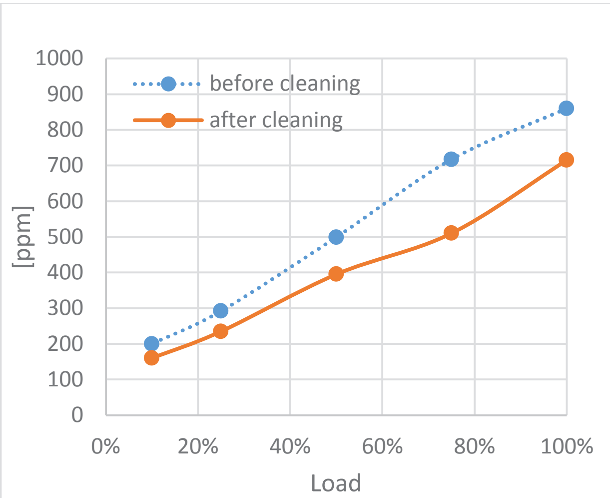


Fig. 6 Concentration of nitrogen oxides NOx – load characteristic at 1400 rpm

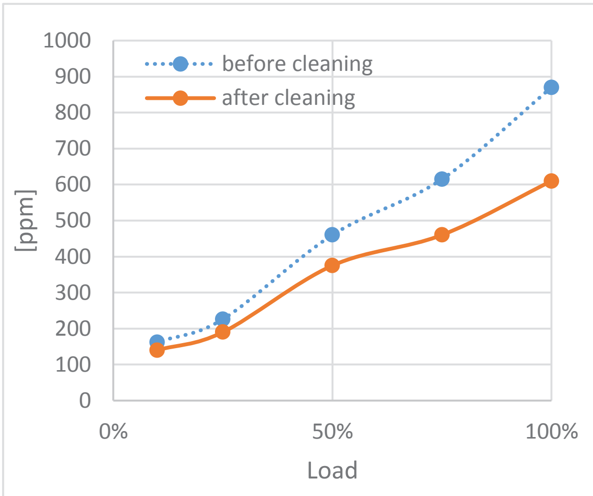


Fig. 7 Concentration of nitrogen oxides NOx – load characteristic at 2200 rpm

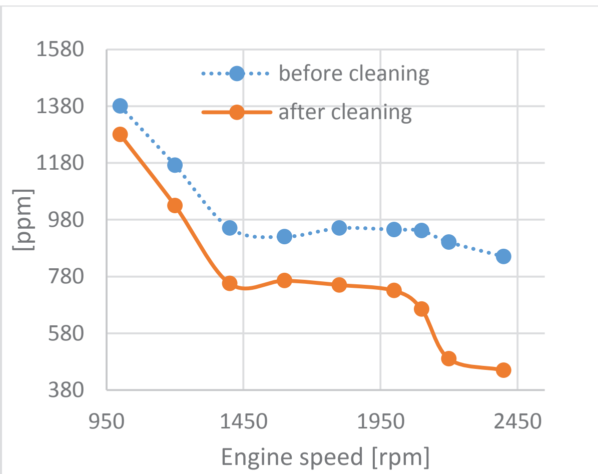


Fig. 8 Concentration of nitrogen oxides NOx – speed characteristic

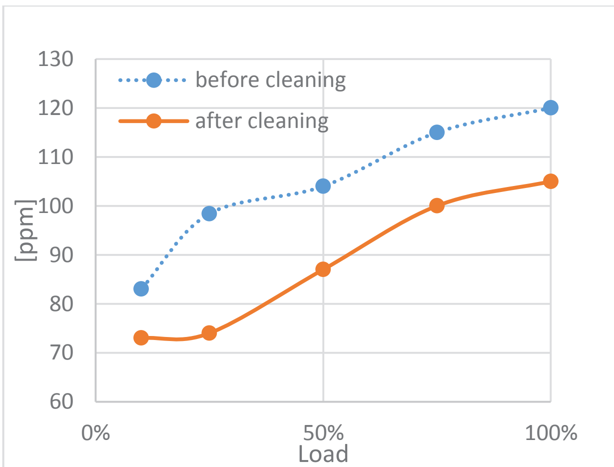


Fig. 9 Concentration of hydrocarbons HC – load characteristic at 1400 rpm

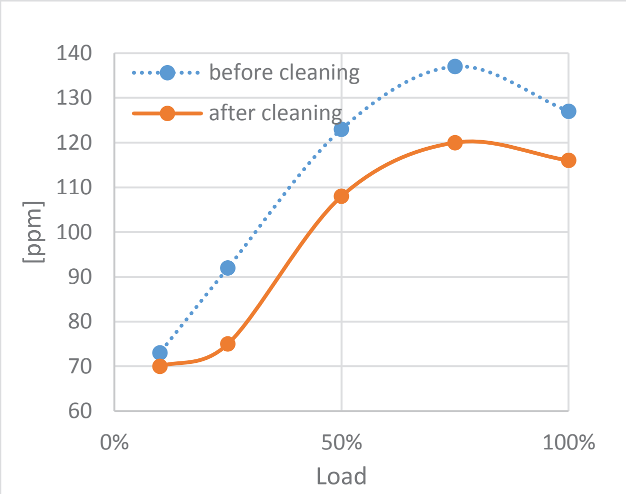


Fig. 10 Concentration of hydrocarbons HC – load characteristic at 2200 rpm

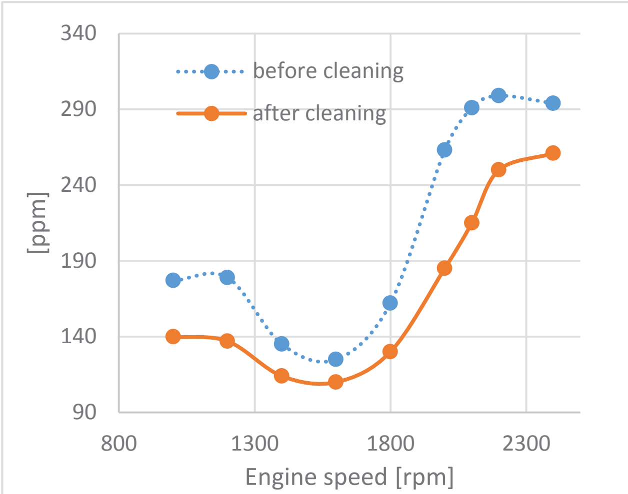


Fig. 11 Concentration of hydrocarbons HC – speed characteristic

Concentrations of carbon monoxide are shown in Fig. 12 – 14. During experimental research dependences for emissions of particulate matters were also obtained.

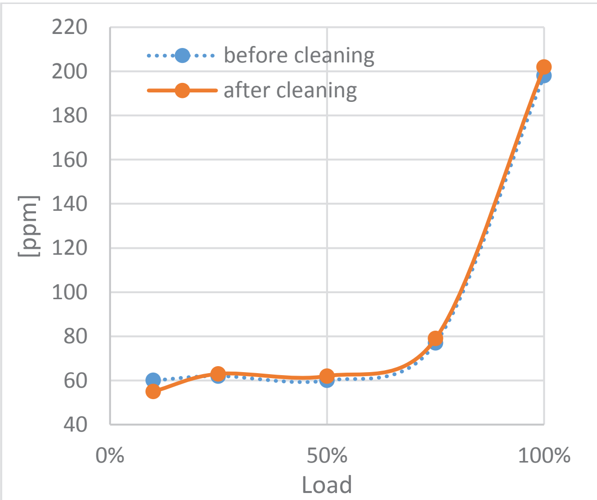


Fig. 12 Concentration of carbon monoxide - load characteristic at 1400 rpm

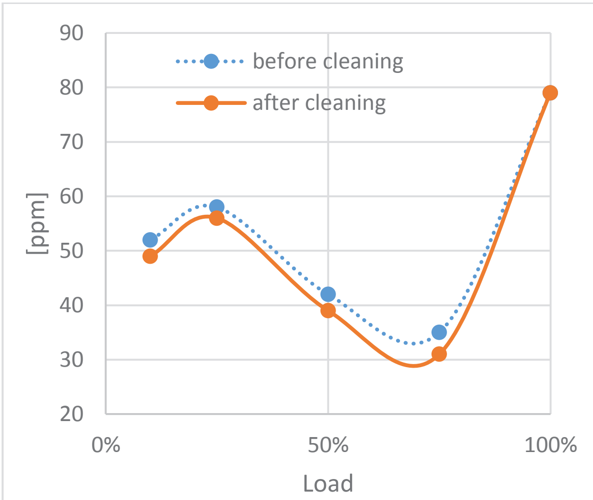


Fig. 13 Concentration of carbon monoxide - load characteristic at 2200 rpm

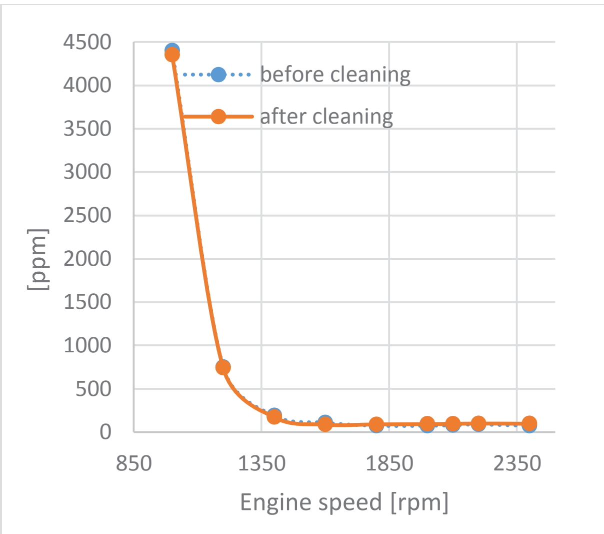


Fig. 14 Concentration of carbon monoxide - speed characteristic

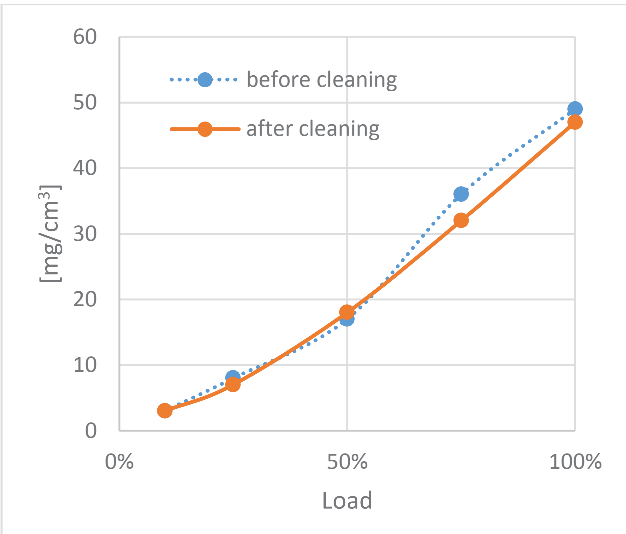
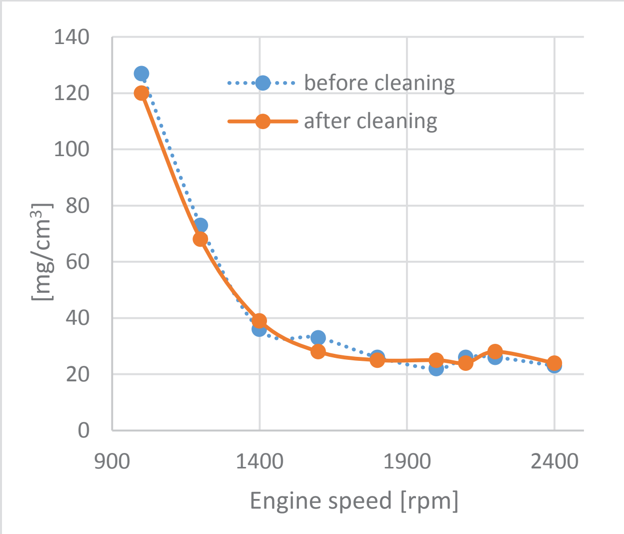


Fig. 15 Emission of particulate matters PM – load characteristic 1400 rpm



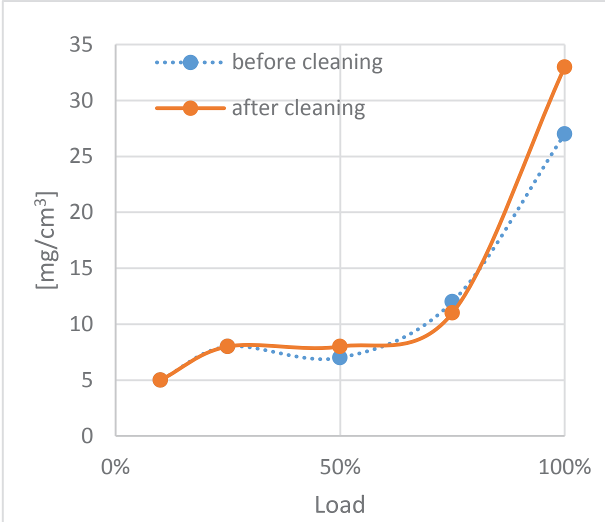


Fig. 16 Emission of particulate matters PM – load characteristic 2200 rpm

Fig. 17 Emission of particulate matters PM – speed characteristic

6. Conclusion

The analysis of the torque curve (Fig. 4) shows the lack of influence of the regeneration process of the fuel delivery system on the torque. In the case of fuel consumption (Fig. 5), there is a clear reduction in fuel consumption and thus a positive effect of the regenerative chemical process on this parameter. Such influence can be explained by improvement in combustion process and higher engine efficiency as result. By analyzing the dependence of nitrogen oxide concentrations, it can be seen that in some cases this parameter decreases by as much as 48% (Fig. 8). On average, however, it drops by about 20%. The maximum detected decrease in hydrocarbon concentrations was 27% (Fig. 9), while for carbon oxides the level of emissions dropped by 12% (Fig. 13). Concentrations of particulate matter remained at a comparable level, but their growth was noticeable when the engine was running at increased load and almost maximum crankshaft rotation speeds. This may indicate that deposits were still separated from the fuel delivery system surfaces even after the cleaning process was finished.

So, the charts presented in Figs. 4-17 show clear evidence of effectiveness of the fuel additive used and its positive effect in terms of the environmental impact from the engine by reducing the concentration of selected toxic components in exhaust gas. Therefore, it is advisable to use periodically such additives to clean the injection systems in compression ignition engines. In addition to the reduction of toxic emissions, the extended life cycle of the diesel fuel injection system components will be reached and consequently the reduction in failures during operation of this engine can be predicted.

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Change Management in the Context of the Social Responsibility of the Transport Company

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Abstract
Change management is a prerequisite for the successful operation of road transport undertakings. Many changes in the external environment significantly affect the business of road transport and management of these enterprises must timely respond to them. The problem with the current management is to unwillingness and reluctance to introduce changes in the company due to rigid management mode. Managerial work becomes more demanding, modern equipment managers to include modern management methods and tools. Changing world of work brings new risks and requirements for human resources management with special emphasis on the social aspects. Competitive nature of the transport sector leads to a potential conflict of interest between the support of the social aspects of human resource management and commercial pressures facing businesses. The aim of this paper is to analyse the changes in the management of the transport company in the context of social responsibility focusing on its internal dimension, identification of the most important problems and proposing solutions.
KEY WORDS: *change management, social responsibility, human resources, transport company*

1. Introduction

The organization and quality of transport activity affects the functioning of the entire national economy of the state, its socio-economic development and the growth of living standards. Transport creates the conditions for optimal use of economic and social potential; Enables and supports the free movement of persons, goods, the free provision of services and the free movement of capital, which creates the conditions for the functioning of the single EU internal market. Transport holds a key role in globalization; within the transport system, priority is given to road transport, both in passenger and freight transport.

Road transport is a flexible mode of transport, but it is linked to a number of negative sites. There is a lot of competition that is characterized by demanding investment costs and also operational costs, especially fuel costs. Many issues are related to emissions, congestion, accidents, infrastructure wear and energy claims. Nevertheless, the importance of road transport on the transport market is increasing. Due to the more flexible adaptation of road transport to changing economic conditions, it is possible to assume that the volume of transport and transport performance will tend to increase due to its ability to respond quickly to the needs and trends in the transport of goods. Personal passenger transport is also expected to increase passenger road transport.

For the ever-increasing importance of transport from the point of view of global trends, it is necessary to pay attention to the carriers and thus also to the road transport undertakings. In the 21st century, enterprises compete in a complex and challenging context of globalization, new knowledge and technical development. The management of road transport companies is exposed to difficult tasks in the current turbulent environment to ensure competitiveness under difficult external conditions affecting the operation of the business, whether strict rules on access to the road transport market or the strong influence of globalization and its accompanying phenomena.

A modern enterprise management approach requires a new understanding of management in the context of its internal and external elements. However, more specific approaches, methods and techniques are needed to apply management in specific transport conditions. These are essentially based on general knowledge, but they must be transformed and, in particular, adapted to more realistic practice conditions. Businesses must learn to use future opportunities as well as being able to manage the current ones. This requirement requires a new approach - companies need to find new sources of competitive advantage and engage in a new competition. Management must have an idea of the potential sources of competition and the nature of the environment in which it operates. However, it is important to address mainly those influences that are essential to the enterprise in terms of enterprise prosperity. [1, 2]

Change management is one of the most important elements of successful corporate management, and now emphasis is put on managing change in the context of corporate social responsibility. The aim of the paper is to highlight the current problems of transport company management in the era of change and to propose measures for system approach in this area of management.

2. New Approach of the Sustainable Transport Company Management

As a result of a modern approach and change in company management philosophy, new principles are introduced to create and maintain a thriving business. The goal of the new approach is not only to increase business performance but also to change corporate culture to influence people's thinking and behaviour so as to create an environment that perceives change as a positive phenomenon. It should be emphasized that the hard and soft elements of company management change. We consider the hard elements to be the methods and techniques used, the soft leadership of people and their behaviour, the working conditions and the corporate culture.

For business management under conditions of critical change, it is recommended to emphasize:

– Human capital in all areas of the enterprise and the creation of motivated working teams able to adapt to rapid development;

– The customer and the ability of the business to uncover and respond to it;

– A favourable environment in the enterprise for the adoption of changes by employees and exercising leadership;

– Efficient management systems and tools, using modern information systems and technologies.

2.1. Problems of the Future

Globalization brings new markets, new products, and new way of thinking, new skills and new insights into entrepreneurship. Effective global competition requires more than just creating a product on the domestic market and shipping it to new markets. A comprehensive network of global centres based on technologies used worldwide is needed; rapid movement of products, people, information and ideas to meet local needs; Managing and managing the paradox of global mass economics and local responsibility. It requires a global way of thinking and local loyalty, a sense of commitment - to think globally and act locally. [3]

The problems of the future can be characterized as follows:

1. Value chain for enterprise competitiveness

Businesses must be able to respond to customer needs through innovation, faster decision making, leadership in terms of price or product value; Effective links and links with suppliers and retailers, businesses will strive to create an optimal value chain for the customer.

2. Profitability by reducing costs and economic growth

The paths to achieving business profitability change. While profitability needs to be driven by a combination of rising sales and declining costs, consideration must be given to slimming, reducing the number of driving levels, increasing productivity, reengineering, and focusing on quality. It is necessary to do more with smaller resources, improve processes and reduce costs.

3. Customer orientation

Customer focus does not lose importance; the company's efforts to create new products and the fundamental knowledge of research are at the forefront.

4. Development of new technologies

Technological innovation has a major impact on business management; have changed their use of information flows; Information and ideas have become a modern payment; Intellectual capital becomes an important factor of competitiveness. This involves raising the level of leadership - leadership. Classical measures and business success rates focused on economic capital must be complemented by measures and indicators of intellectual capital.

It follows that the nature of competition is changing. When competition is defined as a unique way of adding value to a customer, businesses need to find new and unique ways to serve their customers. The path to success must lead further to the creation of new production processes and customer relations; Organizations need to be built that change, learn, move and act faster than competition [4].

2.2. Changes in the Company Environment

Under the current business environment, proactive management needs to be applied in the company's business, allowing it to reduce the negative aspects of the changes and the resulting risks on the one hand and, on the other hand, to help create new attractive business opportunities. Changes in the external environment trigger changes in the enterprise's internal environment; Operational, management, and other processes in themselves represent real-time changes while running under changing circumstances. Changes take place over time and in interaction; some changes emerge suddenly, we are talking about the so- Breakthrough changes - discounts. Keeping track of changes over time is interesting in terms of anticipating them.

Road transport enterprises, like all other business entities, are exposed mainly to the following changes in the external environment:

– National economies and their organizations are increasingly being integrated into the global economy. The Slovak Republic is a member of the European Union. Business is influenced by new "players" like China, India, Brazil strengthening the positions and interventions of multinationals and financial capital. Business activities are moving to more cost-effective countries. It raises workers' migration between less and more developed countries. New centres of conflict are also emerging.

– There is a growing supply of demand. Consumers take advantage of domestic and foreign offer; availability of goods is increasing, thereby increasing the role of transport. The advantages of international cooperation are associated with problems of resource dependence, the rise of oil prices, and so on.

– There are political changes in the world, outbreak of resentment, threats of war, and political risks. These often relate to the risks of modern markets, case of oil shock.

– The frequency of sudden changes and their negative impacts on the business environment, which are very difficult to face, is increasing. An example of this is the emergence of a global economic crisis that has also had an impact on road transport business.

– Growing domestic and foreign competition, the new concept of "hyper-competition" is being used. Businesses seek to maintain a competitive advantage in parameter values of product or service value metrics, leading to a shorter life cycle. Increased efforts are made to save costs, delivery times, improve the quality of the services provided. There is a competition of competition and competition, referred to as "co-opetition". [5]

– The pace of science and technology development is accelerating; both national economies and businesses must be involved in the changes brought by those who bring innovation. Even in the area of road transport business, it is necessary to respect these changes, Development of telecommunications, software, hardware, robotics, automation, progress in the development of automotive and communication technology, and so on. Innovations are costly and road transport companies are hardly co-operating with the rapid pace of their deployment to maintain their competitiveness or to meet new legislative requirements if some technological changes are required by law [6].

– The sustainability of current turbulent development requires the protection of the environment, and the role of ethics and morals in managerial work. Business management is strongly affected by these aspects; it must pay attention to the ecological behaviour of the company and its behaviour towards society. Businesses must respect the requirements of energy saving, their alternatives, air protection, as well as the challenges of people's torture in society - protecting employees from the negative effects of work, fighting discrimination, corruption, unfair competition, and so on. Together, these factors are referred to as Corporate Social Responsibility. The European Commission defines it as integrating social or environmental interests on a voluntary basis over statutory requirements. [7, 8]

In relation to the activity of road transport companies, we can talk about sustainable mobility. Changes in the external environment are interconnected, interacting, increasing the chaos of the business environment. Business management needs to focus on this situation, evaluate all the circumstances, and make the right decisions to maintain a successful existence on the market. Top management managers should ideally permeate the nature of these changes, know how to analyse them, understand the mechanism of their origin, and how they interact.

For business management under conditions of critical change, it is recommended to emphasize:

– Human capital in all areas of the enterprise and the creation of motivated working teams able to adapt to rapid development;

– The customer and the ability of the business to uncover and respond to it;

– A favourable environment in the enterprise for the adoption of changes by employees and exercising leadership;

– Efficient management systems and tools, using modern information systems and technologies.

All internal changes are connected with modern management tools respecting social responsibility and system approach.

2.3. Change Management as a Project

All institutions live and work in two time periods: today and in the future. The future is formed today, in most cases irrevocably. Managers therefore have to manage today as well as tomorrow. In dire times, managers cannot assume that tomorrow will be an extension of today. They must work towards change; to change as an opportunity and to change as a threat. [9] Business Change Management is to be understood as a project where it is necessary to follow the following steps:

- Define the target and the partial objectives;
- Identify people, their roles and responsibilities, Agents of change;
- Establish forms and extent of communication;
- Develop a timetable.

Project management is perceived as a very necessary article of an operating organization. It can be used very efficiently not only for investment, research and organizational projects, but also for building a business strategy. The corporate strategy determines the basic direction the company will take, and thus affects investment, research, and organizational decisions. 6 An indispensable component in creating projects is communication between team members and between the team and the environment. [10, 11, 12] Successful project management cannot abstain from any of the following: preparation and planning, start-up, people selection and management, control and change, evaluation and termination. Initiation Preparation is meant to provide information, material and other needs, it is the elaboration of a project plan, where not only the goal has to be set, but also the steps that will lead to its achievement. Project management is conducted by a team of people, and the selection of the right members is crucial to the success of the team. Once the project has been implemented, it must, of course, be reviewed and evaluated. The changes allowed by the project must be analysed in terms of their contribution to the area for which the project was implemented. Phases of the project:

Phase 1: Preliminary planning (Defining the basic terms and conditions of the project; determining the feasibility of the project.

Phase 2: Detailed planning (Preparing a detailed summary of project needs; setting a schedule of tasks and resources. Phase 3: Implementation (Monitoring and control of work progress; documentation of work progress; modification of the plan in case of recognized changes in the work process.

Phase 4: Completion of the post-project project (presentation of the final report; performing stakeholder evaluation on the project; processing historical information.

Successful change requires adaptation of methods, techniques, strategies, and implementation tactics to specific history, culture, and people in the organization. The change process is very complex, but there are models to make the change.

3. Corporate Social Responsibility as a Change

We can see CSR also from the change point of view.

3.1. CSR in the Sustainable Development of Company

One of the well-known definitions of the concept of social responsibility is created by the European Commission, The Green Paper defines the concept of CSR as a voluntary integration of social and environmental aspects into day-to-day business operations and interactions with corporate stakeholders or as a concept where businesses voluntarily choose to contribute to a better society and a cleaner environment. The European Commission furthermore identifies the following features of the concept: It is intrinsically linked to the concept of sustainable development, business Integrate economic, social and environmental impacts into their own day-to-day activities.

The CSR concept is a voluntary behaviour of companies, and therefore goes beyond the legal requirements, as businesses are primarily pursuing a long-term goal. It is a management method; it is not an optional supplement to the main business. [13, 14]

As one of the most prominent authors of the CSR concept, Caroll (1999), in his work The Pyramid of Corporate Social Responsibility defines the levels of corporate responsibility, while at the core of the pyramid he places the responsibility and responsibility of the company to produce acceptable returns for shareholders.

Caroll further defines CSR as the commitment of the entrepreneur to take such decisions and implement procedures that are desirable in terms of the values and objectives of the company.

It is also important to emphasize and identify sustainable human resource management as a new approach to management. Thanks to the sustainability of human resources, the organization continues in the long run. It is also known that such management contributes to the positive effects of the organization's environmental behaviour but also to better socio-humanitarian results. In an effort to promote sustainable development, the organization will have to adapt to business sustainability, which means that corporate success is not limited solely financially, but also in terms of social justice and environmental integrity.

CSR remain marginal interest to human resources professionals even though they are ideally well placed to develop organizations by promoting trust based relationship with employees as well as with stakeholders.

At the level of economic and legal responsibility, the ethical responsibility, the highest level of the pyramid, constitutes a discretionary responsibility that represents the proactive strategic behaviour of the company in the context of sustainable *development.*

The model of the three basic pillars of the Triple-bottom line consists of:

1. Economic pillar:

Organization and its employees avoid corruption and behave ethically in corporate governance: organizations have adopted and applied the principles of good governance.

Organizations are credible, transparent. Relationships with customers and suppliers are correct; attention to ethical and ethical considerations is devoted to the creation of the supply chain.

Behaviour of Owners and Shareholders: Respect for Intellectual Property Protection, Innovation and Sustainability, Compliance with the Rules of Fair Competing.

2. Social pillar:

Creating work conditions: Work-life balance and Human resources development.

Outplacement: the company takes care of retraining redeployed employees, their further application, and offers other types of assistance.

Employee policy: adequate wages, social welfare and others

Benefits beyond legislation: Respecting the principle of equal opportunities. Fight against mobbing, harassment, humanization of work, rotation of work protection and health care and other.

3. Environmental pillar:

– Reducing of negative environmental impacts.
– Creation of ecological policy of the company, eco-friendly production, products and services.
– Environmental management, compliance with national and international standards.
– Investment in environmental technologies monitoring of the impact on the environment.
– Inclusion of environmental principles into supplier and customer selection and others.

3.2. Perception of Change and CSR Management in Transport Companies

In our survey of the need to manage change in relation to the requirements of social responsibility, which was attended by 76 transport managers, 42% of the respondents did not meet the definition of this issue. Within the management, the following priorities were set in order:

• Transport legislation
• Procurement of all products and services with respect to the environment
• reducing water consumption as well as energy-efficient hot water preparation
• Reduction and prevention of waste
• Reduction of fuel consumption
• Optimizing energy consumption through software that automates manages and optimizes building management.
• Environmental training and motivation of employees to activities that contribute to its protection
• Travel that saves natural resources
• Compliance with environmental legislation
• Compliance with social legislation
• Education of drivers of freight transport in the field of ecological and defensive driving
• Optimized transport planning that reduces empty kilometres

Only 22% of respondents can imagine a systemic solution to the issue of driving a transport company with regard to social responsibility. 78% of respondents see the socially responsible management of the transport company in strict compliance with the legislative standards applicable to this area of business. Practice shows that only a system approach can ensure the sustainable operation and development of an enterprise, so we suggest the following measures.

3.3. System Approach Measures

Within the Triple-bottom line, the economic sphere is referred to as profit, the social sphere as the people, and the environmental sphere represents the planet. Consequently, they create the 3P concept.

Corporate Social Responsibility can be introduced into business through Comprehensive Quality Management. Within the EFQM model of excellence, it evaluates results in relation to the company, at local, national and international level. In order for the company to achieve excellent results in this area, it must create the preconditions for achieving it. The EFQM model builds on the ISO 9000 certification system, focusing on enterprise process management, measuring the results of these processes, and continually improving. However, when defining approaches, it has a much looser framework than the requirements set by ISO 9001.

ISO 26000 in the latest edition of ISO 26000: 2010 is an international standard in the field of social responsibility counselling. The guidelines are based on good practice developed both as a private and public sector. By integrating these expertise and practices, the standard defines organizations as they need to deal with in a socially responsible manner. After completing the course recommended prior to the introduction of ISO 26000: 2010, it will be familiar with the chapters of the standard and also with all the necessary requirements. The main topics addressed by ISO 26000 are as follows:

• Managing and managing your organization.
• Human rights.
• Practices in the field of employment relations.
• Environment.
• Business Ethics.
• Consumer issues.
• Communication engagement.

ISO standard 26000 is a voluntary standard for all types of organizations, regardless of the size or location of the company.

SA8000: 2008 is an international standard that primarily regulates and monitors employee working conditions, and is used to certify the organization's independent judgment to meet the requirements of this standard, its legislation, and its own work environment requirements. The system under this standard introduces companies that want to declare that they pay due attention not only to the quality of management but also to the health and safety of workers and the appropriate conditions for their further development in work and personal life.

Because of the lack of legislative requirements for businesses, corporate social responsibility is becoming an increasingly serious tool for tackling welfare issues across society. Since, as mentioned above, this is a voluntary concept, procedures and points of implementation are only recommendations. It is therefore a matter of considering any company that decides to implement CSR in its processes to choose a procedure that will correspond to its corporate culture as much as possible. The aim is to choose such a procedure, taking into account the specificities of change management, which the employees receive with the greatest possible probability. We can recommend the following steps and principles for implementing CSR in company strategy:

1. CSR is based on the top: implementation of CSR in company strategy requires support from the top management firm. Top management uses CSR in internal and external communications and integrates it into the company's statutes.

2. Responsibility of the person responsible: appointment of the CSR manager, who takes responsibility for introducing CSR into today's company strategy and communicates across-the-board concepts, is in close contact with all departments, conducts effective dialogue with individual stakeholders. It compiles annually a CSR report that reflects the company's social, economic and environmental approach.

3. Identifying Key Stakeholders, vision and goals: The goal is to convince stakeholders to cooperate and get

feedback.

4. Integration of CSR into company processes.
5. Communication CSR and Feedback.
6. Maintain CSR in the long run.

4. Conclusion

In order to survive, each transport company must constantly adapt to the circumstances and events that occur in its immediate and surrounding environment. In order to ensure not only survival but also the further development of society, it is necessary to make adjustments and to overcome the problems associated with change. So the companies have a major responsibility to take more initiative and motivate everyone on the organization to meet the challenges of future. Every day, presents new challenges for transport companies to succeed in their endeavour for improving profits of organization and improving the wealth of stakeholders. How managers adopt to the changes in the horizon can make the difference between surviving and thriving. The credibility of corporate social responsibility is depending on effective delivery of communication about the changes in the company that are taking place in company for the wellbeing society. Managers who are holding very high social responsibility play a vital role in the development and implementation of changes in company which leads to better image and better brand name.

Transportation at all levels is focusing not only on facilities but also on dealing with policy issues, system management and preservation, operation, performance, customer needs and issues, financial and fiscal efficiency, the environment, and liveability. The systems management approach is evident in many areas; transport managers at all levels are applying new management techniques to a range of transportation assets in response to public, agency, and legislative expectations, agency's financial capacity, human resources, equipment and materials, real estate, and corporate data and information. Change management from social responsibility aspect is also a challenging human resource issue for any manager; it's imperative for managers and those with leadership responsibility. A significant difference in the understanding of social responsibility is the application of a system approach within a business.

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VEGA 1/0696/16 Design of methodology for measuring quality of life in a regional context

VEGA 1/0244/16 Personnel marketing as a new approach of the ensuring and maintaining the skilled workforce in Slovak companies

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Tracking of Water Transport to the Fire

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Abstract

Transport water to fire is one of the main tasks of fire brigades. Their training environment is difficult for the instructor and the fire brigade itself. The correctness of the implementation activities training ground in preparation units is currently done through direct participation play in space with the unit. Using modern technology, it is possible to control these activities in a safe area. The article describes ways to use RFID technology and technical resources for training fire brigades in the area known for the instructor directly related to transport water to the fire.
KEY WORDS: *safety, pedestrian's safety, safety equipment's, active suspension, damping*

1. Introduction

Communication through wireless devices is currently used in each area of modern technology. The most common technologies that use active and passive information's transmission about objects (processes) are RFID and NCF technology. The article describes the possibilities of using RFID technologies in the field of fire protection. It contains a general description of RFID technology and NFC technology and the principles of their operation. As this is not a new technology, it contains a description of the available applications in fire brigades. It includes suggestions for possible use of NFC technology in fire departments for water transportation and technical marking and fire brigade kits.

2. Radiofrequency Identification System

Radio Frequency Identification (RFID) is a technology for the identification of objects using radio frequency waves (Fig. 1). The information is stored in electronic form in small chips / tags that allow reading and writing of this information using readers. Similarly as with barcodes, the information is recorded on a data carrier - RFID tag, which contains a small chip with antenna and memory. Each RFID tag contains so-called EPC code (Electronic Product Code), which is the unique serial number of the tag [1].

The basic segmentation of RFID tags is for active and passive chips. Active chips transmit data to the environment, TTF (Tag: Talks First), which allows miniature battery in the chip. Passive chips are cheaper and use RTF (Reader Talk First) method. Semi-pass tags have an internal power supply, which is used for powering the integrated circuits, or to store energy sent by a reader for use in future communications. Semi passive chips have up to 100 × greater sensitivity than passive chips. Increased sensitivity allows greater communication distances (10 × more than passive tag).

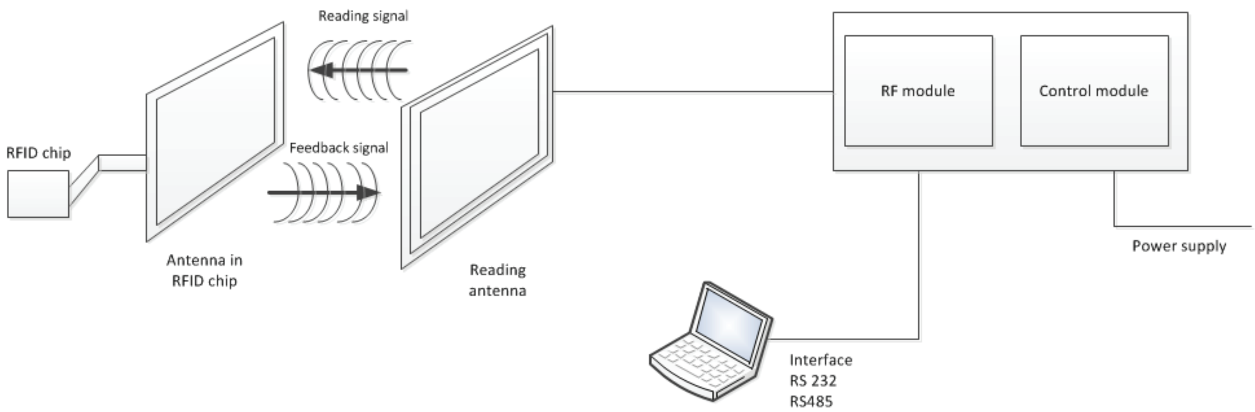

Fig. 1 Principle of passive RFID tags [1]

Based on the bandwidth in which individual RFIDs and systems work, they divide them into low-frequency systems and high-frequency systems (Table 1).

Table 1

Frequency band parameters, advantages and disadvantages systems [2, 3, 4]

Band	LF	HF	UHF	MW
Length	125-134 MHz	13,56 MHz	860-960 MHz	2,45 GHz, 5,8 GHz
Transfer speed	Low	Medium	High	Very high
Benefits	Resistance to interference, can be read through liquids	Higher speed and lower cost than LF, can be read through liquids	Resistance to interference, anticolising system, reach 1-6 meters	Great deal of information, resistance
Disadvantages	High costs, short range	Low interference resistance, range up to 1 m	Low resistance to environmental effect, problems in water use	Need visible distance
Typical applications	Access control systems, livestock monitoring	Access control systems, libraries	Tracking of packages in logistics, post	Toll systems

There are 3 basic types of tags by the data storage:

- Read-Only tags (RO) – designed only for reading. They are programmed once in production without the possibility of transcription. Their memory is from 40 to 512 bits.
- Write Once Read Many tags (WORM) – designed also only for reading. However, the tag is not programmed in the production but only when it is applied. Memory from 40 to 512 bits.
- Tagy RW (angl.: Read Write) - tags can store large amounts of data (passive tags from 386 to 8 Kb, active tags 16 kb to 2 Mb) and have rewritable memory (up to 1000x).

EPC code structure – serial number in the tag:

- 8 bit header, EPC version number,
- 28 bits – manufacturers information,
- 24 bits – product class,
- 36 bits – unique product number [3, 4].

3. NFC Technology

Near Field Communication (NFC) is an electromagnetic wireless technology used to communicate between two devices. Communication takes place at very short distances. NFC technology is a wireless connection between two devices. The major difference and advantage of NFC technology is the fact that it does not need pairing of two devices like a Bluetooth technology. After place two devices at a distance at least 4 cm (working within 10-20 cm but at least 4 cm is secure data transfer), the devices will begin to communicate immediately. The communication is in the band 13.56 MHz and the transmission rate is in the range of 106-424 Kbit/sec. RFID technology also operates in the 13.56 MHz band, so that NFC devices can communicate with RFID devices. The transfer is "Half-Duplex". At that one moment is one device as a transmitter and the other as a receiver or contrariwise. It is not possible to receive and transmit data at any time. An advantage is the energy saving of both devices. NFC devices use their own open source protocol. NFC technology is divided into:

- Active devices (tags) - Devices alternate in signal transmission (read/write). They have their own power supply.
- Passive devices (tags) - The device is powered by the electromagnetic field of the transmitter. NFC tags work on this principle.

NFC tags can store digital content in text, URL, images, short videos, and more up to 32 kBytes [3, 4].

4. Rfid in Firedepartments

The use of RFID technology in the preparation of rescue units is versatile. One area of application is water transport to fire, using fire hoses marked with tags. By correctly deploying the active elements of the system in the vicinity of the intervention (training places), the commander (supervisor) is able to get a precise overview of the practice of the trainees in a dangerous fire environment, without risk. In the training area it is possible to assemble a network of active elements, precisely located in the space. The created 3D space precisely specifies the location of the firefighter with a tag in the smoke area. Another advantage of the system is to verify the correctness of the procedure of the interfering unit, with respect to the position of the trainer in the space and the tagged resources of intervention intended for fire intervention [5].

The efficiency of the proposed solution is confirmed by the real use in the aforementioned cases by fire units in the USA. As part of the water transport training, it is possible to track the overall route in the monitored field (area) practically on-line and evaluate the effective use of resources by fire units [3, 6].

4.1. Checking the Access of Persons into the Fire Place

RFID technology has been tested and used in the New York fire brigade. The fire fighter has an RFID tag in a plastic bag placed inside pocket of Kevlar material on her breasts. The tag sends information every 5 seconds about the presence of a fire truck. The fire truck contains a monitoring centre where information's from RFID tags of firefighters are transmitted. The information's are forwarded to dispatching. In the event of an intervention or departure from the fire, the commander has information about if all the firemen are in the vehicles. Batteries in active tags hold energy for 4 years [8].

4.2. Equipment Checking

RFID technology is usable for fast inspection of fire technology located at fire trucks. Inventory can be done anywhere (either at a fire station or on the site after an action).

Firefighting clothing worn by the crew is required, after a number of applications, sent for service, repairs, security checks or refurbishment. Exceeded the prescribed renewal intervals increase the repairs time and cost the procurement of new clothing.

RFID systems can be used to control the firefighting equipment to intervene if they have all the garment and equipment parts with them. There would be one gate east of the fire station, which would record parts of the clothing and equipment through it. RFID tags can be sewn in garments. A pilot project to control the garment was carried out at Technical University of Ostrava at the Faculty of Safety engineering.

4.3. Command Monitoring

If the commander wants to find the position of firefighters at the place of fire intervention, he must deploy three gates (receivers) at the fire intervention site. It is problematic to use them at the place where the signal is attenuated, for example in underground garages. This case, it is possible to place the RFID tags on the hoses. The position information or lifetime functions of the fire fighters would by sent to the vehicle in the monitoring centre. The RFID tags for life function sensors can be added to monitor life functions.

The RFID tags can be used for orientation in the smoke area, or to search for dangerous substances, explosive gases and the like, whose containers have been marked with passive tags previous to the fire.

The NFC technology is suitable also for monitoring life functions of the fire fighters, but due to relatively low transmission distances rather in combination with intelligent bracelets or watches. The advantage is the possibility of communicating with RFID and the possibility to use the communication routes built by RFID. Like RFID, it can be used to label firefighting resources, equipment, and so on. However, due to the necessary short communication distance, the utilization is limited in practice. It is also suitable for tagging of areas or for inventory of firefighting equipment and equipment.

4.4. Monitoring of Water Traffic in Fire Intervention

In the case of large and prolonged fires, it is necessary to monitor the deployment of forces and firefighters equipment on a large area. There are a number of traffic and offensive lines that the commander is hardly able to monitor realistically from a tactical point of view. Each stream reordering (changing the firefighter status in the area) is a problem for on-line monitoring of the strengths and resources. The use of the above-mentioned technologies and the use of their elements on the fire intervention hoses represent the creation of a transport network of fire-fighting water at a fire area. With suitable software application will be able to track every minute change in fire and evaluate the progress and effectiveness of the interfering units. In the case of active elements on the jets, it would also be possible to monitor the operation of the current and the application of water to fire.

In the case of tank water transport (marked with tags), it is possible to precisely identify not only the number of tank cycles from water source to fire, but also to determine the amount of water delivered to the fire.

It is best to use RFID technology in the LF, HF and MW bands that can resist the environment and disturbance in order to identify the movement of the means and the identification of water traffic routes. In the case of 20-meter hoses, it would be necessary to equally place 2 to 3 passive tags with 868-955 MHz or 2.45 GHz operating frequencies per hose. The positioning itself could be performed independently of each other or by means of an external scanning device located on an unmanned device with a pre-programmed trajectory of motion in the map [9].

Pack away of hoses and other fire-fighting equipment and resources causes a great deal of interference between interference units. Labelling of equipment with tags, simplifies the identification and suitability of hoses for a specific firefighting technique. In this case, it is also possible to check the completeness of the funds before leaving the fire station.

5. Conclusion

When we compare these technologies, the usable in Fire brigade is RFID technology where the transfer of information between elements is a few meters, compared to NFC technology. As part of the Fire Brigade intervention, this technology is useful for training the movement of rescue items in unknown terrain, monitoring the entrance to the hazardous area, or marking and monitoring the resources used in the contaminated zone. The scan distance determines this technology only for contact monitoring of the intervention processes.

Acknowledgments

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The Research on the Intensity of Sports Car Acceleration with the Use of Launch Control System

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Abstract

This article presents different modes of a sports vehicle allowed to be used on public roads on a dry asphalt surface during intensive acceleration with the use of two launch control systems. The vehicle was thoroughly characterized with paying extra attention to power train and braking system. The result of carried out experimental research and analyses was obtaining characteristics of longitudinal acceleration of vehicle movement that allows to assess the improvement of acceleration parameters with the use of launch control system.
KEY WORDS: *acceleration, sport car, launch control*

1. Introduction

Nowadays some of the passengers' vehicle are available in sports versions. In most of the cases these vehicles, in comparison to standard versions, are equipped with a more powerful engine, more efficient braking system, harder suspension with the possibility to adjust stiffness and comfort. It is also possible to distinguish a sports version by mounting car body parts that improve aerodynamics of the vehicle. Throughout history sports vehicle were equipped with manual gearboxes. The development in technology and in automatic gearboxes allow nowadays for the sports gearboxes to change gears in a shorter time than a professional race driver does. Dual – clutch transmission in sports mode allow to change gears within 0,15 seconds. Automatic transmission allows to program a few exploitation modes. Each of the modes has different parameters of transmission operation; from a comfort or economical one up to a dynamic (sport) mode. Each of the modes is programmed so that the car can move with a different dynamic, which influences fuel consumption significantly [2, 4, 6]. There are also other systems that support the driver such as start-stop system, hill-start assist control (HAC), down-hill assist control as well as assist control that helps to accelerate from a standing start for sports cars (launch control) [1].

2. Methodology and Course of Investigations

The aim of the research was to measure the value of longitudinal accelerations of a sports and street car Audi S4. The car was equipped with a measurement device produced by Analog Devices type ADIS 16385 (Fig. 1) consisting of three acceleration sensors and three piezo gyroscopes integrated as one measuring system [8]. A portable laptop computer was used, in order to activate and store data, with a special software for sensors. measurement inaccuracy for the measurement equipment was 2%.

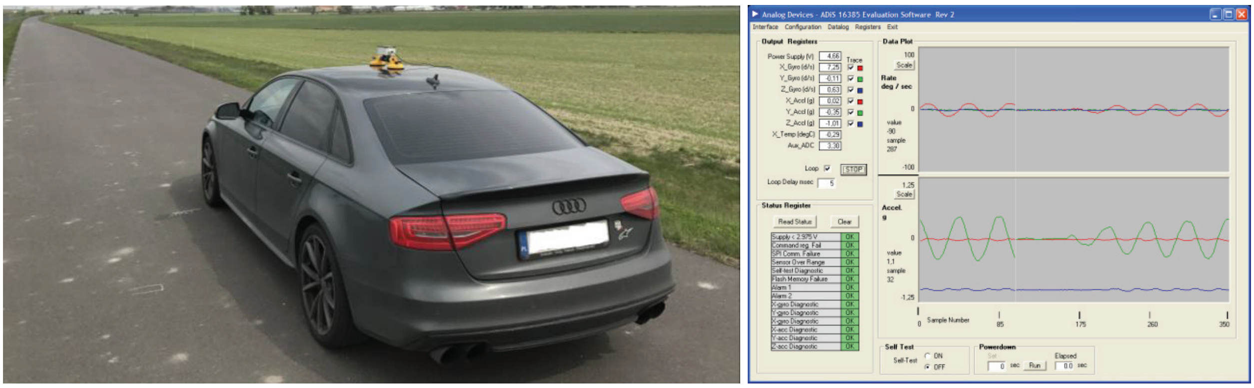

Fig. 1 View of the car with the measuring equipment and print screen of the software for activating and storing the measurements

The tests start from setting a route and marking the starting point of each drive. The environmental conditions were measured before and after the test drives. One test drive means placing the car at a set point, intensive acceleration from a standing start up to the speed of 100 km/h and then intensive braking until the car is stopped. Two series each containing 7 or 8 drives were performed using the test car, with and without the use of launch assist control.

3. Vehicle Characteristics

The test car was Audi S4 produced in 2015 (Fig. 2). The mileage on the test day was 52 000 km. The car was equipped with 3- liter V6 supercharged engine rated at 333 horsepower [12]. The powertrain is transmitted on all wheels (Audi Quarto) by o the seven-speed S tronic dual clutch transmission with the possibility of shifting gears with blades [10]. The rear- wheel drive is transmitted by driveshaft to the rear sports differential [11]. By reading the driver's intensions, meaning the turning angle of the wheels or intensity of pressing the acceleration pedal, the torque is transmitted to a more loaded, outer side of the car while driving around a curve. It results in better traction and enables to drive on a curvy road as planned.

Fig. 2 The view of a test car with the set starting point

The electronic system used in test allows a more dynamic (aggressive) start from a standing start by increasing engine rotation. The system is launched when the car is stopped. The gearshift should be placed in D position. The next step is to choose from driver select the dynamic mode and the final step is to deactivate the traction control system. It is important to remember that with automatic transmissions the brake pedal must be pressed, which was done in the above mentioned procedure. After the system is ready, meaning after the traction control system is deactivated, still pressing the brake, the acceleration pedal should be fully pressed (100%). The steering system of the launch control will raise the engine rotations up to 4200 rpm, which means that when the driver releases the brake pedal at a given moment it will allow the car to start with a considerable overload. During acceleration the control unit detects the wheels rotational speed and distributes the torque between the axles so that the car gained the speed faster.

In order to start moving the car without the starting procedure all that had to be done was to shift the gear shift to D position while the brake pedal was pressed. The moment the car starts moving is by releasing the brake pedal and moving the right foot to the acceleration pedal. The delay moment that is caused by releasing the brake pedal also causes delay in acceleration. The restrictive factor is the driver's reflex.

Fig. 3 The view of brake calipers in Audi S4 ø 345 [left] and Audi A4 ø 330 [right]

The car is equipped with manufacturer's braking systems designed for sports cars. The front axle has single-piston caliper with ventilated disc brake of a diameter of 345 mm whereas the rear axle 330 mm. It is worth mentioning that the case of sports version of Audi S4 compared to the street one of A4 the diameter of the rear disc brake is bigger than the front one by 10 mm (Fig. 3). Disc brakes with bigger diameter enable to transfer heat more efficiently and contribute to a more effective braking process

4. Measurement Results and Kinematic Analysis of Vehicle Motion

The experimental tests to check the intensity of acceleration were carried out on a straightforward sector of an asphalt- covered road. The road surface had no longitudinal or transversal inclinations. The environmental conditions were measured before and after the test drives. The measurement results are shown in Table 1.

Table 1

The measurement results of the environmental conditions

	Before drive trials	After drive trials
Ambient temperature	+16,5°C	+15,1°C
Humidity	38,3%	38,2%
Atmospheric pressure	990,7hPa	991,4 hPa
Temperature of saturation point	+2,3°C	+1,0°C

Tables 2, 3 and 4 present the values of: longitudinal acceleration, full mean deceleration, initial velocity of braking, travelled distance and the length of braking distance of the Audi S4 for use Launch control and Without Launch control.

Table 2

The values of the mean longitudinal acceleration

Trial number	Mean values of the acceleration [m/s^2]					
	With Launch control			**Without Launch control**		
	I gear	**II gear**	**III gear**	**I gear**	**II gear**	**III gear**
1.	6,905	4,604	4,151	5,94	4,357	2,784
2.	6,74	4,583	3,445	6,023	4,277	2,82
3.	6,621	4,57	3,359	5,685	4,277	2,979
4.	6,448	4,584	3,102	5,782	4,217	2,416
5.	6,404	4,61	3,548	5,678	4,174	2,678
6.	6,5	4,369	2,735	5,739	4,045	2,539
7.	6,08	4,017	2,713	5,674	3,964	2,421
8.	--	--	--	5,732	3,986	2,4
Mean	**6,52**	**4,47**	**3,29**	**5,781**	**4,16**	**2,63**
Standard deviation	**0,26**	**0,22**	**0,5**	**0,130**	**0,147**	**0,22**

Table 3

The values of the mean fully developed deceleration (MFDD)

Trial number	MFDD (MeanFullyDevelopedDeceleration) [m/s^2]	
	With Launch control	**Without Launch control**
1.	10,614	11,12
2.	10,355	10,932
3.	10,605	10,936
4.	11,309	11,071
5.	11,42	11,075
6.	11,348	10,99
7.	11,418	11,189
Mean	**11,009**	**11,062**
Standard deviation	**0,463**	**0,102**

The movement parameters of the vehicle on the asphalt and concrete road surface, i.e. initial velocity of braking $V_h\left[\mathrm{km}/\mathrm{h}\right]$, travelled distance $S_c\left[\mathrm{m}\right]$, braking distance $S_h\left[\mathrm{m}\right]$, time of accelerations $T_{acc}\left[\mathrm{s}\right]$ are presented in Table 4.

Table 4

The movement parameters of the vehicle with and without Launch control system

	Asphalt road surface							
	With Launch control				**Without Launch control**			
Trial number	S_c [m]	S_h [m]	V_h [km/h]	T_{acc} [s]	S_c [m]	S_h [m]	V_h [km/h]	T_{acc} [s]
1	91,474	41,112	104,8	5,570	98,393	36,752	106,293	6,448
2	99,639	38,906	108,7	5,923	101,77	37,815	105,822	6,351
3	103,992	38,691	110,6	6,098	113,007	37,489	110,037	7,227
4	104,46	31,121	111,9	6,345	111,962	33,494	109,602	7,03
5	97,096	37,789	110,6	5,897	111,386	36,243	108,673	7,081
6	105,988	41,95	107,4	6,032	119,749	36,881	109,360	7,14
7	115,345	35,866	109,8	6,789	116,506	34,148	107,19	7,247
8					115,604	33,612	106,084	7,164
Mean		**37,919**	**109,151**	**6,093**	--	**35,804**	**107,883**	**6,961**
Standard deviation		**3,616**	**2,410**	**0,386**	--	**1,773**	**1,728**	**0,355**

5. Analysis of Measurement Results

During the test of car Audi S4 with and without launch control system the acceleration timing characteristics were obtained. The chosen characteristics are shown in Fig. 4.

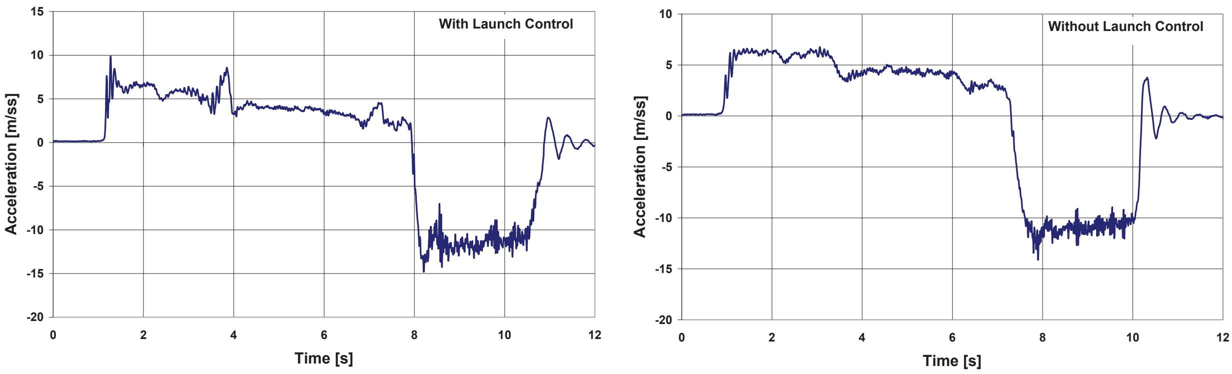

Fig. 4 Longitudinal acceleration characteristisc of a vehicle with and without launch control

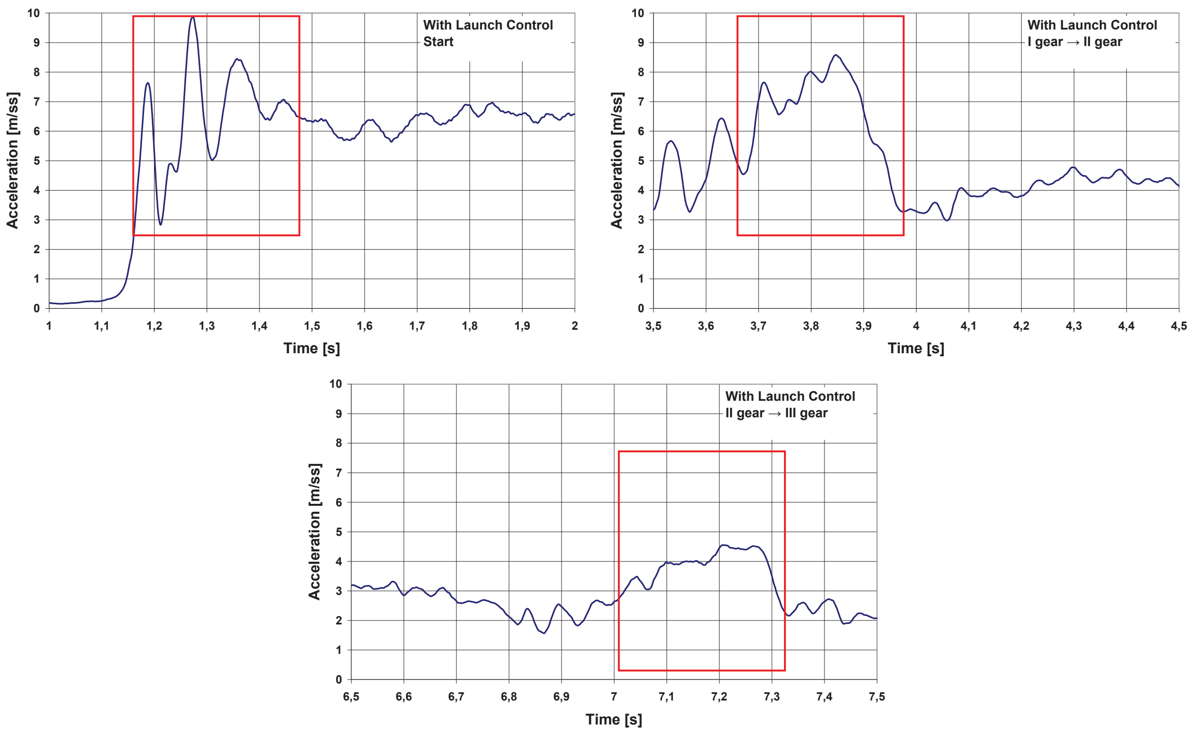

Fig. 5 The exemplary areas of acceleration impulses occurrence for specific gears

Using the launch control system generates an area with the increased values of acceleration. Bothe the driver and the passenger observe the change of these values as a "hitting at the back of the car". Such an impulse of acceleration occurs while moving from a stopped start and while shifting the gear. Although the acceleration impulse only lasts about 0,3 s it contributes significantly to the total acceleration time of the car to a set speed.

In case of the results shown in Table 4 it can be observed that car reaches the speed of 110 km/h almost 1 second faster when the launch control system is used. The exemplary areas of acceleration impulses occurrence for specific gears and their values are shown in Fig. 5.

The dynamics of a car without launch control system is characterized by a lower intensity of acceleration. The car despite shifting gears accelerates all the time and in the area of shifting the acceleration value decreases only a little bit. It causes a significant difference when compared to cars with manual transmission, where while shifting the acceleration value drops to zero (Fig. 6).

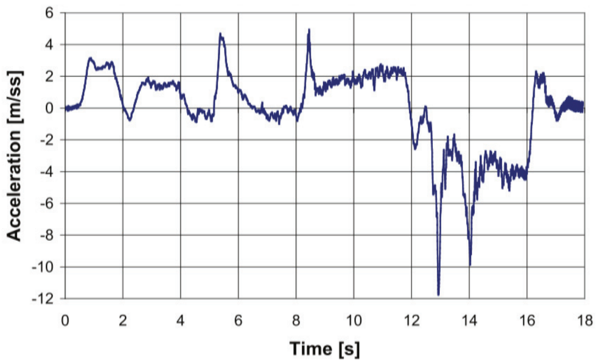

Fig. 6 An exemplary characteristic of acceleration of a vehicle acceleration MAN TGA 18.440 equipped with manual transmission [9]

6. Conclusions

The carried out tests showed that the acceleration with the use of „launch control" system is more effective in comparison to the acceleration without using the system. The difference of about 0,9 second while accelerating to a set speed of 110 km/h allows to make a statement that the system does its role. The criteria of arming the maximum acceleration procedure may be regarded at the same time as advantages and disadvantages as it is necessary for the car to be stopped, wheels set straight, gearstick set in a sports mode and all traction control systems must be deactivated. It is possible to use the launch control system only when accelerating from a stopped star position and it is impossible to use it when the car moves. Using the launch control system by inexperienced driver may pose a threat in traffic as all traffic control systems are off [3, 5, 7]. It may result in, if steering wheel reaction is not quick enough, wheel skidding, lower acceleration intensity or losing control over the vehicle.

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Railway Freight Transportation Perspectives in the Context of Lithuanian Transport Sector

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Abstract

Transport plays an important role in the development of material values, in rational distribution of productive forces in a certain territory, in the use of natural resources, in meeting the needs of people's communication, in raising the level of material and cultural life of people, and in strengthening production [3]. Railway transport is an indispensable part of economic growth of a country and plays a vital role in its domestic economy. This article aims to analyze the state of the Lithuanian transport sector and to assess the prospects of freight transportation by rail in the light of general state of transport sector in Lithuania.
KEY WORDS: *railway transport, freight, import, export*

1. Introduction

Railway transport is part of the transport system and also part of economy that aims at meeting the needs of public and business players that are involved in passenger and cargo transportation [7]. The main task for today‘s transport system is to ensure continuous and efficient flow of goods and of cargo, as well as a high level of people‘s mobility in the contemporary space of global trade and economic connections [5].

Railway transport is referred to as a tool for efficient functioning of the modern economy. Railway transport has always played a vital role in encouraging intense economic growth [1].

The trends in transportation sector are predetermined by the activeness of region‘s economic operators in international trade, depending on the relevant factors of the country, such as the abundance of domestic natural resources, the size of the domestic market, the volume of trade and the development of trade links [6]. In addition, each country or region seeks to increase its share of GDP in the development of international trade (World Bank 2009). This is natural, since transport services make a significant contribution to the formation of GDP.

International trade and rail transport are closely interlinked because goods or goods produced in different countries have to be transported to consumption areas. Naturally, there is a need for transportation services [7].

The article aims to assess prospects of cargo transportation by rail transport in Lithuania.

To achieve the aim, the following tasks have been formulated:

1. To analyze transport sector in Lithuania.
2. To analyze cargo transportation by Lithuanian railway transport and to assess prospects.

Methods: analysis of the literature; statistical analysis and forecasting.

2. Analysis of the State of Lithuanian Transport Sector

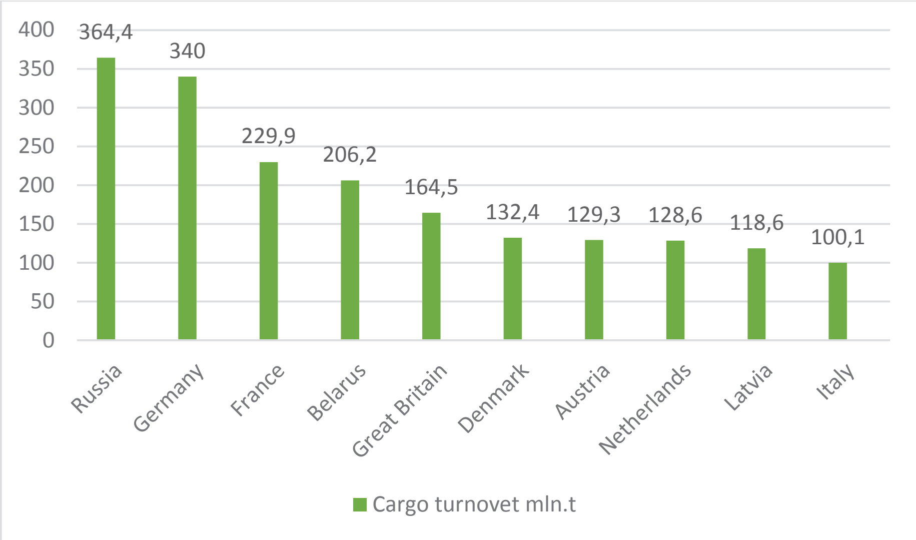
According to the analysis conducted by the Ministry of Transport and Communications of the Republic of Lithuania in 2017, the contribution of the Lithuanian transport and logistics sector to the Lithuanian-based transport and logistics sector grew by 4.3% (up to 3.97 billion EUR), respectively, the sector's contribution to GPU amounted to 11.6%, the activities of the country were 7,155 enterprises of the country (+1.4%), employed 110 857 employees (+5.2%).

When analyzing the significance of transport to the Lithuanian economy it is important to take into account the assessment of logistics services, which is evaluate:

- LSE – 14,20 %;
- Customs – 12,50 %;
- Infrastructure – 12,30 %;
- International shipment – 12,60 %;
- Quality of Logistics – 16,70 %;
- Cargo tracking – 16,10 %;
- Punctuality – 15,00 %.

As the presented data shows, logistic services in Lithuania receive fairly positive evaluation. In the light of such results it can be said that this also has positive effects on the indicators of international trade.

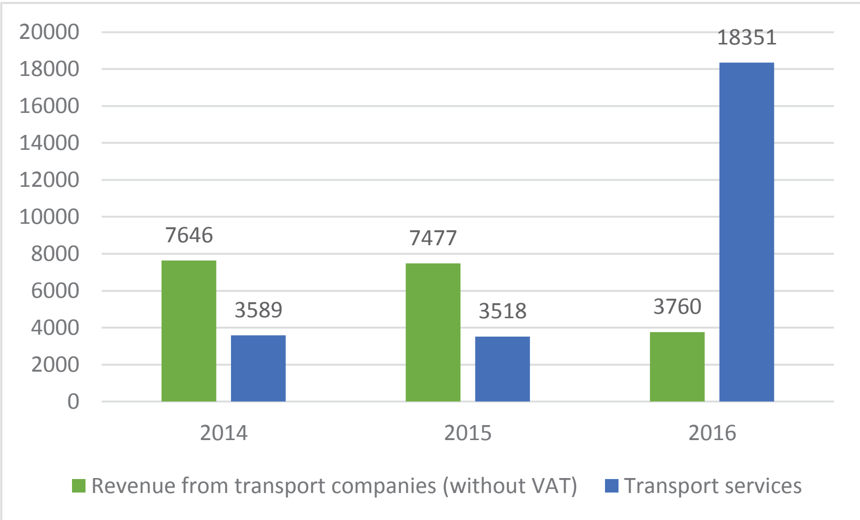
According to the preliminary data, exports of Lithuanian transport services amounted to 3.69 billion Euro, and growth - 5.1%. Data of 2016 estimates that transport exports accounted for 56.7% of total exports of services and 12.5% of total exports. Total transport service balance in 2016 increased by 27.3% (from 875.9 million EUR to 1114.7 million EUR). The rapid growth of exports of transport services to EU countries is also observed. It should be noted that the share of exports of transport services is increasing most due to the export of car transport services. Export volumes increased to 41% to the United Kingdom, 41% to France, 31% to Austria, 32% to Italy, 8.2% to Germany; exports to the eastern market and export volumes to Russia and Belarus are gradually stabilizing (Fig. 1).



Source: data by the Ministry of Transport and Communications of the Republic of Lithuania

Fig. 1 TOP 10 of Lithuanian transport market services mln. Eur (2016 y.)

Transport companies in 2016 reported of income of 3.7 billion Eur. More than half of the revenue came from the turnover of land transport companies, which amounted to 2 billion Euro, which is 8.4% more than in 2015. (Fig. 2).

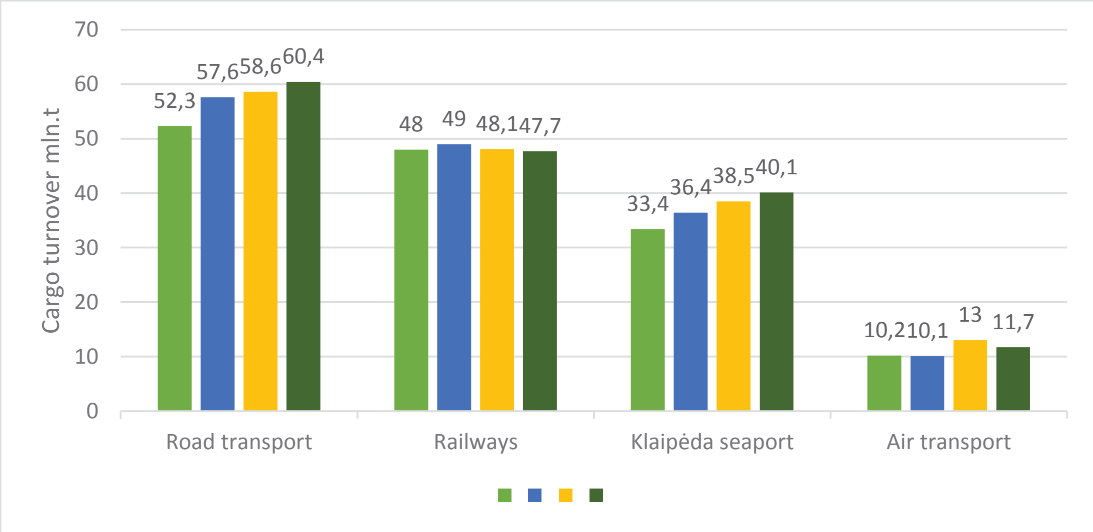


Source: Composed by authors on the basis of the data provided by the Ministry of Transport and Communications of the Republic of Lithuania, 2017

Fig. 2 Financial results of transport service sector of Lithuania (mln. Eur)

Exports of transport services increased by 5.9% in the first half of 2016. Compared to the same period in 2015, exports of transport services amounted to 1835.1 million Euro (increased by 5.9%) and accounted for 57.9% of total exports of services. The total transport service balance increased by 22.4% (from 597.6 million EUR to 731.3 million EUR).

Taking into account data on the systemic dynamics of Lithuanian transport turnover and transportation dynamics in 2013-2016, freight volumes in 2016 January-December grew by 1% (totaling 114.8 million tons) compared to the corresponding period in 2015: rail transport decreased by 0.8% (a total of 47.7 million tons), road transport increased by 3% (totaling 60.4 million tons) . Cargo handling in Klaipėda port increased by 4.1% (totaling 40.1 million tons), while at airports it decreased by 10% (total 11.7 thousand tons) (Fig. 3).



Source: Data by the Ministry of Transport and Communications of the Republic of Lithuania [4]

Fig. 3 Freight flows by road, railway transport, in Klaipėda port and air ports

When analyzing rail transport it is important to mention that rail transport accounts for almost 68% of all cargo flows transported in Lithuania, i.e. 32.6 million tons. General assessment of the situation of cargo carried by Lithuanian railways calls for observation that in 2016 transit of crude oil and oil products, ferrous metals, fertilizers to the Kaliningrad region declined. The volumes of mineral products, food industry and products of vegetable origin (cereals) saw a slight increase.

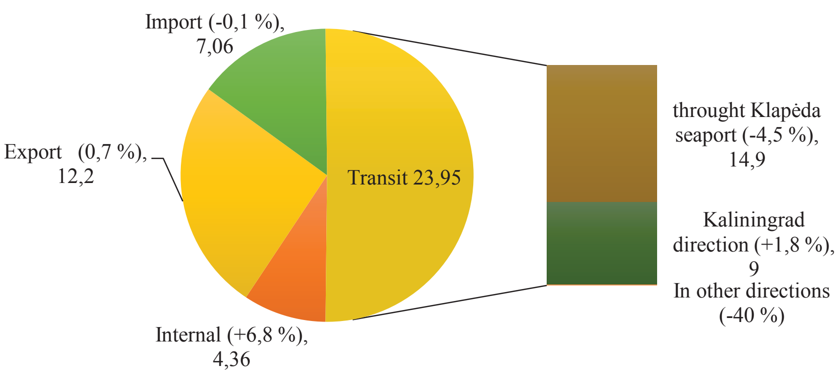
Transportation by rail is mainly limited to transportation by transit through Lithuania to Kaliningrad and to Klaipeda port. Rail transport is dependent on the external environment and the economic as well as trade potential of neighboring countries. There is little internal transport by rail. Aviation sector has been developed weakest of all modes of transport. Freight turnover at Lithuanian airports has a strong downward trend.

3. The Trends of Lithuanian Railway Transport Sector

Railways in Lithuania make up only about 1% of the total EU rail network. The length of railways in Lithuania remains almost stable. The length of the electrified railways also does not change.

JSC Lithuanian Railway transported 47.65 mln. tons of freight in 2016, i.e. 0,8% less if compared to 2015. Transportation of petroleum and petroleum products comprised 14.46 mln. tons (+1%). Growth was driven by a slight increase in the production flow of Orlen Lithuania and Belarus factories. Transportation of fertilizers made up to 14.33 million tons (-8%), of metals 3,03 million tons (-14%).

Analysis of the dynamics of the distribution of carried cargo reveals that cargo flows to Klaipėda Seaport also decrease (Fig. 4).



Source: Data by JSC Lithuanian Railway [2]

Fig. 4 Freight flows, transported by railway transport

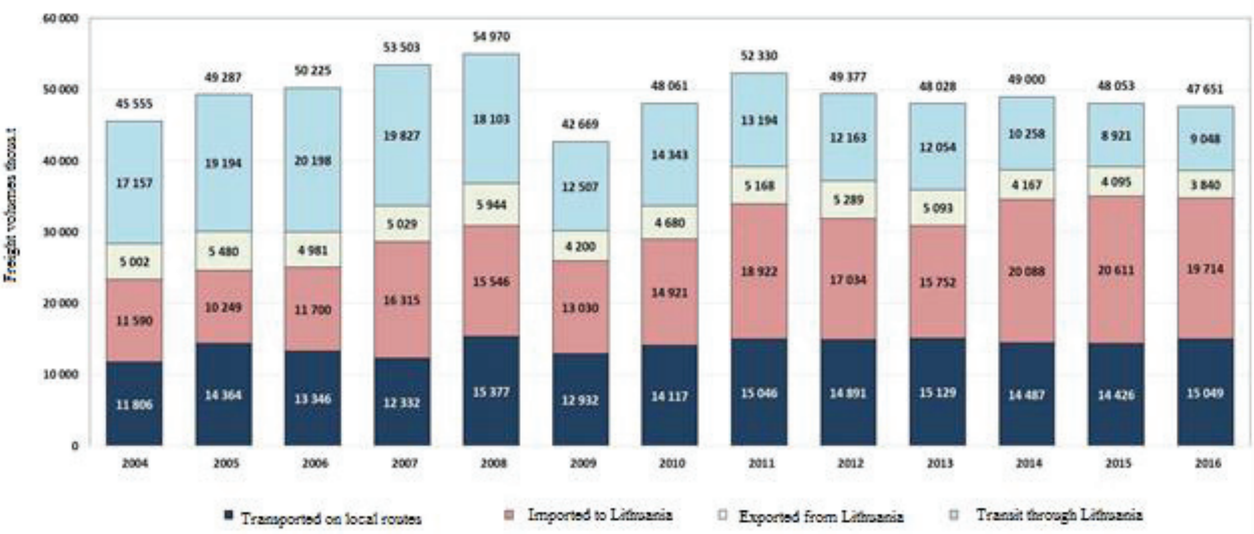
Transit cargo flows accounted for 50.4% of all freight, decreased by 2.4% (total 24.0 million tons), of which:

- Transit flows through Klaipėda decreased by 4.5% - totaling 14.9 m. tones (fertilizers from Belarus (-3%), ferrous metals (-25%), oil from Belarus (+5.6%) shrank);
- To the direction of the Kaliningrad Region, flows grew by 1.8% - 9.0 m. tones (growth of solid mineral fuel

(+8%), food (20%) and vegetable products (+14%), oil and products (-30%) fell);

- exports decreased by 0.7% (total 12.2 million tons);
- Imports (for domestic consumption) decreased by 0.1% (total 7.06 million tons);
- Inland freight increased by 6.8% (a total of 4.36 million tons).

Analysis of cargo transportation by Lithuanian railways since 2004 (Figure 5) reveals that cargo flows have been steadily increasing until 2008 and reached the highest level during the period of independent Lithuanian rail transport in the amount of 54 970 million tons of cargo transported. However, since 2008, with the beginning of the global economic crisis freight flows gradually began to decline. In 2009, as the economic crisis gained its momentum, freight volumes fell to 42.669 million tons. This was the biggest drop in the volumes of cargo transportation.



Source: Data by JSC Lithuanian Railway [2]

Fig. 5 Freight flows of JSC “Lithuanian railways” (t)

After the stabilization of the economic crisis, the volumes of Lithuanian railways recovered and reached 52,330 million tons in 2011. In subsequent years freight volumes ranged from 48-49 million tons, while in 2016 cargo volumes dropped to 47 million.

Over the past year, the share of the Kaliningrad region in the total transit traffic fluctuated and recently decline trends have been observed. The main cargo flows to Kaliningrad come from Russia. Kaliningrad accounts for 88.9% of Russia's transit through Lithuania, while the bulk of transit cargo from other CIS countries is being transported to Klaipeda. Trends in freight transportation from the eastern countries, including Russia, are linked to the poor economic situation of CIS countries, as well as Russian markets. This is due to two reasons: Russia began shipping part of the transit to Kaliningrad by sea ferries from the port of Ust-Lugo, thus circumventing Lithuania, and the second reason is the weakening of Russian exports.

In terms of freight traffic, the largest part of the traffic flows through Belarus and Russia. Over the past four years, cargo flows from Belarus have increased by 4 million tons. The second largest volume of cargo transporter is Russia.

11 774 tons of cargo were transported from Russia to Lithuania in 2016, of which 2 583,3 tons were transported to Lithuania and the rest was transported to Kaliningrad. There is a gradual decrease in cargo flows from Russia.

The main railway traffic flows take place into the country's East-West direction. 85% of all transit cargo transported by rail enter Lithuania through the border with Belarus.

Analysis of transportation between Lithuania and Latvia reveals that in recent years freight transportation to Latvia have remained stable. Major part of railway cargo to Latvia are oil products. Transfers between Lithuania and Latvia dropped from 2,354.7 tons in 2012 to 1,676.2 thousand tones in 2016.

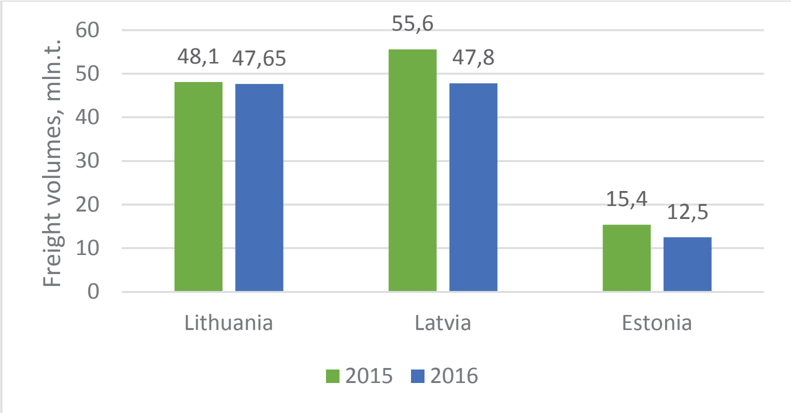
During this period, the volumes of transportation to Estonia remained stable with a slight fluctuation and amounted to about 700 thousand tons. The largest volume of cargo, like in Latvia, is made up of oil products (Fig. 6).

Analyzing the situation in the railway transport sector of the Baltic States, it should be noted that the volume of transportation decreased in all Baltic States. In 2016, the largest drop in freight volumes is observed in Estonia (-19%) and Latvia (-14%). The amount of oil and oil products, bulk cargo segment, transported by Latvian railways dropped by 24% (totaling 16.2 million), by Estonian railways - 54% (3.5 million tons in total), while railways in Lithuania saw only 4% drop.

The main reason for the decline in freight flows is decreased freight flows from Russia, since major part of transportation is linked to the East.

Based on the analysis, it can be argued that Russia, having decided to reorient its oil shipment to Russian ports, will further reduce freight flows in the Baltic States. It should be noted that the Russian railways intend to offer large discounts to export these goods from the Baltic countries in order to further reduce and, in the near future, to stop transit of goods through the Baltic States, not only intensively reduce their transit freight transportation, but also export

Belarusian oil products to the ports of Russia. The fact that most Russian cargoes are being diverted to Russian ports is clearly evidenced by the load volumes of the Ust-Lugos port in Russia, which increased from 11.7 million tons in 2010 to 93.4 million tons in 2016.



Source: Data by the Ministry of Transport and Communications of the Republic of Lithuania [4]

Fig. 6 Freight transportation by railway transport in the Baltic States (mln. t.).

When considering trends of freight transportation by Lithuanian railways, it is worthy mentioning carriage by containers (Table 1).

Table 1

Statistics on container transportation by the routes of JSC "Lithuanian railways" (TEU)

Year	Viking train	Vilnius Shutle	Šeštokai express	VIT express	Milano express	Saulė	Baltijos Vėjas	Merkurijus
2015	36 298	4 814	3 618	787	–	421	318	205
2016	33 994	9 400	2 841	1 687	339	212	150	3

Source: Data by JSC Lithuanian Railway, 2017 y.

Comparing container shipments in the recent period, it can be said that in 2015, JSC Lithuanian Railways transported 46,540 containers, in 2016 it shipped 48,657 containers. Container shipments in 2016 increased by 4.5%. Container transportation is executed by container trains, by which Lithuanian Railways AB carries containers on various routes.

The largest volume of freight containers in 2016 was transported via Viking train 33 994 TEU. Compared to 2015, the volume of containers on this route decreased by about 10%. Transportation on the route "Vilnius shuttle", "VIT express" almost doubled. On all other routes, volumes of cargo decreased. Transportation from China by the container train "Sun" has practically ceased. When assessing the trends in container shipping, it is evident that container shipments are decreasing on many routes.

In summary, cargo turnover during the analyzed period increased; compared to 2003, it increased by 24.9% in 2013. Very high cargo turnover growth was observed in 2007 (111.4%). Therefore, even in 2009 marked by crisis, cargo turnover was higher than in 2003. Taking into account future prospects, cargo turnover is expected to grow (Fig. 7).

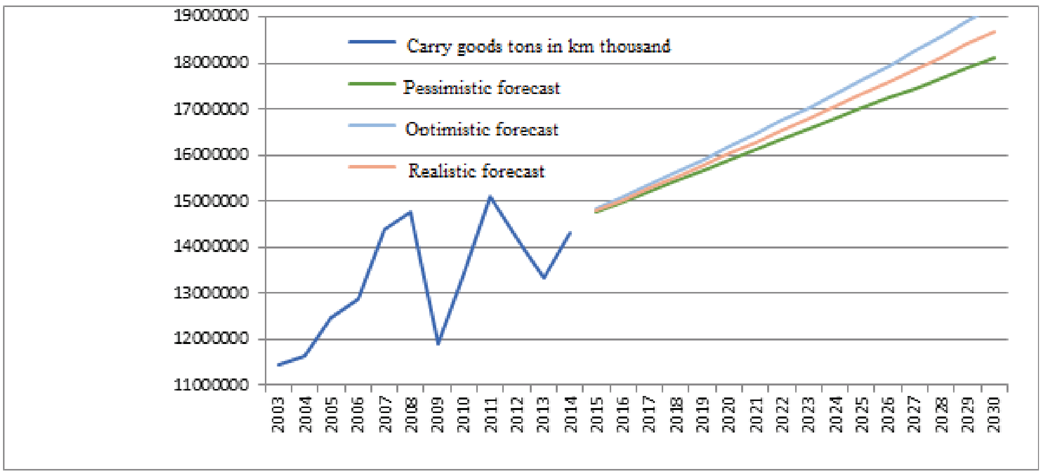


Fig. 7 The dynamics of freight transportation turnover since 2003 and forecast until 2030 y

4. Conclusions

1. Changes in the competitive environment of freight transport are directly related to macroeconomic trends, especially international trade, and it is therefore important to analyze global and regional trends in GDP and international trade and to assess forecasts.

2. In assessing the prospects of the Lithuanian transport sector, it should be noted that in order to strengthen the role of the Lithuanian transport sector in the Baltic region, it is necessary to seek for deeper and wider cooperation methods and solutions which would help to achieve common goals while simultaneously strengthening the competitive position in the region by providing complex transport and logistics services, purposeful sharing of influence and role depending on the specificity of the services provided and on the available infrastructure.

3. In terms of freight traffic, the largest part of the traffic is comprised of freight flows through Belarus and Russia. Over the past four years, cargo flows from Belarus have increased by 4 million tons. The second largest volume of freight belongs to Russia. 11 774 tons of cargo were transported from Russia to Lithuania in 2016, of which 2 583,3 tons were transported to Lithuania and the rest was transported to Kaliningrad. There is a gradual decrease in cargo flows from Russia.

4. The main railway traffic flows take place into the country's East-West direction. 85% of all transit cargo transported by rail enter Lithuania through the border with Belarus.

5. In the assessment of transportation through the Republic of Lithuania, it is evident that freight transport from the freight-forming markets tends to decrease. This is due to the fact that the volume of freight traffic is also decreasing in other countries, the flows of which are directed to Lithuania. This is also reflected in the flows of rail freight in Lithuania.

6. It can be claimed that container transportation is not very efficient.

7. The forecast made up to 2030 shows that the turnover of Lithuanian freight transport has tendencies to grow.

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Dynamic Analysis of Single Stage Gearbox with Backlash Influence

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Abstract

The helical gear is the most used type of gears in automotive. The understanding of the gears dynamic behaviour is key to improve design with goal of decrease vibration and emitted noise. For that purpose, the dynamic modelling approach based on the finite element method and multi-body dynamic software approach on single stage gearbox is proposed. After validation of numerical approach by experimental measurement, the backlash influence on dynamic behaviour is investigated.
KEY WORDS: *single stage gearbox, noise, vibration, harshness, damping*

1. Introduction

The automotive industry is one of the largest industries in the world with a lot of major producers. The number of vehicles is increasing. The market of the product is more and more balanced, thus the NVH parameters are one of the key to success, moreover the ISO standard are more tighten. The developing departments are focused on hybrid and electric vehicles, thus the dominant source of noise is changed from engine to another component, specifically on the gearbox. The gearbox belongs to source of noise, which could be significant at low speed in the city and so it can touch people living near the roads. On the other hand, the noise and vibration at high speed can affect the passenger's comfort. The transmissions are developed for wide spectrum of operation conditions. Unlike a combustion engine using the rotation starts at approximately 900 RPM, the electric motor rotational speed range starts at 0 RPM. From that reason, it is necessary to focus deeply on the transmission dynamic behaviour also at the starting phase.

The helical gear is the most used type of gears for transmission in automotive. The bearing clearance and backlash is present in each transmission and affect the variability of the tooth contact under different operation conditions. Tooth separation and tooth wedging lead to the vibration and noise. This behaviour is known as rattle which is one of the phenomena in the gearbox. With the increasing emphasis on noise, the modeling of the gear dynamics behaviour has become more important.

In cases where the transmission is expected to be the dominant source of noise, the housing is responsible for more than 80% of the whole transmission emitted noise and only 10 % of noise is from the gear contact, but the main excitation of housing is initiated by the gears. The modal analysis is often used to the housing NVH improvement, which can provide basic information about frequencies and mode shapes. On the other hand, this approach has some disadvantages, the frequency does not have to be, necessarily, excited by operation conditions or the higher mode (over the operation mode) can be excited. The modal analysis does not provide any information about surface velocity, which is closely connected to the emitted noise. The modal analysis is dominantly used in a design phase when validating the differences between possible design options takes place [1]. It is necessary to use harmonic analysis to get information about surface normal velocity. It can be performed by experimental or numerical approach. To get information about real dynamic behaviour the exciting forces must be known, but that is sometimes very difficult. For that reason, harmonic analysis is widely used to compare multiple designs with the same boundary and load conditions.

To get information about excitation force the Multibody dynamics system can be used. Inputs causing excitation can be formulated in an easier form – input torque and rotational speed, which are transferred into related forces, acting on each model part. The numerical simulation of transmission is frequently examined and extensive topic, but all models have to be at the end verified by technical experiment. The same approach is used for truck vibration caused by unbalanced rotating shaft in [2]. The most advantageous variant of the transmission seems to be the single stage gearbox, because of easy modification to different gearwheels, bearings, shafts and covers. This kind of transmission is widely used for examination of oil properties, the influence of contact behaviour, unbalance, backlash, torque value and transmission error [3-5]. This paper deals with dynamic simulations of the single-stage gearbox, where the surface normal velocity on the top cover, torque and angular deformation are observed.

2. Analytical Approach

Unlike vector dynamics that works with vector variables, analytical dynamics works with scalar variables (work, energy). Basics of analytical analysis are formulated using principles of mechanics that work with generalized coordinates, because of it, analytical approach is universal approach for solution of dynamic problems. Thanks to this approach is possible to derive Lagrange's equations of motion.

Using generalized forces and the principle of virtual work, we can write virtual work as:

$$\delta A = \sum_{j=1}^{N} \boldsymbol{p}_{\boldsymbol{F}_j} \cdot \delta \boldsymbol{r}_j = \sum_{j=1}^{N} \boldsymbol{p}_{\boldsymbol{F}_j} \cdot \sum_{i=1}^{n} \frac{\partial r_j}{\partial q_i} \cdot \delta q_i = 0, \tag{1}$$

where $\boldsymbol{p}_F$ are workforces, δq_i, δr_j, represents virtual displacement, respectively written in vector approach. Using principle of minimum energy, D'Alembert's principle for body system and mathematical adjustments, we obtain from Eq. (1) basic form of Lagrange's equations of motion of second kind:

$$\frac{d}{dt}\frac{\partial L}{\partial \dot{q}_i} - \frac{\partial L}{\partial q_i} = 0\,, \tag{2}$$

where L represents Lagrange's, function expressed by kinetic and potential energy of the form:

$$L = E_k - E_p. \tag{3}$$

Eq. (2) can be extended by adding other variables like for example Rayleigh's dissipative function R_D and Lagrange's multipliers λ_s, which are used to express dependent variables. Using above mentioned extensions we get extended Lagrange's equations of motion of second kind:

$$\frac{d}{dt}\frac{\partial L}{\partial \dot{q}_l} - \frac{\partial L}{\partial q_i} + \frac{\partial R_d}{\partial \dot{q}_l} + \sum_{s=1}^{k} \lambda_s \frac{\partial f_s}{\partial q_i} = \tilde{Q}_l\,. \tag{4}$$

For the applications in specific cases, Eq. (4) can be rewritten with help of an expression kinetic energy using generalized mass matrix $M(q)$, potential energy using generalized stiffness matrix K, generalized gravitational force f_g and Rayleigh's dissipative function using damping matrix B. Using these extensions, we obtain the following equation

$$\boldsymbol{M}\ddot{\boldsymbol{q}} + \dot{\boldsymbol{M}}\dot{\boldsymbol{q}} - \frac{1}{2}\left[\frac{\partial \boldsymbol{M}}{\partial \boldsymbol{q}}\dot{\boldsymbol{q}}\right]^T \cdot \dot{\boldsymbol{q}} + \boldsymbol{K}\boldsymbol{q} + \boldsymbol{f}_g + \boldsymbol{B}\dot{\boldsymbol{q}} + \left[\frac{\partial \boldsymbol{f}}{\partial \boldsymbol{q}}\right]^T \cdot \boldsymbol{\lambda} = \widetilde{\boldsymbol{Q}}. \tag{5}$$

3. Numerical Approach

The numerical simulations are widely used in automotive industry for comparative study of dynamic behaviour of component or whole transport machines [6]. The presented virtual prototype enables to perform comparative study of dynamic behaviour of two transmission designs or sensitivity study to see the effect of input parameters. The benefit of this approach is reducing the number of prototypes, which significantly saves money. For that reason, it is widely used in research and developing phase of transmission [7]. On the other hand, the prototypes are necessary to create methodology at the beginning and confirm it at the end.

The presented paper uses approach based on dynamic model with multiple degree of freedom. The whole model consists of gears mounted on the flexible bodies of shafts and gearbox housing. The bearings are modelled by radial and axial stiffness and the interaction between gears is done by variable gear mesh stiffness, model is shown in the Fig. 1. The whole approach is based on the basic equation of motion, which corresponds to the analytical Eq. (5).

The input representing gear mesh stiffness, see Fig. 1, and bearing stiffness is calculated by using FEM. The model of gears is fully parametric, thus it enables to perform change of characteristic gear parameters as well as perform whole spectrum of tooth modification.

To include the dynamic behaviour of bodies, the flexible variant is necessary. It can be performed by the Craig - Bampton modal reduction, which replaces real modal properties with simplified approximation established from the two variants of degree of freedom and multiplied by the special Craig-Bampton transform matrix, see Eq. (6).

$$\{\boldsymbol{u}_A\} = \begin{Bmatrix}\boldsymbol{u}_b\\ \boldsymbol{u}_L\end{Bmatrix} = \begin{bmatrix}\boldsymbol{I} & \boldsymbol{0}\\ \Phi_{\boldsymbol{R}} & \Phi_{\boldsymbol{L}}\end{bmatrix}\begin{Bmatrix}\boldsymbol{u}_b\\ \boldsymbol{q}\end{Bmatrix} = \Phi_{\boldsymbol{CB}}\begin{Bmatrix}\boldsymbol{u}_b\\ \boldsymbol{q}\end{Bmatrix}, \tag{6}$$

where $\boldsymbol{u}_A$ is the original vector of deformation, $\boldsymbol{u}_b$ are the boundary degrees of freedom (DOFs), $\boldsymbol{u}_L$ stands for interior DOFs, $\boldsymbol{q}$ represents modal DOFs, $\boldsymbol{I}$ is the identity matrix element, $\boldsymbol{\Phi}_R$ is rigid body matrix element and in the analogical way $\boldsymbol{\Phi}_L$ are the fixed base mode shapes matrix element.

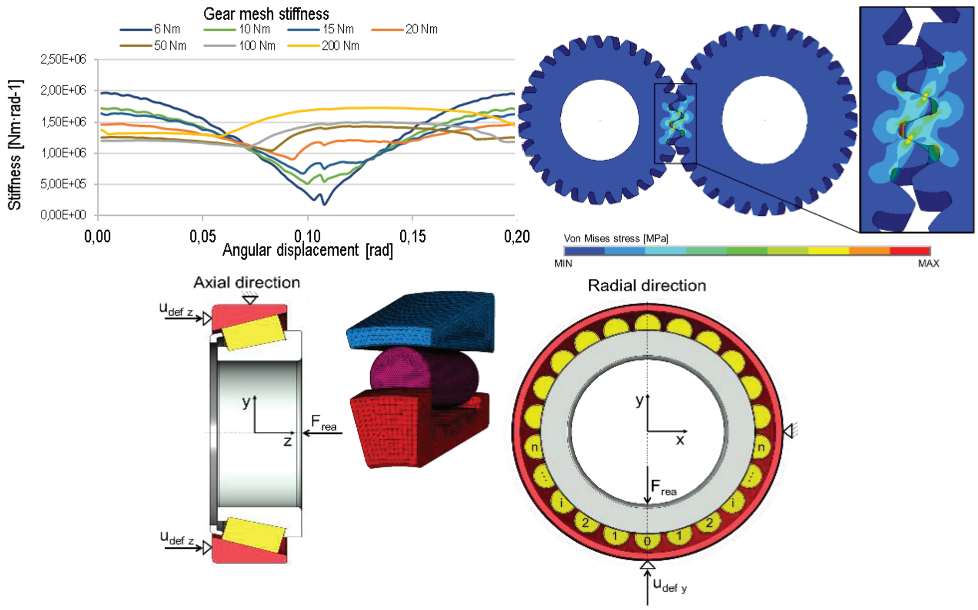


Fig. 1 Single stage gearbox virtual prototype features

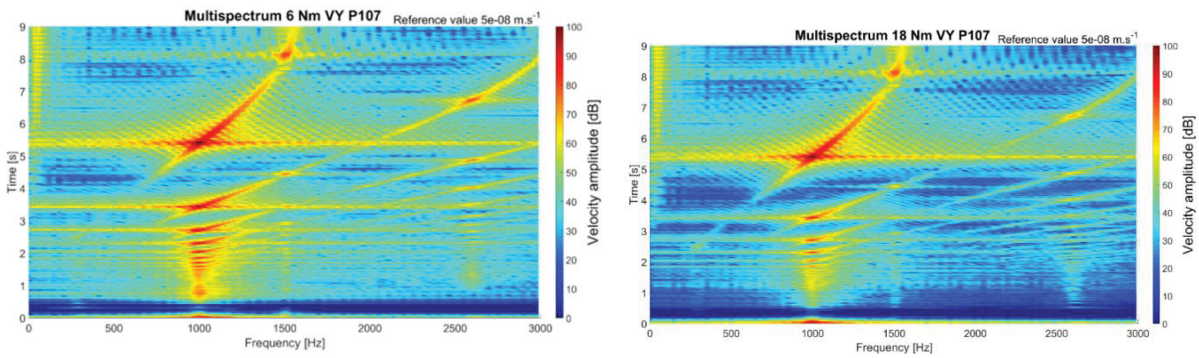
4. Results

The simulations are focused on the rattle phenomena at the starting phase. For that purpose, the dynamic simulation is done for different values of torque and backlash to cover whole operation range. In the first part of the simulation, the constant change of rotational speed of input shaft is used in range 0 ÷ 3000 RPM. The backlash 100% corresponds to the measured one. The ideal case without backlash is marked as 0% and 200% is case with backlash two times higher than measured.

First, the multispectrum is compared, to see if there are same extremes in surface normal velocity, which corresponds to the increasing noise. In the Fig. 2 can be seen that with increasing of transmitted torque the width of frequency range excitation of the housing occurs. For better understanding of this phenomena the gear mesh angular deformation is shown in the Fig. 3. The first chart presents that during the whole run up simulation the rattle phenomena did not occur. In case of deeply focused to the early start of the run up, we can see the releasing of the tooth contact. This release, which has an impact character has a strong influence also to the noise, mainly in electric powered powertrains.

The dynamic behaviour is visible on torque value charts for more cases, see Fig. 4. This variability of the torque is a wide-frequency range type of excitation, which is transferred to the whole structure of the gearbox and must be eliminated.

The second part is focused on the influence of the input speed variability, which occurs due to function principle of combustion engine. The variability is shown in the Fig. 5 and corresponds to the numerical simulation published in [8]. In case of multispectrum comparison between variable and non-variable input speed (Fig. 2 and Fig 5), it is noticeable, that one significant critical state comes. The velocity of the top cover middle point is plotted in Fig. 6 for 0% and 100% backlash to see the most critical state. Based on this the steady state simulation is performed. The rotational input speed corresponds to the value in critical state, which is 2159 RPM. The first second of simulation is to reach required input speed and afterwards the torque is increased from 0 to 30 Nm. The multispectrum in the Fig. 7 shows that in torque range 0 to 10 Nm the rattle occurs, which is documented by progress of angular deformation.



a b

Fig. 2 Multispectrum diagram of run up simulation for non – variable input speed of surface normal velocity of top cover middle point for backlash 100 % at a) 6 Nm; b) 18 Nm

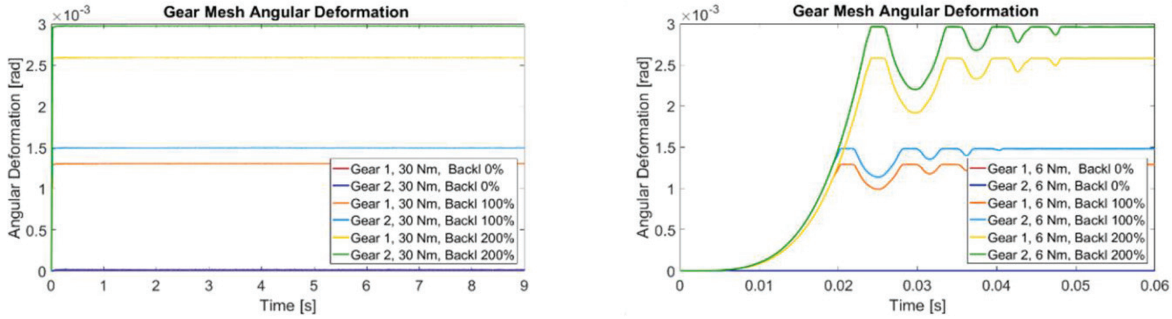


Fig. 3 Angular deformation for loading moment 6 Nm; 30 Nm and 100 Nm

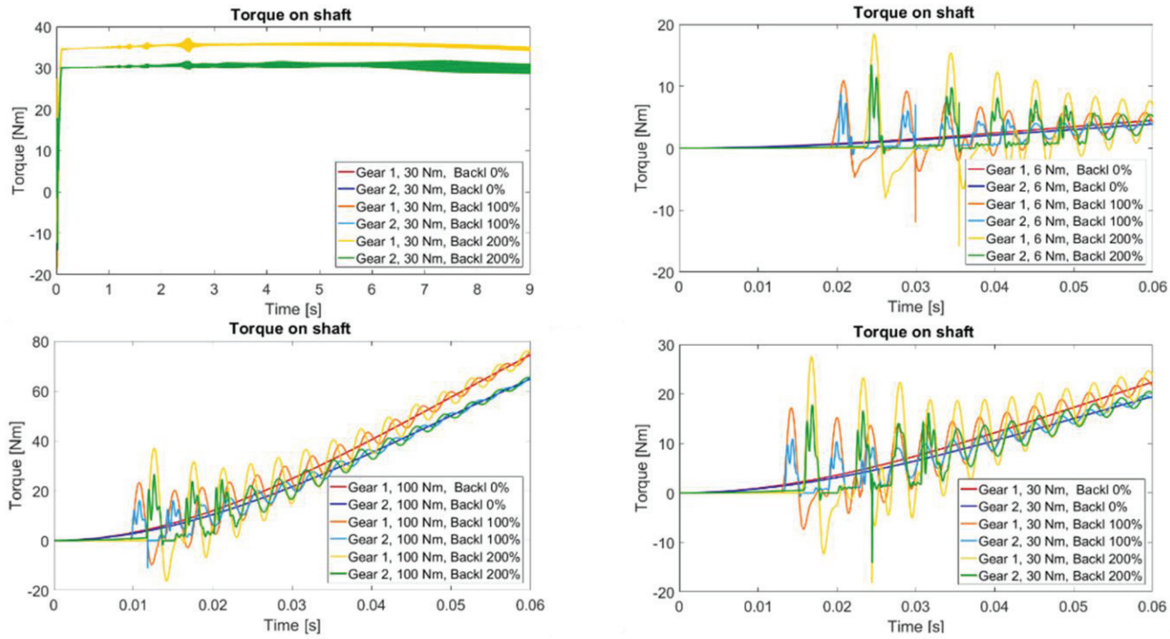


Fig. 4 Torque on shaft for loading moment 6 Nm; 30 Nm and 100 Nm

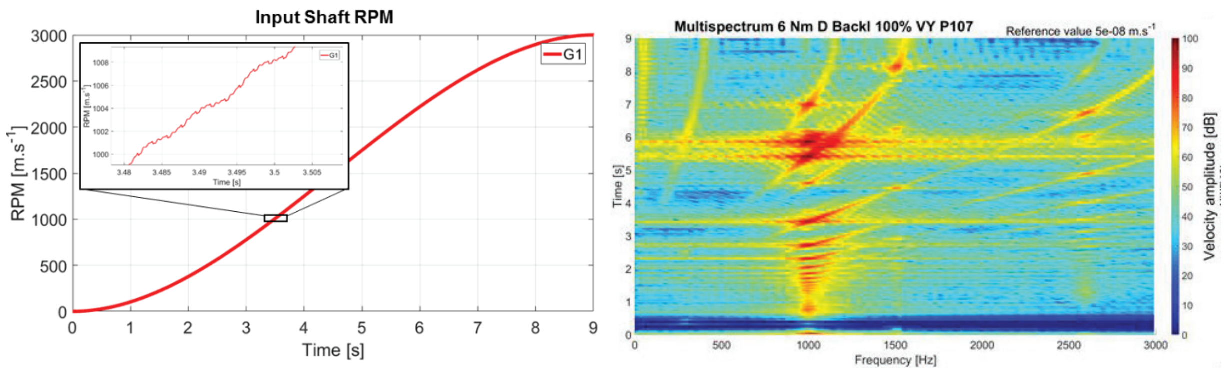


Fig. 5 Rotation variable input speed (left) multispectrum of run up simulation at 6 Nm for variable input speed (right)

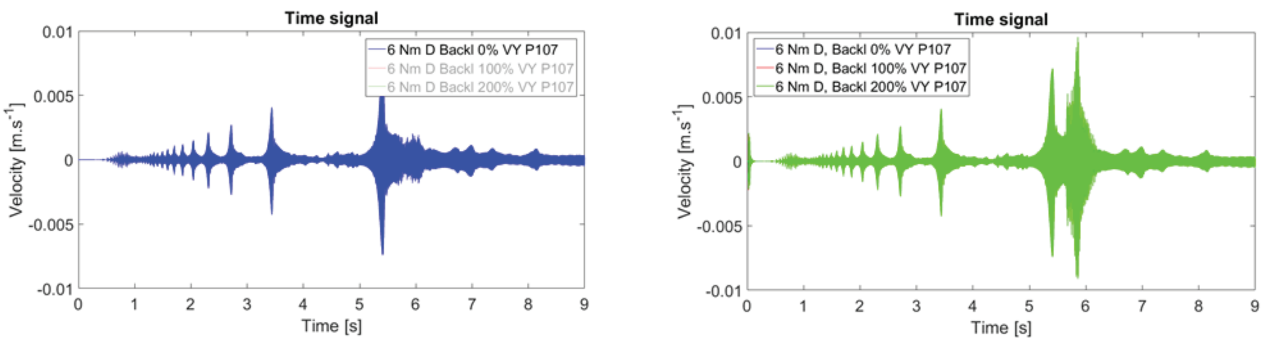


Fig. 6 Time signal of run up simulation 0 ÷ 3000 RPM backlash 0% (left) backlash 200 % with new critical location (right)

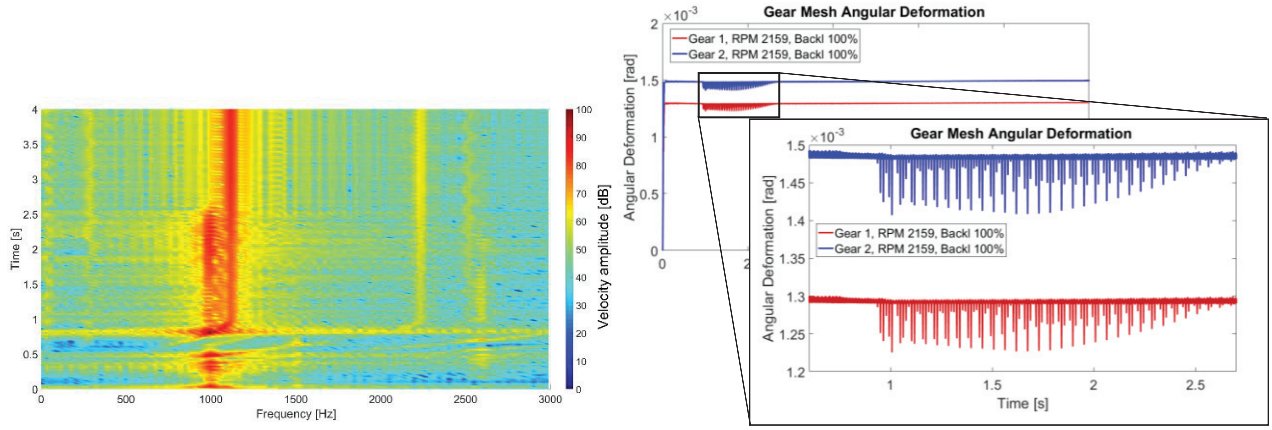


Fig. 7 The multispectrum diagram of steady state at 2159 RPM (time 1 ÷ 4 seconds) (left) Angular deformation when rattle occurs (right)

5. Conclusion

The methodology used for sensitivity study is developed on single stage gearbox and evaluated by technical experiment. This paper is focused on the rattle. The influence of the backlash value and rotational variable input speed is investigated. First the non-variable input speed is applied on three values of backlash. With the increasing value of backlash the contact loosening at the starting phase occurs for longer period. For this reason, at the low rotational speed the excitation of the whole structure becomes. The hitting tooth to each other cause peaks in the torque.

Afterwards the effect of the variable input speed is investigated because this phenomenon significantly affects the surface normal velocity. The new critical location is present out of the teeth frequency. To see the effect of torque value on the surface normal velocity, the input speed steady state is simulated with increasing value of torque. The contact loosening occurs at low value of torque. The presented method, which combine the MBS and FEM, enables to simulate sensitivity study on the input and output parameters including rattle. To simulate rattle phenomenon, it is necessary to include variable input speed, variable moment and the real value of backlash.

Acknowledgement

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The Research into Dynamical Properties of Railway Transition Curves with Smooth and Non-Smooth Curvatures

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Abstract

This article relates to the assessment of dynamical properties and the shape optimization of railway polynomial transition curves (TCs) for the range – 600, 1200 and 2000 m – of circular arc radii. The search for proper shape means here evaluation of the curve properties based on chosen dynamical quantities and generation of a such shape with use of mathematically understood optimization methods. As a transition curve in the studies performed the authors of current article adopted polynomial of *n*-th degree, where *n*=9, 11. In the study one model of rail vehicle was used. The model represented 2-axle freight car of average values of parameters. The authors also used so-called standard polynomial transition curves of 9th and 11th degrees, and 3rd degree parabola as an initial transition curves in the optimization processes. As the quality functions (evaluation criteria) the authors adopted 5 functions concerning lateral and vertical dynamics of the vehicle, as well as creepages in wheel-rail contact. In this work the results of the optimization – smooth and non-smooth optimum transtion curves of 9th and 11th degrees – were presented and compared.
KEY WORDS: *railway transition curves, rail vehicle, optimization*

1. Introduction

The subject of the current work was the optimization of railway transition curves (TCs). As the results of mentioned optimization, the authors obtained TCs treated by them as TCs with the best dynamical properties. As the transition curve the authors of the work adopted a polynomial of degree *n*, where *n*=9 and 11. In fact, for needs of the current article the authors utilised also 5 quality functions (*QFs*). *QFs* applied here concerned both a lateral and vertical dynamics of the vehicle, as well as creepages in wheel-rail contact. All 5 *QFs* concerned a minimisation of maximum values of 5 different functions and they were as follows:

$$QF_1 = max\left|y_b\right|; \tag{1}$$

$$QF_2 = max\left(\sqrt{\upsilon_{1lp}{}^2 + \upsilon_{2lp}{}^2} + \sqrt{\upsilon_{1rp}{}^2 + \upsilon_{2rp}{}^2} + \sqrt{\upsilon_{1lk}{}^2 + \upsilon_{2lk}{}^2} + \sqrt{\upsilon_{1rk}{}^2 + \upsilon_{2rk}{}^2}\right); \tag{2}$$

$$QF_3 = max\left|\dddot{y}_b\right|; \tag{3}$$

$$QF_4 = max\left|z_b\right|; \tag{4}$$

$$QF_5 = max\left|\phi_b\right|. \tag{5}$$

where y_b – lateral displacement of the vehicle body; $\boldsymbol{\upsilon_1}$ – longitudinal creepage in wheel-rail contact; υ_2 – lateral creepage in wheel-rail contact; $\dddot{y}_b$ – change of lateral acceleration (jerk) of the vehicle body; z_b – vertical displacement of the vehicle body; φ_b – angular displacement around x axis; indices *l*, *r*, *p*, *k* refer to left hand-side, right hand-side, front (leading) wheelset, rear (trailing) wheelset, respectively.

2. Method of the Analysis Used in the Work

To make the optimization of TCs the authors used one rail vehicle model. This model represented 2-axle freight car of the average values of parameters. It was the same model as this one used in the earlier studies by the present authors. Its structure is shown e.g. in [3]. It is supplemented with discrete models of vertically and laterally flexible track. Linearity of the vehicle suspension was assumed. So, linear stiffness and damping elements in vehicle suspension were applied. The same concerns the track models. Here, also linear stiffness and damping elements were applied. One can find all parameters of the used models e.g. in [3].

The route of vehicle passage was always consisted of straight track (ST), transition curve and circular arc (CA) and was characterised by a shape of the track centre line, which was the general three-dimensional space curve. A necessary condition to apply the method was description of the curves (sections) by parametric equations, with the curve's current length *l* as the parameter. The cases of CA and ST were treated in the method as the special cases of two- and one-dimensional geometrical objects, respectively. Such an approach was described in [5].

The optimization problem, which was solved in the current studies aimed to find the optimum polynomial coefficients A_i, that define TC's shape. Type of a TC chosen for optimization is the polynomial TC of degree $n = 9$ and 11, as mentioned. It was defined by Eq. (6), that was related to space curve parametric equations:

$$y = \frac{1}{R}\left(\frac{A_n l^n}{l_0^{\,n-2}} + \frac{A_{n-1} l^{n-1}}{l_0^{\,n-3}} + \frac{A_{n-2} l^{n-2}}{l_0^{\,n-4}} + \frac{A_{n-3} l^{n-3}}{l_0^{\,n-5}} + ... + \frac{A_4 l^4}{l_0^{\,2}} + \frac{A_3 l^3}{l_0^{\,1}} \right), \quad (6)$$

where y, R, l_0, and l define curve lateral coordinate, curve minimum radius (at its end), total curve length, and curve current length, respectively. In [4] the authors presented formulas for curvature k, superelevation ramp H (being the scaled curvature), and inclination of superelevation ramp i. The A_i are polynomial coefficients ($i = n$, n-1,..., 4, 3), while n is polynomial degree. Number of the polynomial terms (terms in Eqs. (6)) must not be smaller than 2. On the other hand the smallest degree n_{min} of the last term in Eq. (6) must be $n_{min} \geq 3$. Such definition of the curves gives possibility of proper k and h values at TCs terminal points. They should equal 0 in the initial point and to $1/R$ and H in the end point. Note, that values for both always equal 0 for $l = 0$. In order to ensure $1/R$ and H values for length $l = l_0$, normalisation of the coefficients is necessary, such as in [4].

The scheme of the software used in optimization of TCs shape was shown e.g. in [4]. The major objects within this scheme were two iteration loops visible there. The first loop was the integration loop. This loop was stopped, when distance l_{lim}, being the length of route, is reached by the model. The second one is the optimization process loop. It is stopped, when number of iterations reaches limit value i_{lim}. This value means, that i_{lim} simulations of vehicle motion have to be performed in order to stop optimization process. In the calculations done so far $i_{lim} = 100$ was used as standard value. If the optimum solution is reached earlier, i.e. for $i < i_{lim}$, then the optimization process stops automatically and the corresponding results are recorded. When no optimum solution is reached for $i_{lim} = 100$, then this value has to be increased manually, while the optimization process has to be repeated.

3. Basic Informations on Polynomial TCs of *n* Degrees

Each TC has minimum length l_0, which is calculated in accordance with the method presented in [1]. This minimum length arises from two conditions. They demand that two values are not allowed to be exceeded. First one is the velocity of the unbalanced lateral acceleration change ψ and second one is the velocity of wheel vertical rise along the superelevation ramp f. For needs of this work the authors always took a greater length calculated from both conditions (l_f and l_ψ). Velocity of wheel vertical rise along the superelevation ramp f was always equal to 56 mm/s and velocity of the unbalanced lateral acceleration change ψ was always equal to 1 m/s^3. Radii of circular arc R were assumed to be equal to 600 m, 1200 m and 2000 m and superelevations H were assumed to be equal to 150 mm, 75 mm and 45 mm. For given values of R and H, the authors always calculated two velocities of vehicle according to formula known from engineering practice. Lower velocity always corresponded to lateral acceleration in the plane of track a_{lim} equal to 0 m/s^2, whereas higher velocity corresponded to lateral acceleration equal to 0.3 m/s^2 and 0.6 m/s^2. Full list of the values assumed in optimization processes is demonstrated in Table 1.

Table 1

Conditions of optimization

Radius of circular arc R [m]	Superelevation H [mm]	Lateral acceleration a_{lim} [m/s^2]	Vehicle velocity v [m/s]	Specific conditions of optimization
600	150	0.0	24.26	(1)
		0.6	30.79	(2)
1200	75	0.0	24.26	(3)
		0.6	36.17	(4)
2000	45	0.0	24.26	(5)
		0.3	34.47	(6)

In all optimization processes two standard TCs of degree 9th and 11th [2] were used as initial ones. Additionally, the authors used 3rd degree parabola – TC traditionally used in engineering practice. It was done only in 2 cases:

1) when standard TC apppered to be a local minimum and optimization procedure was not able to find an another solution;

2) for TCs with lengths not greater than 100 m, if otimum TC had the curvature different than linear. The work [3] showed that for such lengths the best TC had a linear curvature.

4. The Results of Optimization and Dynamical Simulations

Generally each polynomial transition curve obtained during optmization process had the curvature (and also superelevation ramp), which may be qualified to one of 5 groupes. These mentioned 5 groupes (types) of TCs are as follows:

1) type 1 – curvature (superelevation ramp) is in practice very similar to the curvature of standard TC of 9th and 11th degree;

2) type 2 – curvature (superelevation ramp) is something between standard TC of 9th and 11th degree and 3rd

degree parabola;

3) type 3 – linear curvature (superelevation ramp) of 3rd degree parabola;

4) type 4 – curvature (superelevation ramp) has convex character. It has slope subtype (4a) or G_1 continuity subtype (4b) at the beginning of TC and it has slope at the end;

5) type 5 – curvature (superelevation ramp) has a concave character.

All types of the curvatures are presented in Fig. 1.

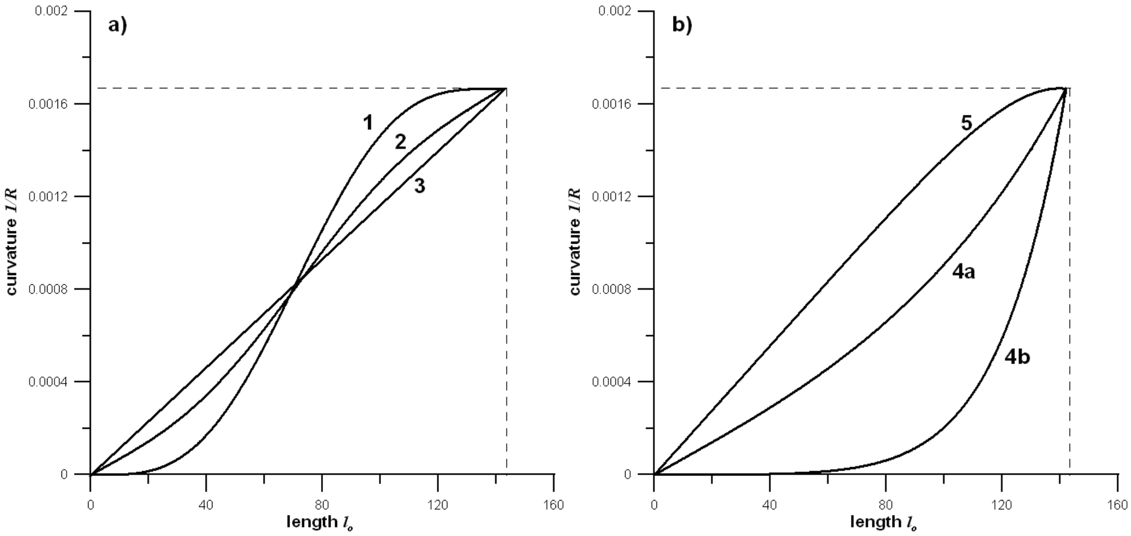

Fig. 1 Types of curvatures: a) 1, 2, 3; b) 4, 5

In Tables 2-4 the authors of the current work presented the results of the optimization – the types of transition curves – obtained in the their research for specific conditions of optimizations:

- circular arc R;
- degree of polynomial n;
- velocity v and unbalanced lateral acceleration a_{lim};
- cant H;
- length l_0.

Table 2

Results of the optimization – the types of transition curves – R = 600 m

n	v, [m/s]	a_{lim},[m/s^2]	H, [mm]	l_0, [m]	QF_1	QF_2	QF_3	QF_4	QF_5
9	24.26	0	150	142.15	5	2	2	1	3
	30.79	0.6	150	180.46	1	1	3	1	2
11	24.26	0	150	159.86	3	1	1	1	3
	30.79	0.6	150	202.94	1	1	1	1	2

Table 3

Results of the optimization – the types of transition curves – R = 1200 m

n	v, [m/s]	a_{lim}, [m/s^2]	H, [mm]	l_0, [m]	QF_1	QF_2	QF_3	QF_4	QF_5
9	24.26	0	75	71.07	4a	3	3	3	3
	36.17	0.6	75	105.98	4b	3	2	1	4a
11	24.26	0	75	79.93	4a	3	3	3	3
	36.17	0.6	75	119.18	3	4a	3	2	3

Table 4

Results of the optimization – the types of transition curves – R = 2000 m

n	v, [m/s]	a_{lim}, [m/s^2]	H, [mm]	l_0, [m]	QF_1	QF_2	QF_3	QF_4	QF_5
9	24.26	0	45	42.64	3	3	3	4a	3
	34.47	0.3	45	60.60	4a	3	3	4a	3
11	24.26	0	45	47.95	3	3	3	4a	3
	34.47	0.3	45	68.15	3	3	3	4a	3

Going to the analysis of the types of TCs obtained and presented in Tables 2-4, we see that in general program has found different optimum shapes of transition curves. The corresponding numbers of transition curves obtained were as follows:

- type 1 – 12;
- type 2 – 6;

- type 3 – 31;
- type 4 – 10;
- type 5 - 1.

The mentioned types of the curvatures are presented in Figs. 2-4 in function of transition curve length for each out of 5 quality functions assumed.

Generally, in majority of cases analyzed the betterment in the system dynamical properties for the optimised transition curves shapes in comparison to the initial curve was confirmed by simulation results - the displacements y_b and accelerations $\ddot{y}_b$ of vehicle body.

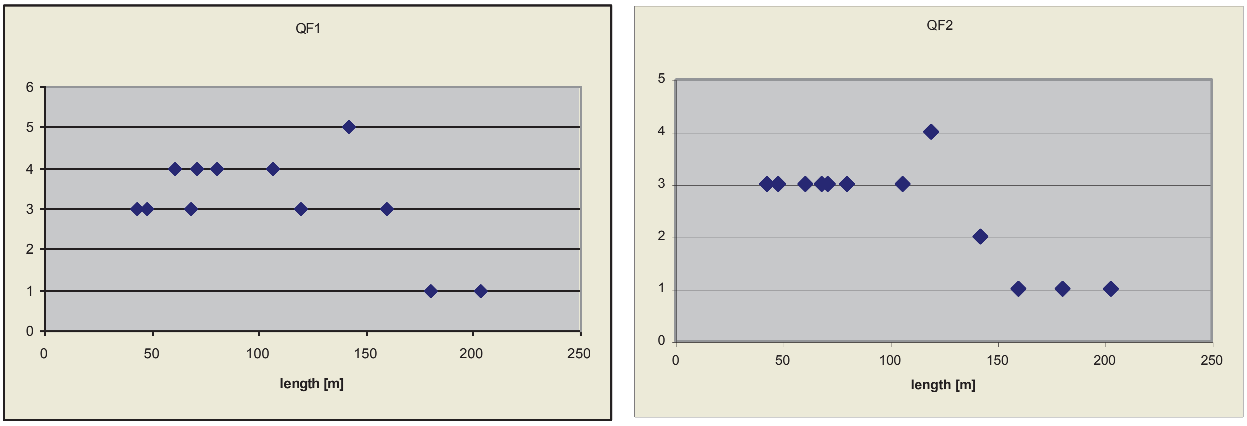

Fig. 2 Types of curvatures (superelevation ramps) in function of the length of the transtion curves for a) QF_1; b) QF_2

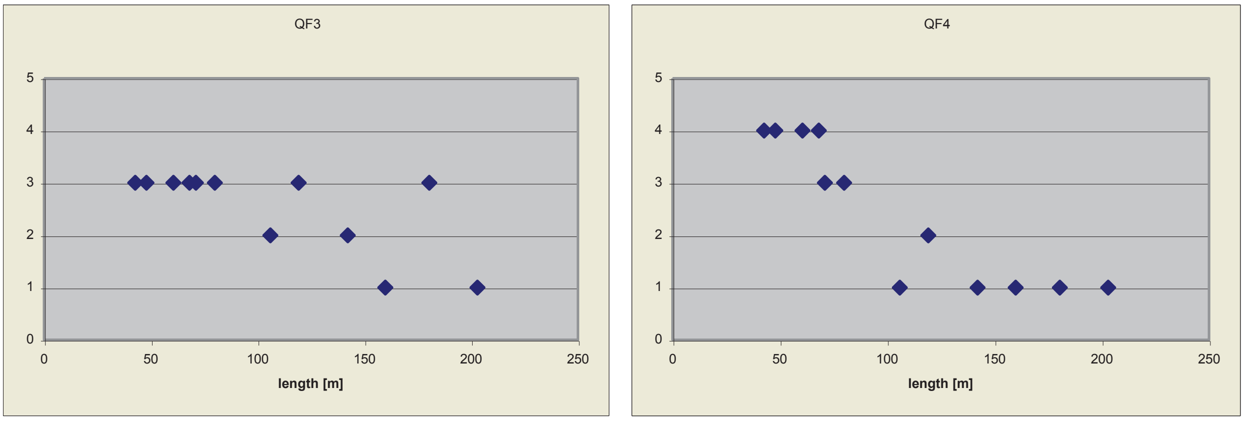

Fig. 3 Types of curvatures (superelevation ramps) in function of the length of the transtion curves for a) QF_3; b) QF_4

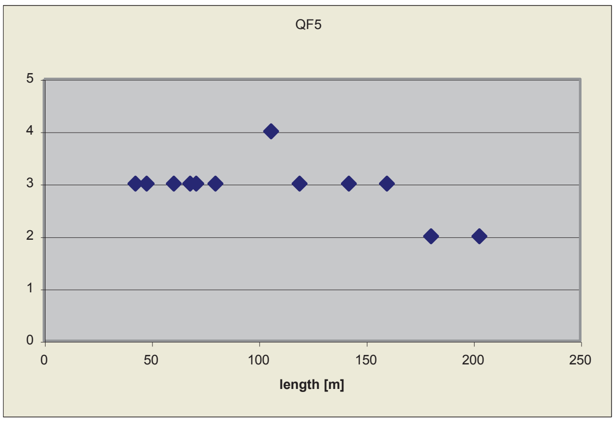

Fig. 4 Types of curvatures (superelevation ramps) in function of the length of the transtion curves for QF_5

Looking at Figs. 2-4, certain observations can be made. For all quality functions assumed, we can see a certain tendency to variation of type of TCs in accordance with the rule 3,4→2→1 in function of increasing transition curve length. Generally, it is visible in similar measure for all quality functions. We see also that the increase of the transition curve length causes the existence of TCs of types 2 and 1, which curvatures have the inflection point in their middle part. In case of type 1 the existance of G^1 continuity in terminal points of a curve is also a fact.

It is also visible that for transition curves with $l_0 < 100$ m, all 3 values of circular arc, and all 5 quality functions assumed the optimum TC was 3rd degree parabola (3 type). In such cases any other transition curve (due to non-linear curvature) is treated by the optimization procedure as the transition curve, which gives greater values of *QF* assumed. Linear curvature of 3rd degree parabola, due to its nature, has no the inflection point in its middle part. The results of the optimization taken from work [3] showed that the existance of a such point have bigger weight (importance) on vehicle dynamics, than the existance of G^0 continuity in terminal point of a curve. Is it very important conclusion for the engineering practice. Moreover, if we take into account the fact that such results were obtained for all 5 quality functions, then we may treat such optimization as multi-objective optimization.

On the other hand, for the case with the greatest length (202.94 m, 11th degree, $R = 600$ m, $H = 150$ mm) of the transition curve, we see that in 4 out of 5 cases (QF_1, QF_2, QF_3 and QF_4), the optimum TCs had type of the curvature no. 1. In mentioned cases, we may say that the length of a TC great enough causes that 3rd degree parabola has not a chance to be the optimum transition curve. It can be explained just by great transition curve length, where there is a lot of time to achieve assumed values *R* and *H* in circular arc. In such case the existance of a inflection point in the middle part has bigger weight (importance) on vehicle dynamics, than the existance of G^0 continuity in terminal points of TC.

It is worth of noting that that 4 out of 5 quality functions (QF_1, QF_3, QF_4 and QF_5) concern vehicle dynamics – both lateral and vertical. In such cases, the dynamical characterics used in quality functions have their biggest values in transition curve zone. The fifth quality function (QF_2) concerns creepages (and also a wear) in wheel-rail contact. The crepages have their biggest values in circular arc. Despite the differences between functions used in quality functions assumed, in 5 all cases, there is a mentioned certain tendency (trend) 3,4→2→1, and there are only 2 optimum transition curves obtained (types of curvature 5), which do not confirm this fact.

The results presented in the current work also confirmed that in general the lateral dynamics (QF_1 and QF_3) of rail vehicles is not conjugated with the vertical dynamics (QF_4 and QF_5) of vehicles. Generally, in engineering practice, we cannot, having the lateral courses – displacements and accelerations – of components of the vehicle (body and wheelsets), determine the corresponding vertical courses. Therefore, the results – the optimum types of transition curves – obtained through the optimizations both for lateral and vertical dynamics in general were different. There are, however, some similarities between them – the mentioned courses have the biggest values in transition curves and approach to a fixed value in circular arc.

5. Conclusions

In the current study their authors showed that for different conditions of optimizations the use of criteria for assessment of the shape of the railway transition curves concerning:

- the vehicle dynamics (lateral and vertical),
- creepages (and also wear) in wheel-rail contact,

Generally resulted in different shapes of transition curves and their curvatures. The adoption of more than one quality functions and different starting points (transition curves) in the shape optimization process enabled to, wider than before (e.g. work [4]), look at the transition curves of higher – 9th and 11th degrees – in the context of their dynamical properties. The mentioned previous work [4] has shown that the polynomial transition curves of degrees 9th and 11th have the types of curvature 1 and 2 only for the cases (transition curves) with the greatest lengths. Therefore, the results presented in work [4] – due to the limit of conditions of optimizations (only one value of circular arc *R* and cant *H*) – are in some measure only a certain fragment of the results presented in the current work. The assuming of more conditions of optimizations allowed to better assess properties of railway transition curves in terms of vehicle dynamics and wear in wheel-rail contact.

The basic detailed conclusions which can be drawn from the study are as follows:

a) for curves of short lengths ($l_0 < 100$ m) in most cases the optimum transition curve was the 3rd degree parabola (type 3),

b) for curves of medium lengths ($l_0 > 100$ m and $l_0 < 180$ m) the optimum transition curves usually have a curvature of 1, 2 and 3 types,

c) for curves of great lengths ($l_0 > 180$ m) in most cases the best dynamical properties have the transition curve with the curvature type 1.

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Helicopter's Fuselage and Tail Boom Joints Testing Using Acoustic Emission Method during Bench Test

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Abstract

An acoustic emission (AE) method allows to perform online helicopter structure monitoring during bench test or real operations. It is very important to be able to find coordinates of a damaged bolts on a tail boom frame No.1 which is one of the most critical areas. In this article is given an experiment of the damaged bolt localization by means of AE method on the tail boom frame No.1 during helicopter bench tests.
KEY WORDS: *Acoustic emission, helicopter, defect localization, fatigue tests*

1. Introduction

As the helicopter operation depends on its resource that provides safe operation up to a certain level and the size of defect, it is important to identify diagnostic methods that provide high sensitivity and their use would allow to assess the level of defect, the nature and to predict its development. Exact defect localization will give an opportunity to plan appropriate maintenance and reduce costs required for repair works.

The most common defects are still fatigue cracks [2, 4, 6, 11] whose basic cause is gradual damage accumulation process during repetitive alternating load appliance. Analyzing helicopter structural defects for different helicopters types it have been concluded that the joint elements of helicopter tail boom are still exposed to fatigue crack formation, crack development process is not controlled, and sometimes it is not possible to detect defects at all. One of the AE method's priorities is the defect detection on the initial stage and precise localization which helps to determine a level of risk and avoid the component failure. This testing method is very attractive due to it allows to increase safety and reduce costs, that is very imports in the aircraft industry.

Despite the fact that exists a theoretical models [1, 3, 10] that link AE parameters with defect occurrence and its stage of development, due to complex data processing they are still incomplete and their application for different materials makes it necessary to assess whether the proposed criteria or their use for real structures in operation is not possible.

2. Test Bench of Helicopter Constructive Elements and Test Performing Methodology

Helicopter test bench [5] was used to develop defect localization methodology of helicopter structure fatigue defect technical diagnostics [7, 8]. The test object controlled structures and parts thereof:

1. Helicopter tail boom;
2. Helicopter keel.

Adopted coordinate system in test trials is as follows: X axis – along the flight path, is located in the horizontal of fuselage structure; Y axis – perpendicular to the horizontal of fuselage structure and is directed upwards; Z and Y axes – in a glider symmetry plane; Z axis – perpendicular to the XY plane.

During test in case of discovered crack in the critical or not critical area of helicopter's boom tail and keel, repair is carried out for particular structural zone and testing continues. The experiments continue until cracks appear in any of the construction of critical areas. If crack is in the same place, then experiments are carried out up to three times. Resource is defined after the test result.

Test bench is attached to the strengthened floor, using the chassis power structures (Fig. 1).

Test bench is equipped with a special system that allows to apply static load:

- at the rotor hub in components F_x^H F_y^H F_z^H;
- at the fastening points of stabilizer for component F_y;
- distribution load F_z^k to keel.

Load values in fatigues test program was set based stress-strain state measurements of helicopter sample during flight trials. The load is applied at the hub of helm rotor – $F_x^H = -2.94\ kN$, $F_y^H = -7.06\ kN$, $F_z^H = -7.85\ kM$, at the fastening points of stabilizator – $F_y = -2.94\ kN$, at the keel – $F_z^k = -4.71$(ribs No.7 and No.8).

Control of the tail boom frame No.1was performed, as it is one of the most critical points.

During research was used a "Vallen Systeme" AMSY-6 hardware and software. AMSY-6 is a multi-channel Acoustic Emission measurement system consisting of parallel measurement channels and a system front end software on an external PC. AMSY-6 consists of AE sensors, preamplifier, signal processors (ASIP-2) and PC running the analysis and acquisition software. Acoustic emission VS-150 RIC type sensors with an internal amplifier were installed on tail boom frame rib No.1 from inside (Fig. 2).

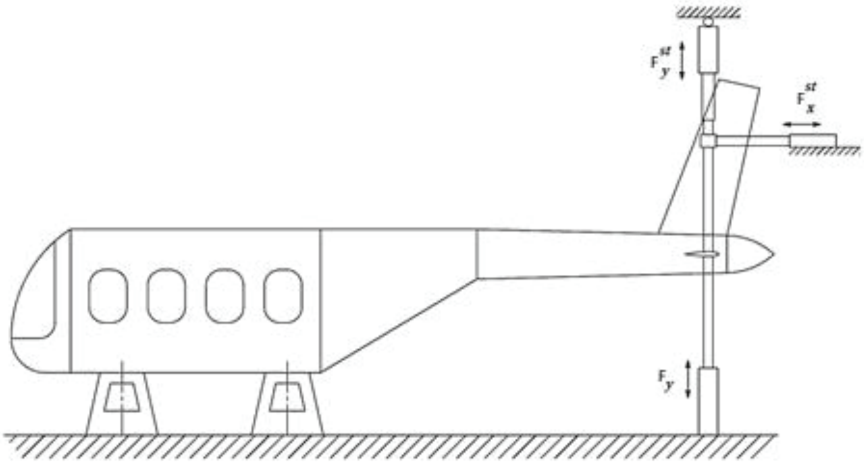

Fig. 1 Helicopter construction fatigue test bench (view from left side) [5]

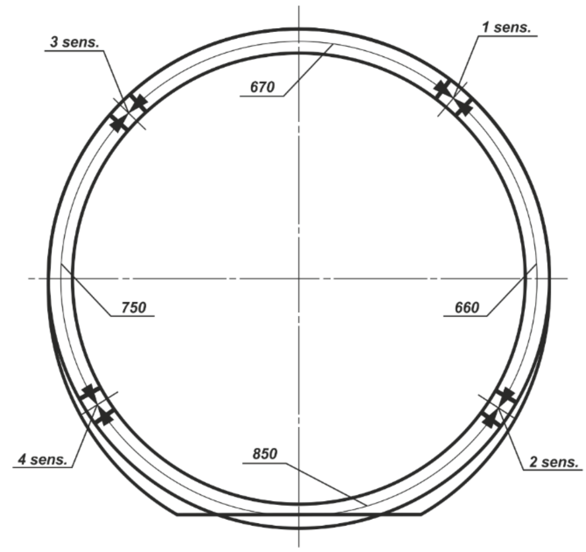

Fig. 2 Location of AE sensors on tail boom rib No.1 and distance between them

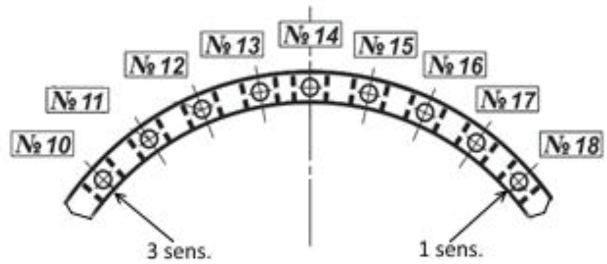

Fig. 3 Joint bolts location between sensors No.3 and No.1

3. Analysis of Test Results before the Failure of Bolt No. 18-3

In 98175 load cycles [9] (each cycle length is 15 seconds and 48 cycles corresponds to 1 flight hour) the 3rd (during the tests) failure of the attachment bolt for hole No. 18 (Fig. 3) in the area of stringer 5 along the right side was revealed. In the process of inspection, the bolt was found without head and 10 mm away (backwards) from the joint hole.

The previous failures of bolts in this hole occurred in 23022 and 51000 cycles. Thus, the life of bolt No. 18-3 is 47175 cycles. It should also be noted that the threaded part of bolt No. 18-1 was produced by cutting and the ones of bolts No. 18-2 and No. 18-3 were produce by thread rolling.

The nucleus area of the crack is under the bolt head in the fillet with a radius of 0.7 mm. By the direction of lettering on the bolt head it was stated that the nucleus area of the crack is on the outer side of the bolt relative to the tail boom axis.

The fracture (Fig. 4) has a fatigue nature typical for all the previously failed attachment bolts. The fatigue zone occupies about 95% of its area and consists of a fine-grained site (about 50% of fracture area) and a coarse-grained site.

On a radius of 2.6 mm from the nucleus area of the crack (bolt diameter under the head in fracture area is 12.5 mm) a narrow fatigue relief band can be clearly seen , which means that the crack stopped to grow due to load redistribution.

The failure of bolt No. 18-3 was detected by all the AE sensors installed in the area of tail boom and fuselage joint. On the basis of AE data, the bolt failure occurred at cycle 97315. It is confirmed by the preceding growth of the crack and high amplitudes reaching a level of 80-100 dB at the moment of failure (Fig. 5) [9].

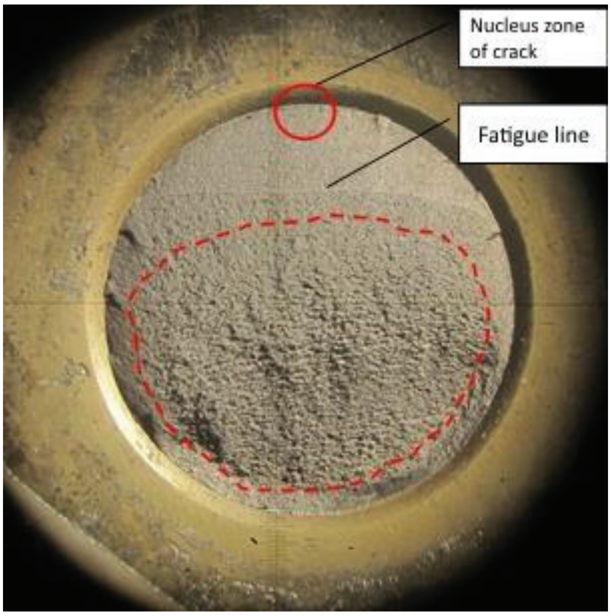

Fig. 4 Appearance of the fracture under the head of bolt No. 18-3 [10]

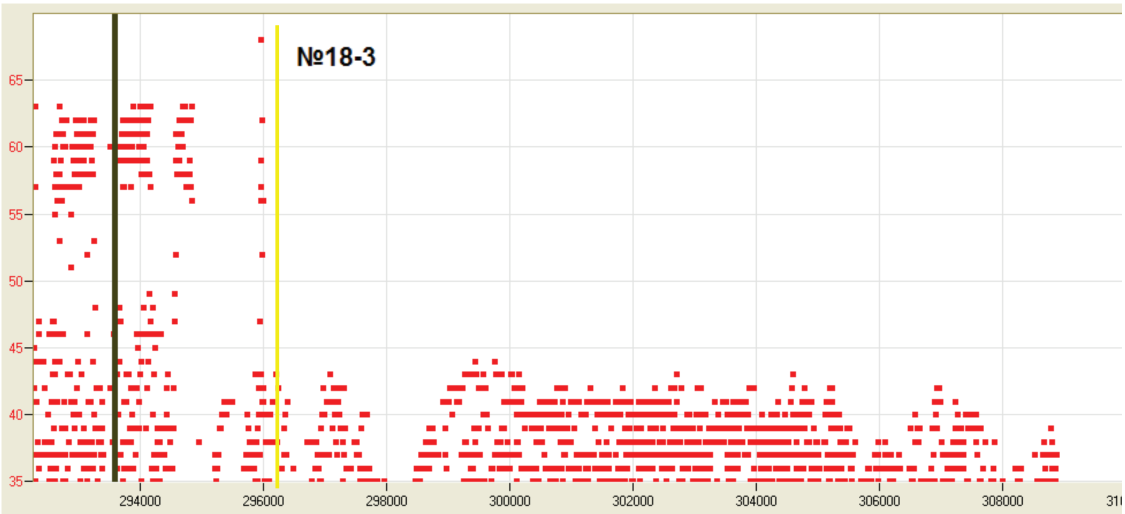

Fig. 5 Criterion of AE signal amplitude at the moment of failure, bolt No. 18-3 [9]

4. Experimental Research of Damaged Bolt Localization on the Tail Boom Frame No.1

Experimentally were proved that an acoustic wave velocity in the material is 3300 m/s. The intervals between sensors are shown in Fig. 4.

An example of measured parameters [12] is shown in Table 1. First of all, measured signals were sorted by the amplitude for noise separation from the real acoustic emission signals.

Table 1

Measured parameters

DSET	HHMMSS	MSEC	SEC	CH	A	R	THR	E	PA0	TRAI	THR
	[hhmmss]	[ms.µs]	[sec.ms]		[dB]	[µs]	[dB]	[eu]	[mV]	[dB]	
1880	16:26:25	213.7319	0.2137319	1	91.4	250.1	45	1.14E+07	3105.63	560	45
1881	16:26:25	213.8423	0.2138423	3	78.7	484.5	45	8.61E+05	3105.63	561	45
1882	16:26:25	213.8949	0.2138949	2	75.8	760.4	45	3.02E+05	3105.63	562	45
1883	16:26:25	214.3379	0.2143379	4	61.5	420.7	45	9.66E+03	3105.63	563	45

For calculation of the defect location were chosen 20 signal with the highest amplitude. In the Table 1 are shown the sequence of acoustic signal emission in the tail boom frame. Firstly, the signal was received with sensor No.1. After that the signal was detected with sensors No.3, No.2 and No.4. Was concluded that the damaged bolt located between the 1st and 3rd sensors, what is enough for linear localization of the defective bolt, using "time difference of arrival" method.

Flat patter of the tail boom frame No.1 is schematically shown on Fig. 6.

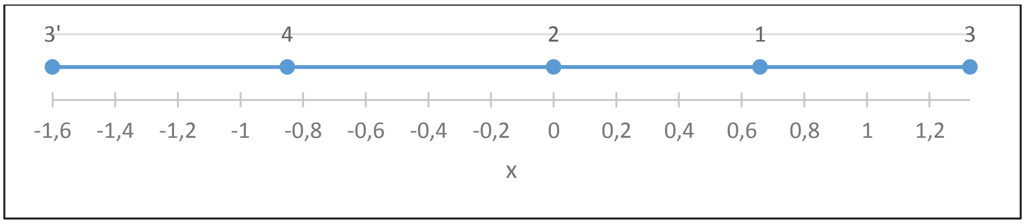

Fig. 6 Flat pattern of the tail boom frame No.1

Time difference of acoustic signal arrival can be expressed as follow:

$$\Delta t = t_3 - t_1, \tag{1}$$

where t_1, t_3 – time of signal arrival at the appropriate sensor.

Distance between source of AE signal and 1 sensor:

$$L_1 = \frac{L - \Delta L}{2}, \tag{2}$$

where L – distance between the sensors; ΔL – signal transmission distance during Δt.

$$\Delta L = C \cdot \Delta t \tag{3}$$

where Δt – time difference of acoustic signal arrival, C – velocity of sound.

Distance between source of AE signal and 3rd sensor:

$$L_3 = L - L_1 \tag{4}$$

where L_1 - distance between source of AE signal and 1st sensor.

After the calculations was found a mean value of the distance between the source of acoustic emission and 1st sensor $L_{1\ avg}$ = 0.133205 (Fig. 7).

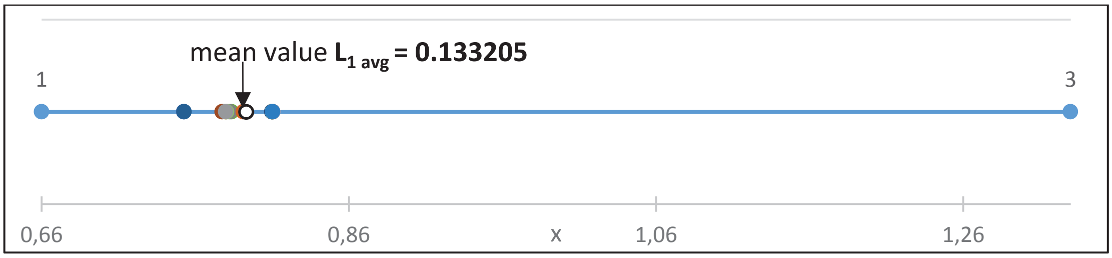

Fig. 7 AE source location between the sensor No.1 and sensor No. 3, and mean value

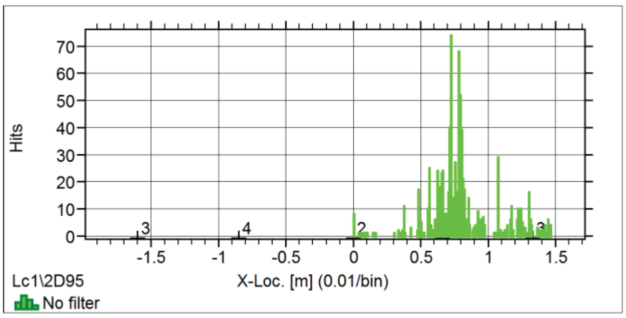

Fig. 8 Number of hits in coordinate points

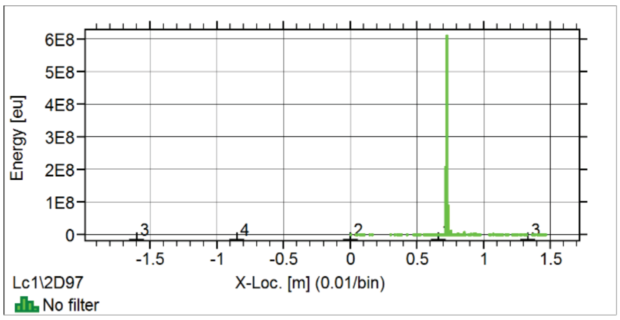

Fig. 9 Released energy in coordinate points

In Fig. 8 are shown the number of hits in coordinate points, where two points have the highest numbers of hits: x = 0.71 m, where were registered approx. 73 hits and x = 0.79 with approx. 69 hits.

In Fig. 9 is shown released energy in coordinate points. It is concluded that the highest value in the point with x = 0.71 was released during the failure of the bolt.

5. Conclusion

The helicopter fuselage and tail boom joint bolt fatigue damage diagnostics with fault localization was performed during bench tests when based on AE data bolt fracture was expected. Bolt fracture was predicted at least 26 to 44 hours before the actual collapse.

Using the "time difference of arrival" method for defect localization, the source of acoustic emission was found between the 1st and 3rd sensors, located by 0.13 m from the sensor No.1. Calculated results were compared with the real location of the damaged bolt and results, provided by the "Vallen Systeme" program. As a result, the calculated location of the acoustic emission source was detected with high accuracy.

AE non-destructive testing method is very promising due to it allows to detect and control growing defect, helps to identify its nature and evaluate a risk of failure. Timely localized defect can prevent accidents and gives an opportunity to plan appropriate maintenance. The correct defect localization during bench test saves time and reduce costs.

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Longitudinal Evenness Quantification of Road Transport Infrastructure

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Abstract

One of the requirements concerning pavement quality is the evenness of its surface. Pavement unevenness has a random character and has an adverse influence to rolling resistance, tyre/pavement coherence, safety and the driving comfort. Knowledge of longitudinal unevenness has been long recognized as an important criteria of road performance, not only for safety by causing vehicle vibrations and affecting ride comfort but also as a major factor in pavement deterioration and working conditions of vehicles. The paper presents the results gathered from a few years´ research activities carried out in the authors´ work place and leading to the construction and testing of original equipment for the measurement of pavement longitudinal unevenness. The equipment has been designed as a single-wheel trailing vehicle and has been constructed on the DMS (double-mass measuring set) principle.
KEY WORDS: *pavement, longitudinal unevenness, power spectral density, unevenness degree C*

1. Introduction

One of the requirements concerning pavement quality is the unevenness of its surface. Pavement unevenness has a random character and has an adverse influence to rolling resistance, tyre/pavement coherence, safety and the comfort of a drive. Knowledge of longitudinal unevenness theory has been long recognised as an important criteria of road performance, not only for safety by causing vehicle vibrations and affecting ride comfort, but also as a major factor in pavement deterioration. Analysis of unevenness can be considered as one of the „first aid“ system to the highway engineer in the survey of road networks and maintenance diagnosis. Based on presented facts we can state, that the quantification of the longitudinal unevenness is essential attribute to the implementation of any Pavement Management System. Our measuring set called the single-wheel vehicle of the University of Žilina (abbr. UNIZA single-wheel vehicle named JP VŠDS) has been designed on the DMS - double-mass measuring set principle [1].

2. Analytical Description of Pavement Longitudinal Unevenness

An analytical description of spatial pavement unevenness is very complicated problem. On this account is advisable to supply spatial problem by two-dimensional one and to evaluate separately cross and longitudinal unevenness. A problem of longitudinal unevenness has been solved for 15 years on our department and next papers were published about it [2], [3]. In the most elementary case, a harmonic sinusoidal form in one trail, we can express a longitudinal unevenness in time scale by equation (1).

$$h(t) = h_0 \cdot sin\left(2\pi \frac{v}{L} t\right) \equiv h_0 \cdot sin(2\pi ft) \equiv h_0 \cdot sin(\omega t) \,, \tag{1}$$

where h_0 - unevenness amplitude (m); L - unevenness wavelength (m); v – wheel velocity (m.s^{-1}); t – time (s); f – time frequency (s^{-1}); ω - angular circular frequency (rad.s^{-1}). The harmonic process of longitudinal unevenness is only rare and real pavements have un-evenness of various wavelength and amplitude. These processes from the point of view of mathematics statistic can be considered as a random process. An important requirement of technical applications is a fulfilment of stationary and ergodic premise [4]. This imposition must be provided by appropriate selection of evaluated road sections, which are homogenous from the point of view of construction and degradation conditions.

Every centred stationary random process can be characterized by correlation function or power spectral density [5], [6]. Correlation function $K_h(\lambda)$ for this type of process is expressed by equation:

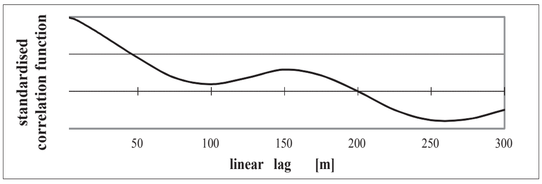
$$K_h(\lambda) = \lim_{T\to\infty} \frac{1}{T} \int_0^T h(t) \cdot h(t+\lambda) \cdot dt \,, \tag{2}$$

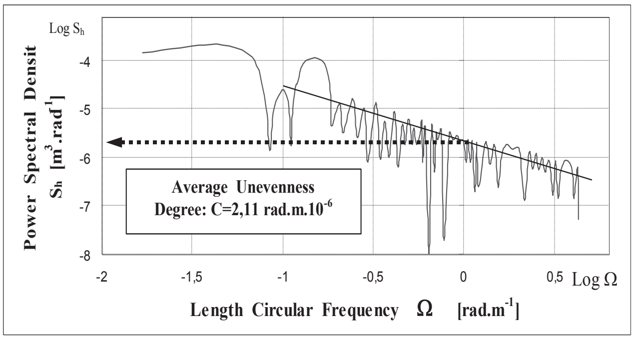
where λ is time lag (s). For our purpose of unevenness assessment, it is more appropriate to use power spectral density $S_{h(\omega)}$, which we can express from correlation function by means of Wiener-Chinčin equation in form:

$$S_h(\omega) = \frac{2}{\pi} \int_0^{\infty} K_h(\lambda) \cdot cos(\omega\lambda) \cdot d\lambda \,. \tag{3}$$

The design of a system pavement assessment from the point of view of longitudinal unevenness was realised for a consideration stationary random process and principle this design is published in chapter 4. Stochastic unevenness is computed as a difference between a real and theoretical profile. In our case we must identify elevations of longitudinal profile per 0.25 m and longitudinal unevenness are evaluated through the standardized correlation function $\rho_h(\lambda)$ (left hand side of Fig. 1).

$$\rho_h(\lambda) = K_h(\lambda)/D_h \tag{4}$$





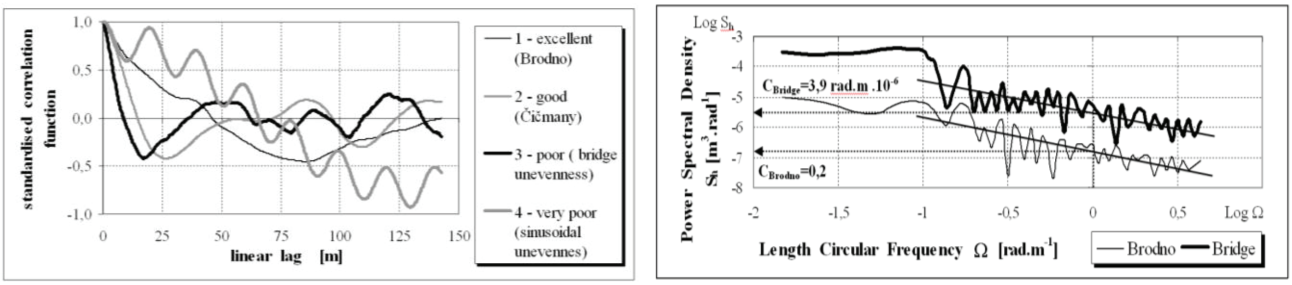


Fig. 1 Standardized correlation function and PSD of stochastic unevenness

3. Description of the Equipment UNIZA Single-Wheel Vehicle

Our equipment represents model of a quarter of the passenger vehicle. Its basic parts and dimensions are presented in Fig. 2. The measuring car requires a towing vehicle equipped with a special frame in order to stabilise the single-wheel vehicle. A measurement velocity is optional in dependence on the character of a measured road.

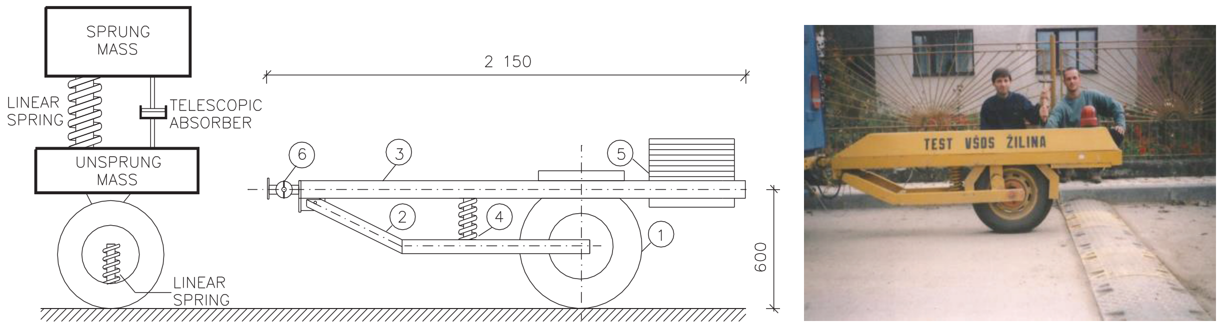


Fig. 2 Basic scheme of a UNIZA single-wheel vehicle: *1* - front wheel with a S 120 charge; *2* - bottom frame; *3* - upper frame; *4* - spring and telescopic shock absorber S 120; *5* - balancing load; *6* - cardan joint

For theoretical calculations and practical measurements some basic characteristics had to be determined.

Weights of individual parts:

- weight of a spring and a shock absorber (part 4 in Fig. 2) 9,5 kg
- weight of an un-sprung mass (parts 1 and 2) 46,0 kg
- weight of a sprung mass (parts 3, 5 and 6) 200,0 kg

Determination of a spring constant:

- by the theoretical calculation 40,4 kN.m^{-1}
- experimentally 39,2 kN.m^{-1}

Single-wheel frequency:

- first resonant frequency - by the theoretical calculation 1,25 Hz
- experimentally 1,30 Hz
- second resonant frequency 11,80 Hz

Presented characteristics have been confirmed by experimental measurements. Improved scanning and assessment of equipment can be seen in Fig. 3. Second version enables to perform all operations as first version and it has plenty of advantages that are described in [2] and consists of the following main parts.

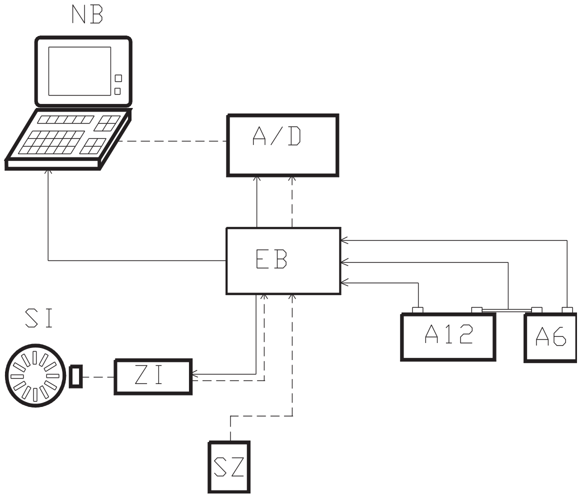


Fig. 3 A scheme of the scanning and assessment equipment - second version

The measuring set enables the scanning, recording, assessment and storing of dynamic responses of longitudinal unevenness. It consists of the following main parts:

- **SZ –** an inductive type of a scanner (working frequency 0 - 100 Hz and sensibility of 0 - 200 m.s^{-2});
- **A/D** - analog-to-digital convertor;
- **EB - power block, A12 and A6 - accumulator + 12 V + 6 V** - enables a current supply of the complex equipment;
- **SI - pulse counter** and **ZI - pulse amplifier –** enables a distance measurement in constant distances (15 cm, 30 cm, 45 cm, …);
- **NB - notebook +** - in dependence on a choice of a sample distance the values of accelerations can be measured and stored on a disk and software support **CMS software -** enables a determination of an unevenness parameter of a selected calibrated section and assessment of a measured section by means of an unevenness degree C.

The mechanical model of UNIZA single-wheel vehicle (Fig.4) was used for measurement. Dynamic responses of sprung mass of single-wheel vehicle was indicated by speed control bump – type CZ 8.

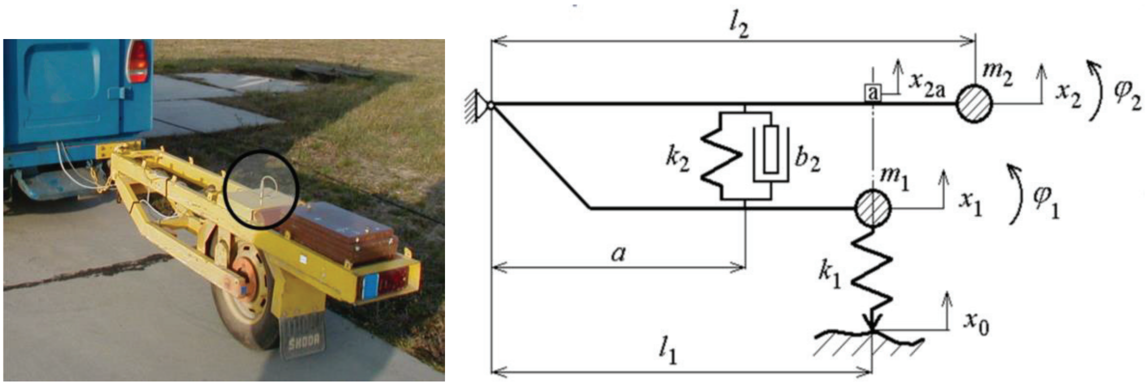


Fig. 4 Mechanical scheme of UNIZA single-wheel vehicle

The equations of motion for dynamic model of UNIZA single-wheel vehicle according to Fig.4 are as follows

$$m_1\ddot{x}_1 = k_1\left(x_0 - x_1\right) - f_{21}; \tag{4}$$

$$m_2\ddot{x}_2 = f_{12}. \tag{5}$$

In the case of small vibrations (φ_1, $\varphi_2 < 5°$) the vertical displacements are given by relations $x_1 = l_1\varphi 1$ and $x_2 = l_2\varphi_2$. The force f_{21} in Eq. 5 means the force effect of suspension spring and damper onto the mass m_1 in the direct of its vertical axle. On the base of moment equation to the cardan joint, the force f_{21} could be expressed as follows:

$$f_{21} = k_2 \frac{a^2}{l_1}(\varphi_1 - \varphi_2) + b_2 \frac{a^2}{l_1}(\dot{\varphi}_1 - \dot{\varphi}_2) = k_2 \frac{a^2}{l_1^2} x_1 - k_2 \frac{a^2}{l_1 l_2} x_2 + b_2 \frac{a^2}{l_1^2} \dot{x}_1 - b_2 \frac{a^2}{l_1 l_2} \dot{x}_2 . \tag{6}$$

Similar, the force f_{12} in Eq. 20 presents the force reduction effect on the mass m_2 in direct of its vertical axle:

$$f_{12} = k_2 \frac{a^2}{l_2}(\varphi_1 - \varphi_2) + b_2 \frac{a^2}{l_2}(\dot{\varphi}_1 - \dot{\varphi}_2) = k_2 \frac{a^2}{l_1 l_2} x_1 - k_2 \frac{a^2}{l_2^2} x_2 + b_2 \frac{a^2}{l_1 l_2} \dot{x}_1 - b_2 \frac{a^2}{l_2^2} \dot{x}_2 . \tag{7}$$

The equations of motion for small vibrations after substituting the Eqs. 7, 8 into the Eqs. 5, 6 are given by:

$$m_1 \ddot{x}_1 + b_2 \frac{a^2}{l_1^2} \dot{x}_1 - b_2 \frac{a^2}{l_1 l_2} \dot{x}_2 + \left(k_1 + k_2 \frac{a^2}{l_1^2} \right) x_1 - k_2 \frac{a^2}{l_1 l_2} x_2 = k_1 x_0 \tag{8}$$

$$m_2 \ddot{x}_2 + b_2 \frac{a^2}{l_2^2} \dot{x}_2 - b_2 \frac{a^2}{l_1 l_2} \dot{x}_1 + k_2 \frac{a^2}{l_2^2} x_2 - k_2 \frac{a^2}{l_1 l_2} x_1 = 0 \tag{9}$$

In fact, we do not measure acceleration on the mass m_2 but on the accelerometer placed on the sprung mass in the distance of tyre vertical axle, see Fig. 3. From this point of view, it is necessary to rewrite the equations of motion.

The vertical displacement (velocity, acceleration) of mass m_2 can be expressed as a function of geometry and displacement (velocity, acceleration) of accelerometer as follows:

$$x_2 = (l_2/l_1) \cdot x_{2a} \rightarrow \dot{x}_2 = (l_2/l_1) \cdot \dot{x}_{2a} \rightarrow \ddot{x}_2 = (l_2/l_1) \cdot \ddot{x}_{2a} . \tag{10}$$

After substituting Eq. 10 into Eq. 8 and 9 we can rewrite these relations as:

$$m_1 \ddot{x}_1 + b_2 \frac{a^2}{l_1^2}(\dot{x}_1 - \dot{x}_{2a}) + k_2 \frac{a^2}{l_1^2}(x_1 - x_{2a}) + k_1 x_1 = k_1 x_0 ; \tag{11}$$

$$m_2 \ddot{x}_{2a} + b_2 \frac{a^2}{l_2^2}(\dot{x}_{2a} - \dot{x}_1) + k_2 \frac{a^2}{l_2^2}(x_{2a} - x_1) = 0 . \tag{12}$$

The simulated responses were calculated in the algorithm IRI – KCS. The measured accelerations were obtained by transducer B 12/200 of the HBM company (by circle in Fig. 4) - an inductive type of a scanner of a working frequency 0 - 100 Hz and sensibility of 0 - 200 m.s^{-2}. The comparison measured and simulated accelerations can be seen in Fig. 5 [2].

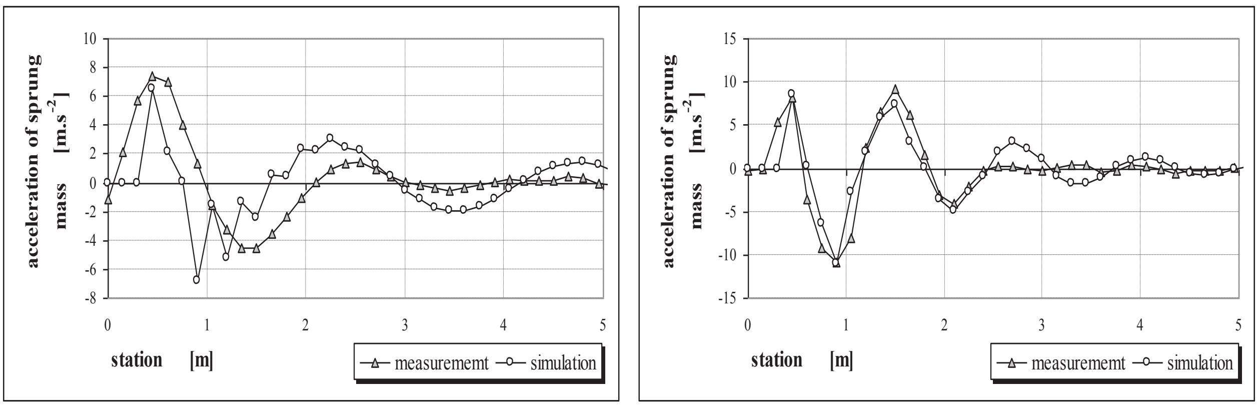


Fig. 5 Comparison of measured and simulated dynamic response of sprung mass of UNIZA single-wheel vehicle

4. Assessment of Unevenness Measurements

The unevenness degree C of evaluated road section is expressed from the basic relation [7]

$$C = \frac{D_y}{I \cdot v} , \tag{13}$$

where D_y - dispersion of an output signal ($m^2.s^{-4}$); I - parameter of a dynamic transfer ($rad^{-1}.s^{-3}$); C - unevenness degree (rad.m); v - quasi-constant velocity ($m.s^{-1}$). In accordance with results of work [1] is convenient to use following input parameters for evaluation in term of the construction conditions (to select window of the length 10 m without overlapping) and from the point of view of ride comfort and safety (to select window of the length 100 m with overlapping 10 m). Our measuring set must be calibrated on road sections of length 500 m which have measured profile elevations at constant interval 250 mm. Determination of an unevenness parameter of a selected section is on Fig. 6.

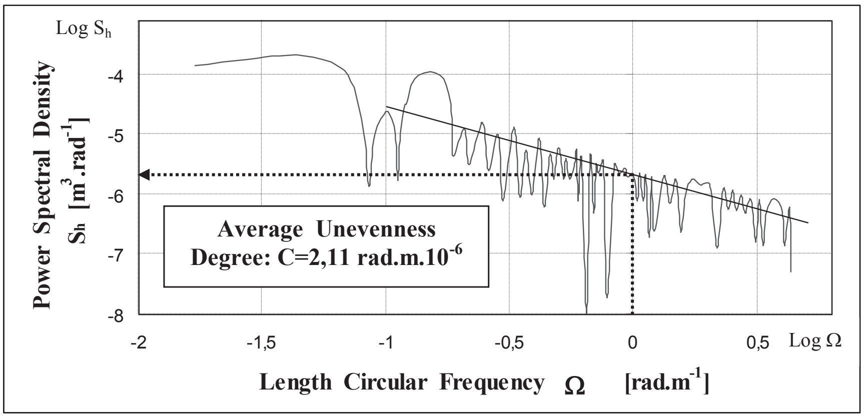


Fig. 6 A determination of parameter C from calibrate section Cicmany [1]

The dynamic transfer parameter of measuring set is detected from measurements (for velocity 10, 15, 20 and 25 $m.s^{-1}$) of calibration sections. The evaluation of urban road with 3 speed control bumps terms of the construction condition can be seen in Fig. 7

The change of a qualification scale of the longitudinal unevenness, according to [1], can be seen in table 1. To determine the criteria for an unevenness assessment, the theory of random functions and statistical dynamics is used, paying attention to two factors: **influence to the vehicle crew** and **influence to passengers.**

The unevenness degree C [$rad.m.10^{-6}$] of an evaluated road section is expressed from the basic relation [2] that was modified for our mode of unevenness identification by were calculated.

$$C = \frac{D_y}{I \cdot \frac{1}{N} \sum_{i=1}^{n} v_i}, \quad (14)$$

where C - unevenness degree (rad.m), D_y - dispersion of sprung mass acceleration ($m^2.s^{-4}$) and I - parameter of dynamic transfer ($rad^{-1}.s^{-3}$), v_i - digital values of a measured velocity ($m.s^{-1}$).

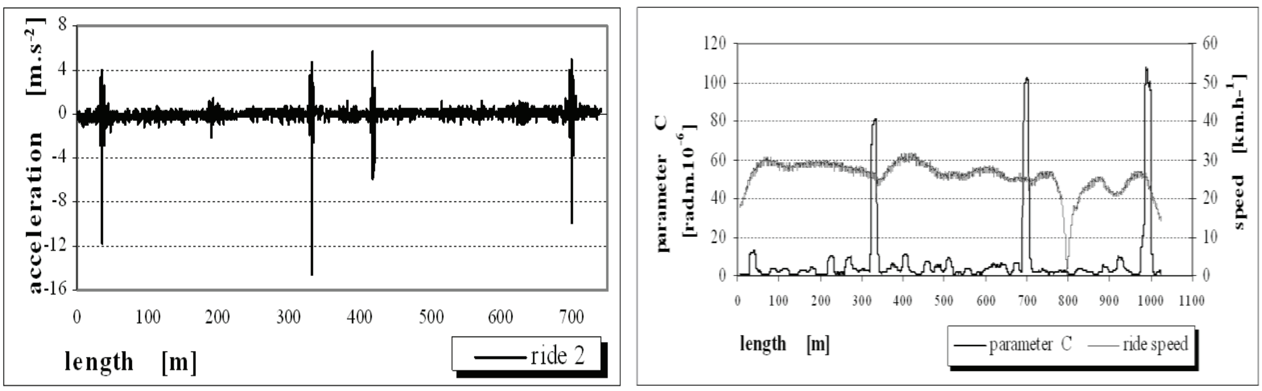


Fig. 7 Vertical acceleration indicated by speed control bump and ride speed / parameter C evaluated by UNIZA vehicle

Results of many experimental measurements have been used for a determination of the unevenness criteria about qualification scale of road longitudinal unevenness (Table 1) too.

The characteristics of UNIZA single-wheel vehicle, presented in chapter 3, have been confirmed by experimental measurements. This verification has resulted from premise, that cross unevenness of concrete pavement, at constant distance 6 m, negatively affect evaluated longitudinal unevenness by parameter C. Experimental measurements of a road section I/64 near Bytča-Hrabové have been realised to determine this assumed influence. The results of these measurements can be seen in Table 2 and in Fig. 8.

Table 1

Qualification scale of road longitudinal unevenness

Qualification degree		Parameter C (rad.m.10^{-6})			
Level	Quality name	Highways		Road and local communications	
		used criteria	our change	used criteria	our change
I.	Excellent	< 2	< 1	< 5	< 2
II.	Good	2 – 5	1 - 2	5 - 10	2 - 5
III.	Poor	5 – 10	2 - 5	10 - 20	5 - 10
IV.	Very poor	10 – 20	5 - 10	20 - 50	10 - 20
V.	Unsuitable for traffic	> 20	> 10	> 50	> 20

Table 2

The results of the longitudinal unevenness measurements of road section I/64

Direction	Ride number	Measuring velocity		Frequency [Hz]	Parameter C [rad.m.10^{-6}]	
		[km.h^{-1}]	[m.s^{-1}]		average	maximum
Bytča- - Považská Bystrica	3	10	2,77	0,46	3,28	5,61
	5	20	5,55	0,93	3,75	8,53
	7	28	7,77	1,30	4,55	10,98
	9	36	10,00	1,67	3,37	7,46
	11	54	15,00	2,50	2,2	4,62
	13	72	20,00	3,33	1,91	4,21
Považská Bystrica- -Bytča	6	20	5,55	0,93	3,46	6,78
	8	28	7,77	1,30	3,92	7,55
	10	36	10,00	1,67	3,07	6,74
	12	54	15,00	2,50	1,84	4,26
	14	72	20,00	3,33	1,76	3,72

The presented assumption has been almost absolute confirmed for first resonant frequency and second self-frequency has not been able to find out but we can presume its correctness for a consideration trend of curves in Fig. 8.

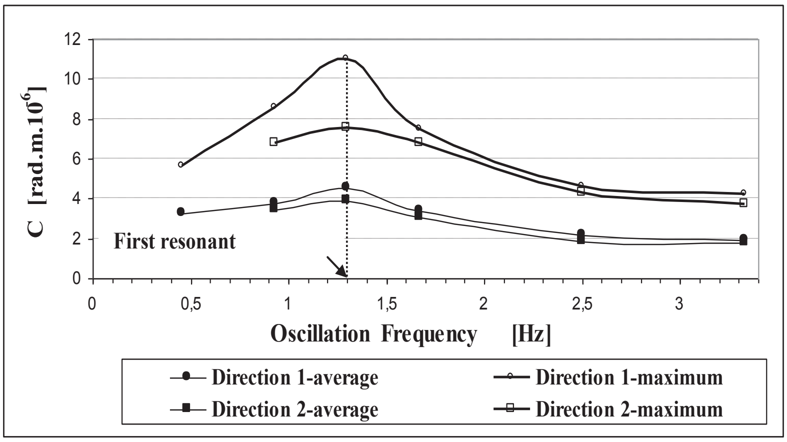


Fig. 8 The dependence of parameter C on oscillation frequency for concrete pavement

5. Conclusions

The UNIZA single-wheel vehicle has been designed for continuous high-speed survey. It can be used on any type of surface, paved or unpaved, and under severe environmental conditions. Among more advantages of the UNIZA single-wheel vehicle we would like to point out the following:

- the results are given instantly;
- the results are given in the graphic and text form;
- the accurate localization of concrete longitudinal unevenness;
- the possibility to obtain output file in a form of the parameter.

The results detected by the UNIZA single-wheel vehicle can be used for need of a maintenance planning. These advantages enabled the preliminary unification of qualification scales of the road longitudinal unevenness for the parameters IRI and C and therefore now the results detected by the UNIZA single-vehicle could be used for Pavement Management System [7], [8].

Acknowledgement

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Upcoming Changes in IFR Training

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Abstract

Paper dissertates about upcoming impacts of changes in EU legislative in area of IFR flying. Changes proposed by EASA committee aims to change approach for instrumental flying. Change of paradigm aims into improving theoretical training and to make instrumental training more achievable by general aviation pilots. Upcoming changes will introduce new instrumental rating as well as changes in the existing ratings. Paper is mostly based on NPA 2016-03 and NPA 2016-14.
KEY WORDS: *ATO, pilot training, IFR*

1. Introduction

In 2017 there will be upcoming changes in the IFR pilot training. These incoming changes are brought by two EASA NPAs. Namely NPA 2016-03 [1]. and partially also NPA 2016-14. I tis important to stress in the beginning that this paper is based on these NPAs, and because there is still no Comment Response Documents for these NPAS, we are still unaware how the actual changes to PART-FCL will look like. But it is most probable that majority of these NPAs will be turned into AMC to PART-FCL.

2. Changes in Theoretical Training

The most crucial change, from our point of view, is a very deep change in theoretical training syllabus for all IFR training. Namely trainings impacted by NPA 2016-03 are all modular and integrated CPL/ATPL course both for aeroplanes and helicopter, also changes are proposed for CB(IR) and EIR. The amendments proposed in this NPA affect ATOs, student pilots, competent authorities, providers of textbooks and training materials, as well as the Agency and the ECQB in particular [1].

The first most important change which triggers additional changes is introduction of new subject to theoretical training. The new theoretical training „subject" is called KSA – knowledge, skills and attitudes. The word subject is in quotation marks because KSA is not traditional subject but it is referred more as a new philosophy of training. The new Area 100 KSA is proposed to be introduced only for the ATPL, MPL, and CPL courses.. As stated in [1]. The aim of Area 100 KSA, is to clearly develop and elicit a higher level of thinking in future pilots already during their ground training, and to challenge student pilots to enhance their decision-making skills, their problem-solving ability, their level of understanding of assimilated knowledge, and generally to facilitate the development of their core competencies. All these are very positive intentions but it seems very ambitious also.

Area 100 KSA addresses the lack of integration of various pieces of information that student pilots receive throughout their TK courses while also extending their core competencies during the TK course. This is an area which will be holistically integrated into and throughout the entire training syllabus, and is expected to prepare future pilots not only for the moment of examination, but also for their future career.

Area 100 KSA provides the tool which will enhance student pilots' ability to relate and apply theory to practice as students 'learn by doing'. It promotes practical training and testing — in addition to the assessment method of multiple-choice questions currently in place in the other subjects of the ECQB. This new set of LOs is grouped by the ICAO/IATA/IFALPA10 core competencies, with the extra addition of 'knowledge' (this is included by Airbus in its core competencies

In other words EASA tries to combine some parts of theoretical training and practical skills. Advantage of addition of these practical skills and attitudes into theoretical knowledge training is decreasing cost of such training. If any part of training shouldn´t be provided by ATO of practical training in real aircraft it may decrease the costs. Disadvantage of this approach will be increased cost for ATO to prepare their syllabus and theoretical training for this new approach. It can before ATO quite difficult to upgrade their learning material and manuals according this new approach. Words like holistic, philosophy and core competencies is typically not incorporated in ATOs learning materials.

With this new are 100 KSA is connected another new technicality. Testing of pilot students from questions from area 100 KSA will not be provided by CAA but by ATO. This decision is output of logical presumptions that every ATO is equipped with another types of equipment usable for such training. Because there is expected to use simulators, mock-ups and demonstrators of many types i tis quite obvious that the testing may not be provided by some standardised practice by CAA. Such testing would contradict to the aforementioned approach of to prepare future pilots not only for the moment of examination, but also for their future career. But testing within ATO brings additional responsibility for instructors and costs to ATO. Theoretical instructors may now be under same pressure from pilot students to decrease the difficulty of such exam. This is not new phenomena and many Flight instructors occurred in such situation, and the proper solving of such situation is many only on experiences of the instructor. There is afraid from side of ATOs with high standards, that they might loose some clients because these clients would prefer ATO with lower standards to be able to pass testing. As mentioned earlier this is not a new phenomenon, ATOs have to already deal with similar situation during practical training, but this new change will bring them another complicated area of customer service to solve.

Also it is important to mention that there is quite complicated walkthrough how such testing should be provided and ATOs will have to cooperate with CAA to set limits and options for such testing. There will be some additional costs and work to do for ATO to fulfil the prescribed way how to test this. The EASA proposes new GM (GM1 and GM2 to ORA.ATO.230(a).'Training manual and operations manual') for the assessment of student pilots in the Area 100 KSA.

Word pictures are used to explain the method by which the new Area 100 KSA should be properly evaluated by ATOs. This assessment step should be included in each ATO's course design. EASA suggests the use of word pictures, as introduced in evidence-based training (EBT), as a tool to standardise the assessment of student pilots' core competencies for the Area 100 KSA.

A word picture is a method of converting indicators, observed during an exercise or assessment, into a competency grade level. Word pictures typically describe five numerical grade levels, which then enable standardisation of the assessment.

As stated in 'GM2 ORA.ATO.230(a) [1], 'Word pictures' are a proven assessment tool that standardises student pilot core competencies. A word picture is a method of converting indicators, observed during an exercise or assessment, into a competency grade level. Word pictures typically describe five numerical grade levels which then enable standardisation of the assessment. A word picture is normally constructed with elements containing:

(a) HOW WELL the core competency was demonstrated in the exercise; together with

(b) HOW MUCH assistance was required from the trainer assessor, which enables the assessment exercise to be used for further development as well as assessment;

(c) HOW OFTEN and HOW MANY of the indicators were observed to enable

(d) the OUTCOME (how successfully the exercise was achieved).

Despite the fact that this model is proposed to achieve a meaningful and standard grading framework based on the core competencies, which could then be used across a student pilot's training to enable continuous relative assessment as their core competencies develop, there is still quite large window for instructor own interpretation. Although new taxonomy was introduced by this NPA. THe BENJAMIN BLOOM TAXONOMY was introduced in KSA 100 assessment process and now clearly specifies what each used verb means. But only most often used verbs are specifed:

'Demonstrate' means the selection and use of the appropriate knowledge, skills and attitudes within a strategy to achieve an effective outcome. It signifies a high taxonomy level and would normally be assessed using multiple indicators from more than one core competency.

'Show' means the attainment of knowledge, skill or attitude. It signifies a lower taxonomy level than 'demonstrate' and would normally be assessed by a single indicator.'

So these two terms are sati factionary define and there should be no special problem. But several indicators are designed in such way that instructor shall decide if student achieve satisfactory level to pass based upon other verbs which are not specified by this taxonomy. For example:

Asks relevant and effective questions. — Communicates relevant concerns and intentions. — Correctly interprets non-verbal communication. — Uses appropriate eye contact, body movement and gestures that are consistent with and support verbal messages. — Adheres to behaviour and communication related to the 'adult' mode etc. (These are actual proposed indicators from part KSA 100 communication).

Many valuation and decision about these indicators will be solely on instructor decision. Therefore it is questionable if such complicated tool how to evaluate student is even needed, when the core decision is still upon instructors decision.

With KSA100 are connected several other proposed changes to PART-FCL, for example there is proposed elimination of theoretical training division to individual subject with minimal theoretical learning hours prescribed. Now there is only minimal total time (75hours, 650hours, 500 hours, 350 hours), and vague description: „The minimum of XX hours of training, which includes the development and assessment of the Area 100 KSA LOs, should be divided between the subjects, the interwoven LOs of Area 100 KSA, and the assessments, as based on the ATO's systems course design and agreed upon between the competent authority and the ATO".

This may again lead to bypassing the regulation by ATOs with lower standards by decreasing subject hour dotation for those they have insufficient theoretical instructors and adding hours to subjects which they have better covered. From our point of view complete elimination of subject hour division was not necessary, although some freedom for training syllabus preparation is suitable.

The new aspects and philosophy introduced by subject KSA 100 shall be projected to all existing IR trainings, all instructors shall be provided with proper training how to fulfil aims of this new regulations. All learning materials shall be changed to ensure the ability of students to pass the KSA 100 in-house testing. Great importance is stressed on incorporating of threat error management into the theoretical training in all those subjects where it is suitable.

3. Changes in Other Subjects

Although addition of new are 100 KSA into the training is the most discussed feature of NPA 2016-03, in fact for most theoretical knowledge instructors will be the major challenge major change in theoretical training syllabus introduced by NPA 216-03.

Changes in theoretical training are massive. The main philosophy of this proposal is to remove all parts of pilot training which is not directly connected to aircraft operations. Apart from actual changes in number of learning objectives (LO) the main shift in philosophy is that pilot doesn´t always need to deeply understand how the system works he only needs to know how to properly use it.

Therefore there hundreds of Los removed across all subjects. Which will lead to need of complete rework of all study materials and all theoretical training instructors will have to be prepared to change their training practice.

Los were not only removed but also added. Several additions are completely understandable and are connected with legislative changes or technical advance. But changes are not equivalent across all subjects. It is obvious that changes in each area was prepared by different group of experts and that every group approached this task with different goal. Several subjects are changed only by removal of topic and no additional Los are introduce. In other subject it seems that authors removed obsolete Los but to achieve same number of LO they added several with questionable value. Important information stated in these proposed changes is that there is strong recommendation from expert groups, which prepared the Los, that that EASA should develop a process to regularly review and update the LOs so that they are up to date with emerging safety threats as well as with developments in technology and operational practice.

4. Costs of Proposed Changes

There will be significant costs for each ATO providing these trainings. This fact is mentioned even in the NPA where estimated the main additional costs for each ATO. Details about the estimated costs may be found in Fig. 1.

Larger ATOs		
Presentations	1 month EUR 5 000	1 month EUR 5 000
Lesson exercises	1 month EUR 5 000	1 month EUR 10 000
Progress tests/exams	1 month EUR 5 000	1 month EUR 5 000
Assessment development	n/a	4 weeks EUR 5 000
TKI professional development/training	each TKI 5 days (EUR 1 000/TKI) e.g. EUR 10 000	— each TKI 5 days (EUR 1 000/TKI), e.g. EUR 10 000; — each TKI 2 days (EUR 500/TKI), e.g. EUR 5 000; — each assessor (4 assessors) 2 days, e.g. EUR 2 000
Training, operations and management system manuals: course outline, lesson plans, course processes and procedures	3 months EUR 15 000	3 months EUR 15 000 + 1 week EUR 1 250
Total per larger ATO	**EUR 40 000**	**EUR 58 250**

Fig. 1 Costs – second column are changes without incorporation of 100ksa, third column is with 100 KSA [1]

These costs are significant therefore there should be transition period long enough to provide time for ATO to incorporate these changes and to spread these costs to longer time period.

Very strange situation is with this with EIR qualification. The NPA 2016-03 propose changes to this training which will lead to additional costs for ATO making them, but in NPA 2016 -14 EASA proposes removal of EIR training completely. This men that depending on time when final decision about these NPAs will come into effect ATOs shall decide if they are willing to invest fund into upgrading of EIR training with possibility of removal of this qualification. NPA 2016-14 proposes completely new qualification Basic IR, which will be based on evidence based training so training materials will be different from those used for EIR: Therefore costs of EIR training changes would be completely wasted. This all because there seems to be very limited cooperation between expert groups preparing NPA 2016-03 and NPA 2016-14 because they are not taking each other into account.

5. Conclusions

Incoming changes in legislative connected with all instrumental flying trainings will be significant, all training organization should be prepared to in-depth changes in their training. Introduction new philosophy condensate in area 100 KSA and in-depth changes in all theoretical knowledge training subjects will bring lot of addition l work to all ATOs. These ATOs shall prepare to bear additional costs with this legislative change and their responsible personal should study NPA 2016-03 and NPA 2016-14 to be prepared for these changes in advance.

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Non-Parallelism of Toothed Gear Shafts Axes as a Source of Gear Housing Vibration

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Abstract

The article is dedicated to the subject of vibroactivity of toothed gears which are widely used in the construction of various transmission systems of means of transport. In the text, the authors presented information connected with causes of vibration of gear housing. In work, authors attempted to demonstrate the significant influence of non-parallelism of the toothed gear shafts axes on the vibration level generated during its operation.
KEY WORDS: *gear vibroactivity, gear housing vibrations, non-parallelism of axes*

1. Introduction

Toothed gears are constantly popular and because of the many advantages they are widely used in the construction of various transmission systems of means of transport. The toothed gear allows you to transfer and change the torque and speed values. One of the undesirable phenomena associated with the operation of the gears are vibrations, which greatly influences the durability of its components. Machine vibrations are not always a completely negative phenomenon, because after proper signal processing they can be used effectively to diagnose damage to their components[6-10]. It should also be noted that vibrations are also a source of noise that adversely affects the environment [2, 3]. The vibration level of the gears is influenced by numerous structural, technological and operational factors [3-5]. The vibrations attend the operation of the transmission as well as of the entire transmission systems are the subject of many research and scientific work which the authors constantly looking for solutions to reduce the vibration level of the gears. In paper [11] the influence of the total contact ratio on stimulated vibrations was analyzed. In the works [3, 12], the influence of different structural designs of the transmission housing on the level of generated vibrations was investigated. Also, the gear shaft bearing is an area where vibration and noise reduction is sought-after. Bearing diagnostics, bearing dynamic stiffness and bearing preload are taken into consideration in works [13-15]. Also exploitation factors are a popular issue in scientific deliberations. The subject of the research described in the headings [3, 16, 17] is the influence of the lubricant parameters and its temperature on the noise level of the working gear.

An important aspect of transmission operation is also the distribution of load on the width of the meshing. Any deviation in the performance of the gear elements affecting the shaft axle's non-parallel, assembly errors or deformation of the components as a result of transmitted torque contribute to uneven distribution in the load distribution along the tooth contact line. This phenomenon not only adversely affects the life of the gears, but can also be the cause of its increased vibroactivity. The work attempted to demonstrate the significant influence of the axial gear shaft's non-parallelism on the vibration level generated during its operation.

2. Reasons of Gear Vibrations Caused by Working Meshing

As a result of torque transmission by the working gear, the pinion teeth and gear teeth which are in the contact are affected by intermittent forces such as the peripheral force P, the radial force P_r, and the axial force P_a. The author of the work [1] defines the unitary load (nominal) of the teeth Q as the ratio of the peripheral force P to the product of the mesh width b and the diameter of the pinion pitch circle d_{w1} according to the following relationship:

$$Q = \frac{P}{b \cdot d_{w1}}, \tag{1}$$

here P- peripheral force, b – width of meshing, d_{w1} – diameter of the pinion pitch circle.

In the vast majority of gearboxes operating under real conditions, the torque transmitted by the gearbox is characterized by variable values over time. The torque waveform may be periodic or random. In the latter case, it is usually random, so it is usually impossible to replace it with a periodic run. In order to take into account the variable torque value and the uneven distribution of load along the tooth contact line for calculations, the same applies to the operation [1] of the total load Q_c obtained by multiplying the nominal load Q by the coefficients K_p, K_d, K_r, K_s, according to the formula:

$$Q_c = Q \cdot K_p \cdot K_d \cdot K_r \cdot K_s, \tag{2}$$

here Q - unitary load (nominal), K_p- coefficient of external overloads, K_d - coefficient of dynamic force, K_r- coefficient of uneven load distribution along the tooth contact line, K_s - coefficient of uneven load distribution on the width of the helical gear.

2.1. External Overloads Acting on the Transmission

When designing a gear transmission, nominal motor torque or nominal engine power corresponding to its nominal operating speed are used to determine unitary load Q. In the actual operating conditions of the transmission, the torque generated by the motor is not constant over time but its value fluctuates around the nominal value. It follows that periodically the torque value can be higher than the nominal value. The fluctuations in torque values are influenced not only by the type of engine used, but also by the type of engine that is driven by the gear. The influence of variable external loads acting on the gear can be reduced by appropriately selecting the susceptible coupling [18, 19]. In order to account for the variables in time torque values during the calculation of the unitary load were assumed to be a numerical coefficient K_p. Multiplying the nominal torque of the motor by the factor K_p results in a replacement torque calculation value whose constant effect will result in identical gearing reliability as in the case of real-time torque variability.

As already mentioned, the value of the K_p coefficient is significantly influenced by the type of torque generator and type of driven machine. Its values, especially in the case of preliminary analyzes, can be in the range of 1 to 2.25 (or more) as presented in [1]. In the work [2, 20] dynamic model of the drive system with gear transmission was used to determine dynamic forces in the meshing.

2.2. Internal Overloads Acting on the Transmission

The source of the extrinsic effects on the transmission does not have to come exclusively from external factors. The toothed gear alone, which is a set of inertial components made of resilient material, tends to undergo vibrations as a result of its work. The frequency of the exertion with which the transmission from external sources is induced is usually significantly less than that of the transmissions. Much higher frequencies are caused by internal induction, which is much more important in the dynamics of the working gear and their effects are more noticeable.

As a result of these forces, the gear teeth of the gear wheels undergo cyclical deformations such as deflection and flattening. The phenomenon of the deformation of the teeth of the wheels turns out to be a significant cause of oscillation of the working gear. Teeth are most affected when one pair of teeth is working. This causes a delay in the drive wheel relative to the gear wheel. At the moment when the next pair of teeth starts work, the load breaks down into two pairs of teeth, whereby the deflection of the teeth decreases, resulting in a sudden acceleration of the driven wheel relative to the driving wheel in the direction of rotation. When the first pair of teeth is out of meshing, the driven wheel retracts and the teeth of the working pair become deformed. The phenomenon of cyclic acceleration and peripheral delays of the driven wheel is the internal source of oscillation of the running gear and its effect is taken into account by the dynamic force coefficient K_d. In works [2, 10], the product of the K_d and K_p coefficients was determined on the basis of the model of dynamic drive systems with gear transmission.

2.3. Uneven Load Distribution Along the Tooth Contact Line

A very important phenomenon contributing to the oscillation of the working gear is uneven distribution of load along the tooth contact line. Any shortcomings and inaccuracies in the machining of gear components result in unwanted deviations such as the non-parallel and twisting of the transmission axis or tooth alignment errors. As a result of these deviation the teeth of the co-operating wheels are not loaded equally across the whole width, and their co-ordinate track is usually one-sided. The consequences of implementing deviations when calculating the gear load are taken into account with the K_r factor.

Not only executive mistakes cause uneven distribution of load along the tooth contact line. Under actual conditions, the working gear transmits torque, and the associated forces interact with its components. In spite of the high level of accuracy of the assembly and assembly of the gearboxes, under the influence of the load, the shaft and the gear wheels are deformed, which significantly affects the load distribution in the gear width. The effect of the aforementioned factors on the load distribution was taken into account using K_{r0} coefficient.

2.4. Uneven Load Distribution on the Width of the Helical Gear

During gear operation, the stiffness of the cooperating teeth changes along the line of action. In the case of straight teeth, these changes occur simultaneously over the entire width of the teeth, which does not significantly affect the irregularity of the load distribution along the tooth contact line. A different situation occurs with helical gears. During their operation, the individual teeth sections are in another phase of the meshing. As a result, for each of them, the working tooth is characterized by a different stiffness, whose changes directly affect the uneven distribution of load on the width of the meshing. Changes in the stiffness of the teeth along the line of action were taken into account using the coefficient K_s.

3. Description of the Test Stand and the Research

The study was conducted to demonstrate the effect of uneven distribution of load on the mesh width on the level of vibroactivity of the working kinematic gear. The tests were made at a specially modified back to back test stand shown in figure 1, where the driven gear with number of teeth of 16 was placed on a stationary axis. The number of teeth of the driving wheel was 24. The other parameters of the gears were as follows: module $m_n = 4.5$ mm; wheels width $b = 20$ mm; helix angle $\beta = 0^o$; profile shift coefficient $x_1 = 0.864$; profile shift coefficient $x_2 = -0{,}5$; nominal axes distance during vibration acceleration measurements was 91,75 mm. The axle 2 (Fig. 1) mounted on the eccentric bushings made it possible to change the non-parallelism and misalignment of the transmission axis. During the tests, the vibration acceleration of the transmission housing at point 4 (Fig. 1) was recorded.

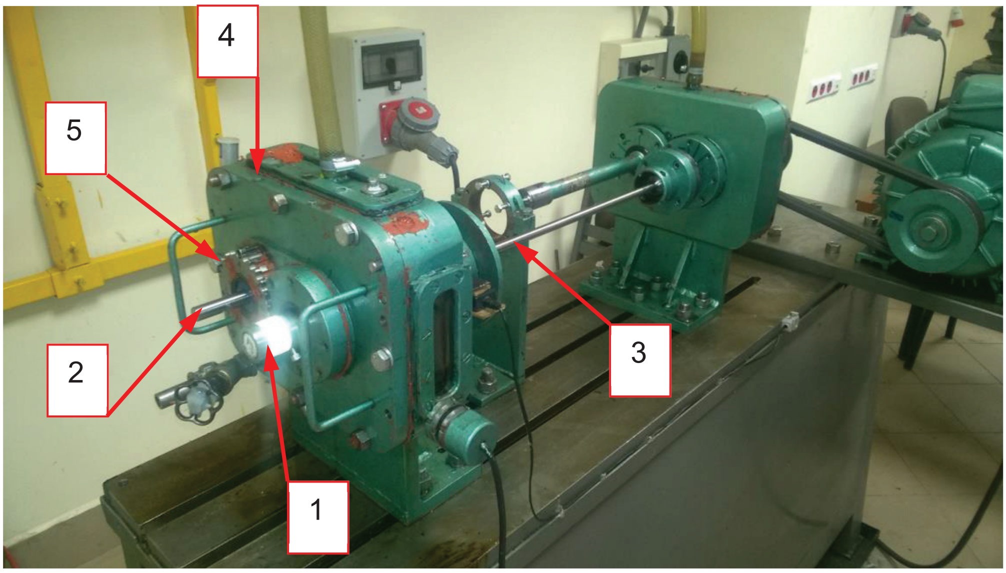

Fig. 1 Modified for the purposes of this test, the back to back test stand: *1* – driving gear shaft (number of teeth $z_2 = 24$); *2* – axis of driven gear (number of teeth $z_1 = 16$); driving shaft; *4* – vibrations acceleration sensor mount point K_{1ZFO}; *5* - bearing attachment system that allows the center of the inner ring of the bearing to change in the direction parallel to the direction of the peripheral force P_o and also in the direction parallel to the direction of the radial force P_r.

4. Test Results and Their Analysis

Fig. 2 shows the acceleration signal of the gear housing recorded in a direction parallel to the direction of the peripheral force P_o when the center of the inner ring of the bearing 4 (Fig. 1) has been shifted relative to the nominal position by:

- 198 μm in the direction of the component radial force P_r, increasing the bearing axis distance,
- 152 μm in the direction of the component peripheral force P_o causing the bearing axle 4 (Fig. 1) to be raised relative to the gear mount base (position A).

During measurement, the rotational speed of the gear with teeth number $z_2 = 24$ was 10 Hz while the gear rotation with teeth number $z_1 = 16$ was 15 Hz.

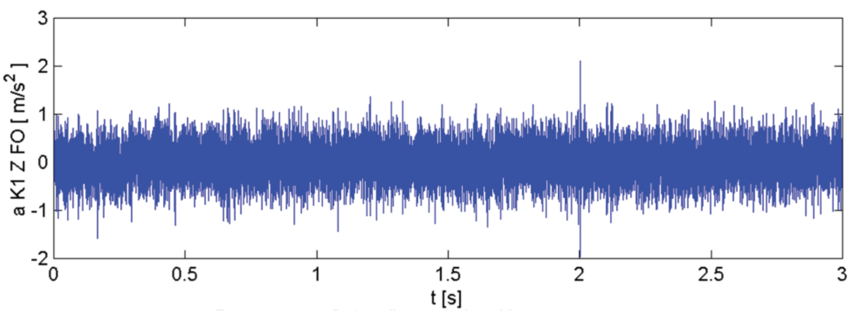

Fig. 2 Acceleration signal of the gear housing recorded at K1ZFO point in the direction parallel to the direction of the peripheral force P_o in the case of the position A of the toothed gear axes.

Fig. 3 shows the acceleration signal of the gear housing in the direction parallel to the direction of the peripheral force P_o when the center of the inner ring of the bearing 4 (fig.1) has been shifted relative to the nominal position of:

- 198 μm in the direction of the component radial force P_r, decreasing the bearing axis distance,
- 152 μm in the direction of the component peripheral force P_o causing the bearing axle 4 (fig.1) to be lowered relative to the gear mount base (position B).

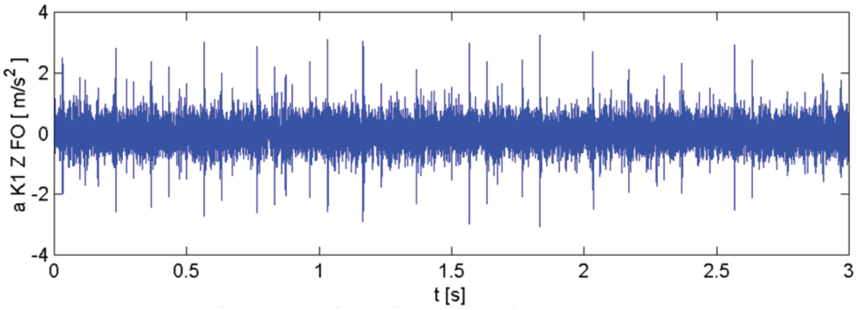

Fig. 3 Acceleration signal of the gear housing recorded at K1ZFO point in the direction parallel to the direction of the peripheral force P_o in the case of the position B of the toothed gear axes

As a result of the change the center position of the bearing axis 4 (Fig. 1), the parallelism of the axes of the gear wheels also was moved from position A to position B resulted in a significant change in the root mean square (Fig. 4) of the vibration acceleration of the gear housing shown in figure 1 and 2. In turn, the change of the axis parallelism of the gear wheels from position A to position B resulted in an increase in peak to peak acceleration of gear housing vibration by 55% relative to position B (Fig. 5).

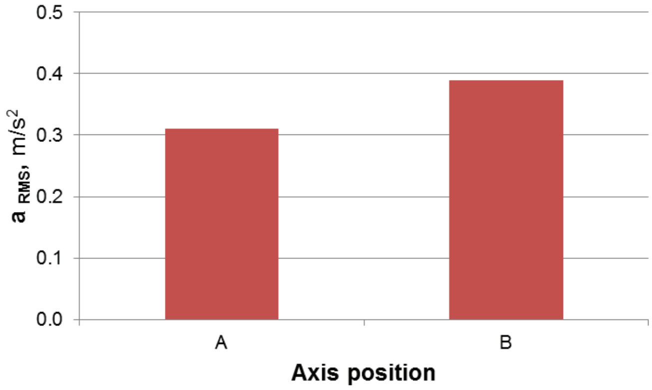

Fig. 4 Change of root mean square value of the vibrations accelerations of the gear housing due to change of the axes position from A to B

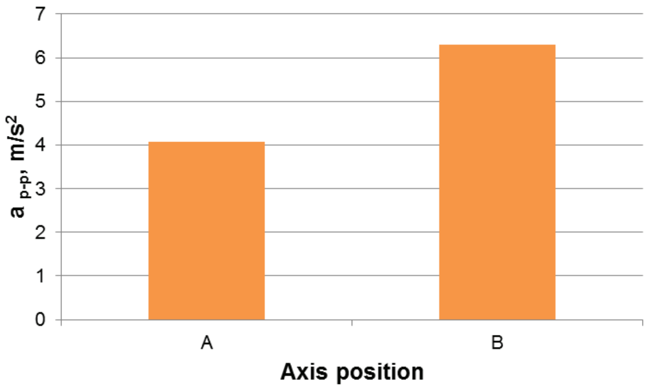

Fig. 5 Change of peak to peak value of the vibrations accelerations of the gear housing due to change of the axes position from A to B

In the results of the frequency analyzes of the recorded signals shown in Figs. 6 and 7, it can be seen that the change in the parallelism of the gear wheels axes from position A to position B resulted in an increase in the second harmonic frequency of the meshing (2fz ≈ 480Hz).

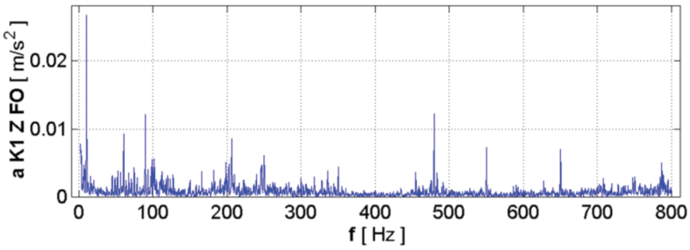

Fig. 6 Spectrum of vibration acceleration signal of the gear housing registered at K1ZFO point in the direction parallel to the direction of the peripheral force P_o (Fig. 2) in the case of the position A of the toothed gear axes

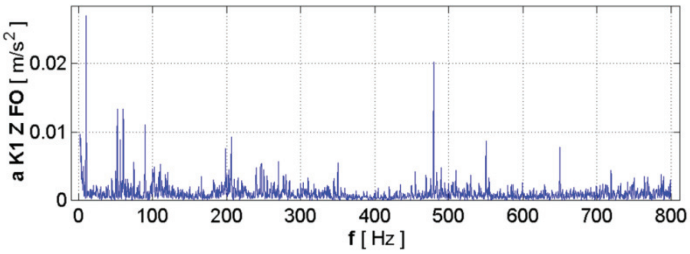

Fig. 7 Spectrum of vibration acceleration signal of the gear housing registered at K1ZFO point in the direction parallel to the direction of the peripheral force P_o (Fig. 2) in the case of the position B of the toothed gear axes

5. Conslusions

Toothed gears are widely used in the construction of various transmission systems of means of transport. Based on conducted researches and analyzes, it can be stated that:

1. As a result of the change of centrum position of the bearing axis 4 (fig. 1), the parallelism of the axes was also changed from position A to position B. It increase the root mean square (RMS) of the vibration acceleration of the transmission housing by 25% relative to position A.
2. As a result of the change of centrum position of the bearing axis 4 (fig. 1), the parallelism of the axes was also changed from position A to position B. It increase the peak to peak value of the vibration acceleration of the transmission housing by 55% relative to position A.
3. As a result of the change of centrum position of the bearing axis 4 (fig. 1), the parallelism of the axes was also changed from position A to position B. It increase the value of second harmonic frequency of the meshing by around 60% relative to position A.

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Transport of Dangerous Substance in Territory

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Abstract

This article deals with a transportation of the dangerous substances on the roads in the Czech Republic. The Czech Republic is characterized by the roads sections with a high frequency of the trucks traffic with a transport of the dangerous substances. These mentioned accidents usually cause a threat to health and lives of people, property, environment and critical infrastructure. This article also involves a list of the procedures and approaches to an evaluation of the risks associated with the transport of the dangerous substances on the roads in the territory. In conclusion, the results are evaluated and safety measures of prevention proposed.
KEY WORDS: *transport, dangerous substance, risk*

1. Introduction

There are various types of risks in the territory. One of these may be an accident associated with the transport of dangerous substances and things. In the event of accidents, lives are lost and human and animal health is damaged, there is loss of property and sometimes irreversible damage on the environment. Consequences may cause outages of protected interests and may endanger the health and lives of people who move in the territory or live in the affected area.

An important part of international trade is the transport of goods between countries. The transport of dangerous substances by road system is an integral part of everyday activities throughout Europe, but also other world continents. Transportation takes place on the most frequented roads, where accidents often involve dangerous issues. These accidents can be accompanied by explosions and fires. The impact of accidents has negative consequences on life and health, property, infrastructure and the environment. The risks associated with the transport of dangerous substance must be reduced to a minimum and outline the conditions for transporting them. The conditions are implemented in European Union legislation, incorporated into the legislation of the Member States and are an instrument for ensuring the safety of transport of these substances and objects. The basic regulation relevant for this area is the European Agreement on the International Carriage of Dangerous substances by Road, the English name of which is the Agreement on Accord Dangerous Route (henceforth as ADR), outlining the conditions for the international transport of dangerous substances by road [1-3].

2. Transport of Dangerous Substances in the Czech Republic

The transport of dangerous substances is used throughout the Czech Republic (henceforth as the CR). One possible source of risk is the transport of fuel to service stations. Tanker transport tanks are one of many ADR-compliant transports. On some parts of the road, the transport of dangerous substances is excluded. The reason is damage to health, life, property, infrastructure and the environment in the immediate vicinity of roads systems.

It is necessary to define the scope of the transport of dangerous substances. Sorting dangerous things can be conceived from many different perspectives. For example, from the point of view of the chemical industry, or chemical law act 350/2011 Coll., we would talk about dangerous substances and mixtures. If, on the other hand, we were to focus on the issue from the point of view of fire protection, it would be most useful for us to talk about flammable products or liquids. In the view of this issue in terms of road transport, the concept of dangerous substances is interpreted as defined by the ADR Agreement and the equivalent interpretation is found in the legislation of the individual Member States of the ADR Agreement. The definition of dangerous substances is given below. The interpretation of this concept is based on the ADR Agreement, which is of international importance in Europe. Such sorting and classification of dangerous substances has been around for several decades, which, as opposed to other legislation dealing with dangerous substances or objects, cannot be said. This fact is especially important for the intervening rescue system. The marking system (Kemler Code, UN Code) provides initial information about the items being transported and their properties, which need to be addressed when dealing with emergencies. From the point of view of the prevention and potential elimination of the consequences of extraordinary events connected with the transport of dangerous substances, it is the most important to outline technical conditions, measures and obligations for their transport. For initial information setting out the procedure for the intervening rescue system, it is essential to identify what substance or object it is and what its hazardous properties are [1, 8].

For the purposes of the article, the transport of dangerous substances is defined as the transport of dangerous substances by road in a tanker.

3. Proposal for a Methodical Procedure for the Identification of Risks Related to the Transport of Dangerous Substances

If the movement of a road tanker subject compliant to an ADR Agreement on the road is considered, the potential consequences of potential extraordinary events linked to the nature of the dangerous substances and articles being transported must be calculated. To ensure preparedness for such situations, the most serious scenarios must be taken into account. This is a conservative approach that is essential for establishing effective measures to minimize the consequences of a traffic accident associated with the transport of dangerous substances and things. The greater preparedness to face the effects of a traffic accident, the lesser consequences for the lives and health of the population, property, infrastructure and the environment are [3].

The proposal of a methodical procedure leading to the identification of the potential risks associated with the transport of dangerous substances (hereinafter as transport) can be applied according to the specific needs of the evaluator on a particular territory. The basic step of this procedure is to create a flow chart for a road accident involving the transport of dangerous substances, including the selection of an appropriate analytical method to identify the impact of the accident. Consequently, the above will follow the proposed accident scenarios. On the basis of the data obtained, a specific analytical method is chosen to lead to the detection of risks. The specific method should be chosen according to the nature of the area on which the accident can be expected, especially in relation to the protected interests that are found here.

The outcome of the proposal is a safety measure leading to an increased territorial safety. The proposed procedure may be extended or targeted in a particular direction depending on the nature of the area and the needs of the evaluator.

The first indicators for assessing the transport of dangerous substances and things, is determination of the boundaries of territory for transporting the tanker. Furthermore, it is determination of the scenarios [6]:

- Traffic accident on the planned route (Scenario 1)
- Road Traffic transport accident (Scenario 2)
- Transport through the planned route without damage leaving the monitored area (Scenario 3)

The first scenario is based on the assumption that transport will not be forced to leave the original route and an accident occurs. The second scenario is now based on the assumption that transport is forced to leave the original route and a traffic accident occurs. The third scenario is based on the first two scenarios, provided that the transport does not participate in a traffic accident or other extraordinary events and leaves the monitored area, either on the intended or bypass route to the destination. [6]

The process of scenarios is demonstrated in Fig. 1.

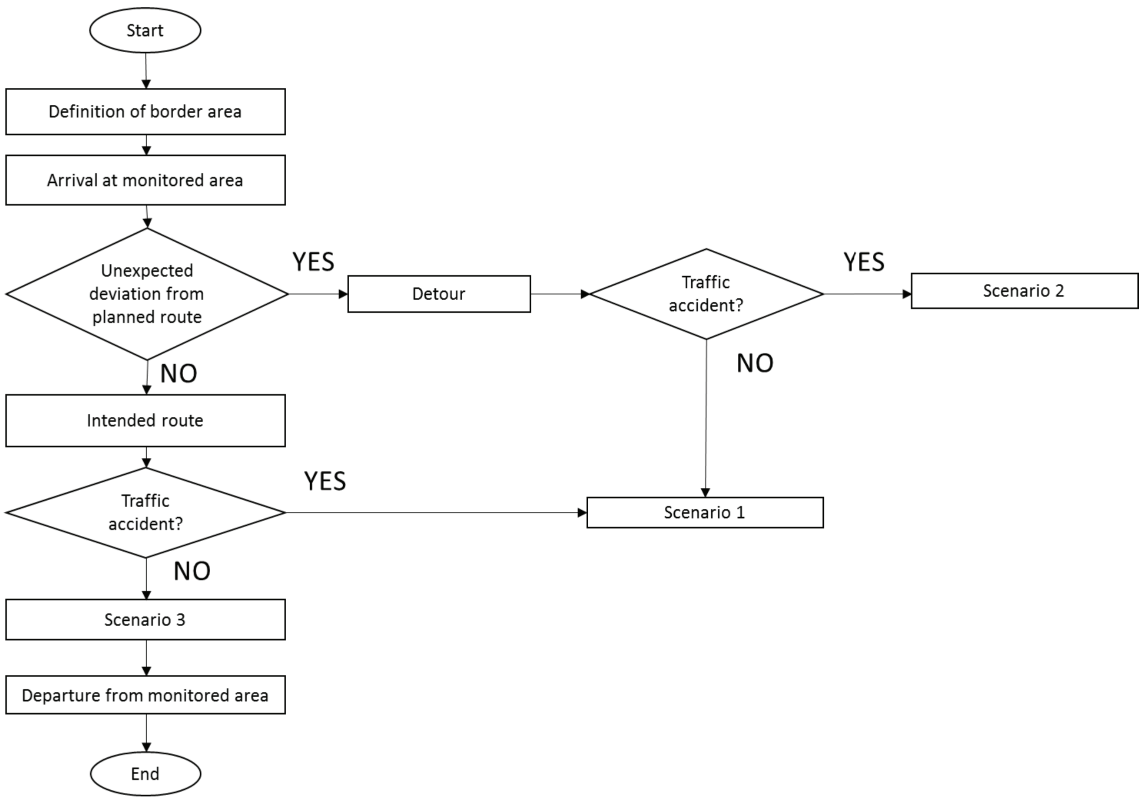

Fig. 1 The process of Scenarios 1, 2 and 3 [own work]

The first point of the emergency scenario diagram is "Start" symbolizing the start of the transport route. An important point is to define the boundaries of the territory with its description [4]. Another point is arrival at monitored area. At this point, the transport unit (tanker) is already in the selected territory and the monitoring of its movement begins. The following is a conditional expression, asking for an unexpected deviation from the desired route, for example, as a result of a detour. This term results from the question "Is there is any unexpected event leading to the diversion of the traffic on the bypass route?". After choosing the answer to this question, it is determined by which route the transport continues to move. If there is no deviation from the intended route, the question is whether there has been a traffic accident. The answer "Yes" leads Scenario 1. Then we will continue as described in the following road transport accident chart. Similarly, after answering conditional expressions in another sequence, you can get to Scenario 2. Again we will continue according to the road accident diagram. In the absence of an accident departure of the transport from the monitored area, which is expressed in Scenario 3.

In both case, when the response sequence leads Scenario 1 or 2, the flow diagram of the road accident of the transport of dangerous goods is applied. Conversely, if the accident does not occur, the transport leaves the area without complications.

The basic prerequisite for the application of scenarios to a given territory is the fact that the road, the original transport route, is planned along main roads and motorway arteries so that an accident does not represent a major threat. Of course, consideration is also given to the sections of the roads whereby the movement of a transport unit subjected to the ADR is prohibited.

For scenarios 1 and 2, the following aspects must be taken into account:

1. Basic input data on the territory and the transported unit (for example tank) [1, 8]:
- selection of territory;
- locality determination;
- determination of the type of transport and
- identification of the transported substance or article.

The choice of territory depends on the transport monitoring. The territory is also characterized by taking into account the protected interests in the territory (school, municipal office, etc.). In the selected area, it is necessary to specify the location, i.e. a site with a precondition for a dangerous substance transport accident.

The location is a specific part of the territory on which the type of the road is to be defined and the character of the surrounding area. When selecting a site, we can use on the accident statistics in the monitored area or focus on the specifics of the area. The type of carriage is distinguished by cabin, tarpaulin or tank. Identification of the substance or object transported is defined using the UN code, Kemler code or safety data sheet.

2. Leak of dangerous substance, possible quantity, rescue and disposal work:
- leak of dangerous substance and
- the amount of leakage.

Leakage requires an assessment of the climatic conditions that may affect the next sequence of events. These conditions are primarily the determination of the direction of wind flow and the determination of meteorological phenomena such as rain, snow, fog, inversion or frost. Climatic conditions can be derived from weather statistics in the area under monitoring. In case of lack of information, we work with the worst possible option.

The quantity of leaked substance is affected by the type of transport specified above. It is always considered the maximum possible amount that is transported. If a large number of separate packages of hazardous substances are transported, the total volume of cargo must be considered (the probability of leakage due to the damage of all packages is small).

3. Effects of the accident:
- fire;
- blast;
- dangerous concentrations (specifically, these effects can be expected with gases and vapours);
- other hazards (effects).

The effects of an accident can be affected by several factors, such as the amount of substance, the combination of the effects of the crash and the domino effect. If a protected interest is hit, multiplying effects may occur.

4. Scope of consequences

It applies to individual areas of protected interests located in the territory. Protected interests include population, property [5], infrastructure, environment (soil, groundwater, biota, air) [7].

5. Choice of method

The choice of method is selected based on previous data and needs of the evaluator. Subsequently, the results of the analysis are evaluated and, with regard to the acceptability of risk, corrective actions are proposed to improve the safety of the area.

4. Conclusions

The aim of the article was to introduce the field of the risk assessment of the transport of dangerous goods in the selected territory and to propose safety measures leading to the decrease of identified threats. This objective has been achieved by proposing a methodology for detecting the risks associated with the transport of dangerous goods, which is of a general nature and can therefore be applied to any territory.

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Proposal of Tariff Rating the Risk in Passenger Railway Transport in Conditions of the Slovak Republic

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Abstract

Tariff is a word of Arabian origin. In today's terminology it is defined as the set list of rates and conditions for the use of these rates. Tariff policy comprises principles by means of which the government or carrier pursues own goals. The government achieves this through a social policy of the state and individual carriers operating in the market achieve this through tariff tools and measures. The purpose of a tariff policy is to harmonise three fundamental elements of an economic relation among the public administration, carrier and customer, namely the economic price of the carrier, available resources and socially acceptable amount of travel costs. The problem of outlining the tariff policy in passenger transport in the current framework of regulated prices in relation to performances in the public interest contains a principal question that provides a solution of economically justified costs of transport systems realising these performances. The basic orientation is directed towards the reimbursement for economically justified costs and a fair profit in a socially sustainable tariff framework. The risk analysis is a process with detailed identification of risks, determination of causes or sources of their origin and investigation of their possible consequences. Every process, system, or human activity is influenced by a number of risks. The same situation exists also in the operation of rail transport. Bursement itself does not arise only from travel cost earnings, because the guarantee of the public interest by the public administration should be applied in a form of paying for the difference between earnings and costs. The main components of the risk are undesirable consequences and the uncertainty connected with them. To determine the risk of the technological system or dangerous activity it is necessary to evaluate both these parameters. If one of the parameters does not exist, there is no risk. The correct understanding of the problem of risk in the rail transport follows from the correct use of professional concepts and manage the content of the legal and technical standards. The aim of this paper is the proposal of tariff rating the risk arising from an incorrect decision about the use of units for the transport of passengers in railway transport. Elimination of this risk was resolved by the cost calculations with using the electric unit 671 during rush hour/ normal time and diesel unit 871 during rush hour/ normal time on selected railway line. at the tip / saddle at the selected session. Cost calculations in all variants are the basis for effective proposal of tariff policy.
KEY WORDS: *risk, tariff rating, passenger railway transport, cost calculations*

1. Introduction

Tariff policy concept fulfils a general goal of transport policy, i.e. to harmonise transport needs of population with transport offer in an existing and creating structure of public transport services on the basis of their integration (economic and spatially functional) in order to improve the quality of satisfying transport needs in a permanently sustainable framework. Such a formulated goal is in compliance with the integration process of the Slovak Republic into the European Union, where transport-political principles are unambiguously oriented towards the support of public mass passenger transport [7, 9].

At the same time there is a need to preferentially specify a real economic price of a transport performance, an optimal division of transport performances between public and individual transport and its dynamics, a measurable factor of social tolerability of the travel cost amount and other related factors arising mainly from the implementation of state transport policy, such as a more accurate performance specification in the public interest, internal structuring of the transport system with priorities determination, IDS support and competitiveness in freight transport [6, 8].

2. Short-Term and Long -Term Goals of Tariff Policy

Tariff policy represents a large scope of the problem incorporated into a social-economic framework of the entire society. Its complex solution is subject to a close cooperation of all involved: state administration authorities, carriers realising public passenger transport, municipal and regional administration authorities as well as the travelling public [1, 4].

Short-term goals of tariff policy:

a. objectification of economically justified costs associated with performances in the public interest;
b. tariffs optimisation of individual types of public mass transport;
c. effectiveness of reimbursing for a loss from realised performances in the public interest based on a system

calculation of economically justified costs;

d. transformation of social discounts in transport – directness of providing and reimbursing for discounts;

e. harmonisation of a charge for using a transport passage for all its users and its transparent transfer into a price;

f. matter-of-fact coordination of public mass passenger transport prices, which is being performed in the public interest based on a valorisation mechanism together with accepting the social tolerability;

g. system transfer of a loss from regulated prices into public budgets (from state ones through municipal ones).

Long-term goals of tariff policy:

h. harmonisation of a pricing policy of public transport services within transport systems integration in order to achieve a higher quality satisfaction of population transport needs;

i. application of an economic price of a transport performance and reimbursement for a loss from performances in the public interest should be tied with its amount depending on public budgets capacities;

j. internalisation of external costs and its progressive tendency into transport systems price formation in order to make environment-friendly transport types more favourable [3].

3. Comparison of Costs with the Use of a Locomotive with Electric Traction / Diesel Traction During Normal Time / Rush Hour and The Consequent Impact on Total Costs with Respect to the Transport Price in a Certain Time Period

The main aim of a case study is to analyze the risk in passenger railway transport that may arise with the use of electric / diesel locomotive on the electrified railway line. The risk arises from the use of a type of locomotive (dependent / independent traction) and from unoccupied capacity of a selected passenger train during the normal time or during the rush hour. The risk identification and its consequent elimination is applied to the model example:

The model railway line is suitable for driving both types of units (electric and diesel)
Distance = 32 km
Transport time = 44 minutes
Average weight of one passenger = 0,08 kg
Number of train crew members = 2

The following part of the case study includes a cost calculation for the four variants of the analyzed risk in passenger transport – cost calculation of dependent traction during rush hour, cost calculation of dependent traction during normal time, cost calculation of independent traction during rush hour and the last variant is the cost calculation of independent traction during normal time. For the solution of the individual variants, rush hour was defined as the 100% occupancy of the train and normal time as the 30% occupancy of the train by passengers. Calculations of own costs are performed with using the model cost rates in all variants.

4. Calculation of the Costs of Dependent Traction During Rush Hour: Electric Unit 671 (100% Occupancy Including Standing Passengers)

The electric unit is composed of the motor wagon type 671, inserted wagon type 071 and driving wagon type 971 (Figure 1). The maximum speed is 160 km/h and it is proposed for a traction power system 3 kV DC and 25 kV 50 Hz AC. [5]

Source: Ing. Matúš Dlugoš

Fig. 1 Electric unit type 671

The basic parameters of the electric unit as important input data for cost calculation are listed in Table 1.

Table 1

Basic parameters of the electric unit 671

Maximum speed	160 km/h
Permanent performance	2000 kW
Multiple control	Yes
Traction power system	3 kV DC
	25 kV 50 Hz AC
Performance regulation	semiconductor (IGBT)
Configuration of the unit	Bo'Bo' + 2'2' + 2'2'
Gauge	1435 mm
Weight	166,7 t
Length over bumpers	79200 mm
Width	2820 mm
Hight	4635 mm
Places for sitting	307 (4 for immobile passengers)
Total number of passengers	640
Wagon class	2

Source: SkodaVagonka, a.s.

Inportant input data for cost calculation

- The model railway line is suitable for driving both types of units (electric and diesel)
- Distance = 32 km
- Type of the electric unit = EPJ 671.001+071.001+971.001,
- Capacity considered for model example and 100% occupancy = 450 passengers (places for sitting and standing),
- Weigh of the electric unit = 166,7t

Based on the previous parameters, it is possible to analyze the total cost which include the calculation of costs of using railway infrastructure, costs of electric unit, costs of train crew and costs of energy. [2]

Costs of using railway infrastructure in SR

Q = (average weight of one passenger number of occupied places) + weigh of the electric unit* = 0,08*450+166,7 = 191,26 *t*

$U_1 = U_{1i} * L$ = 0,019*32 = 0,608€

$U_2 = U_{2i} * L$ = 0,881*32 = 28,192€

$U_3 = 1/1000 * U_{3i} * Q * L * k_e$ = 1/1000*1,261*202,7*32 = 8,17€

$U_{tp1} = 1/1000 * Q * L * U_E$ = 1/1000*202,7*32*0,260 = 1,68€

$U_{tp2} = U_{Oj}$ * *number of train stops at the tariff points of a particular category*= 0,520 * 2 = 1,04

Legend:

L – total length of the railway line of the relevant category between tariff points (km),

Q – gross train weight (t),

U_1–total fee for ordering and allocation of capacity (€)

U_2–total fee for the management and organization of transport (€)

U_3–total fee for operation of the railway network (€)

U_{1i} - maximum rate for ordering and allocation of capacity according to category of railway line (€)

U_{2i} - maximum rate for the management and organization of transport according to category of railway line (€)

U_{3i} - maximum rate for operation of the railway network according to category of railway line (€)

U_{tp1} – total fee for access to the traction system (€)

U_E–maximum rate for using the traction system (for 1000 hrtkm) (€)

U_{tp2}–total fee for using the personal stations and their equipment (€)

U_{Oj} - maximum rate for stop of passenger trains (€)

k_e – coefficient for train using the locomotive with independent traction on electrified railway lines of the relevant category – its value is 1.2 (value for other trains is 1.0) [10, 11].

Total costs of using the railway infrastructure in SR are 39,69 €.

Auxiliary indicators for the calculation of other costs:

∑ *gross tonnage kilometers = (weight of the electric unit + (average weight of one passenger* number of occupied places))*L* = (166,7+0,08*450)*32 = 6486,40.

∑ *locomotive crew employee hours (zamhrc) = (L/average speed) * number of locomotive crew members * (*1 + *coefficient of secondary performances)* = 0,61 *1 * (1+0,5) = 0,96 *(one member of locomotive crew).*

∑ *train crew employee hours (Zamhvc) = (L/average speed) * number of train crew members * (*1 + *coefficient of secondary performances)* = 0,61 * 2 * (1+0,3) =1,664 *(two members of train crew)*

∑ *unit kilometers (Jkkm) = number of units * L* = 1*32 = 32

∑ train kilometers (*Vlkm*) = number of trains * *L* = 1*32 = 32

Total costs of electric unit at 100% occupancy are calculated according to input parameters of transport and input auxiliary indicators. The rates used in the calculation of total costs are model cost rates (the cost rate for driving the electric unit, the hourly rate for train crew and the rate for energy) which are approximately the same as those used by carriers. The values are rounded for the trade secrets by the methodology of the monograph´s authors.

Costs of electric unit = 32 *(Jkkm)* * 6,34 *(rate for electric unit)* = 202,88€
Costs of locomotive crew = 0,96 *(zamhrc)* * *14 (rate)* = 13,44€
Costs of train crew = 1,664 *(zamhvc)* * 11 *(rate)* = 18,304€
Costs of energy = (191,26 * 32 * 37,74 *(consumption)* * 0,15 *(rate for energy))*/1000 = 34,64€

Total direct costs of the electric unit at 100% occupancy are 308.95 €. Total costs (direct + indirect) and also the cost calculation of one place for certain occupancy are calculated in Table 2.

Table 2

The summary of costs of the electric unit type 671 (100 % occupancy)

The summary of costs of (100 % occupancy)	**€**
Total direct costs	308,95
Total indirect costs (20% of the total direct costs)	61,79
Total costs of electric unit at 100% occupancy	370,74
Costs of one place at 100% occupancy (450 passengers)	0,82

In the variant with the electric unit type 671 during rush hour, the total costs will be 370,74 € for all occupied places and 0,82€ for one place. The carrier's profit is not included in this amount.

5. Calculation of the Costs of Dependent Traction during Normal Time: Electric Unit 671 (30% Occupancy)

All input data needed for the calculation of costs in this variant are the same as in variant A, but the difference is only the occupancy of the electric unit The capacity of the electric unit is 307 places for sitting. In this model example, we consider with 30% occupancy of the electric unit from the total number of places for sitting (30% occupancy = 93 passengers).

Costs of using railway infrastructure in SR

Q = (average weight of one passenger number of occupied places) + weigh of the electric unit* = 0,08* 93+166,7 = 174,14 €

$U_1 = U_{1i} * L$ = 0,019*32 = 0,608€

$U_2 = U_{2i} * L$ = 0,881*32 = 28,192€

$U_3 = 1/1000 * U_{3i} * Q * L * k_e$ = 1/1000*1,261*174,14*32 = 7,03€

$U_{tp1} = 1/1000 * Q * L * U_E$ = 1/1000*198,7*32*0,260 = 1,65€

$U_{tp2} = U_{Oj}$ * *number of train stops at the tariff points of a particular category* = 0,520 * 2 = 1,04€

The legend of variables used in the calculation of the fee for the use of railway infrastructure in the previous section - Variant A.

Total costs of using the railway infrastructure in SR are 38,52 €.

Auxiliary indicators for the calculation of other costs:

∑ *gross tonnage kilometers = (weight of the electric unit + (average weight of one passenger* number of* *occupied places))*L* = (166,7+0,08*93)*32 = 5572,48.

∑ *locomotive crew employee hours (zamhrc) = (L/average speed) * number of locomotive crew members* * (1 + *coefficient of secondary performances*) = 0,61 *1 * (1+0,5) = 0,96 *(one member of locomotive crew).*

∑ *train crew employee hours (Zamhvc) = (L/average speed) * number of train crew members* * (1 + *coefficient of secondary performances)* = 0,61 * 2 * (1+0,3) =1,664 *(two members of train crew)*

∑ *unit kilometers (Jkkm) = number of units * L* = 1*32 = 32

∑ *train kilometers (Vlkm) = number of trains * L* = 1*32 = 32

Total costs of electric unit at 30% occupancy are calculated according to input parameters of transport and input auxiliary indicators. The rates used in the calculation of total costs are model cost rates (the cost rate for driving the electric unit, the hourly rate for train crew and the rate for energy) which are approximately the same as those used by carriers. The values are rounded for the trade secretsby the methodology of the monograph´s authors.

Costs of electric unit = 32 *(Jkkm)* * 6,34 *(rate for electric unit)* = 202,88€
Costs of locomotive crew = 0,96 *(zamhrc)* * 14 *(rate)* = 13,44€
Costs of train crew = 1,664 *(zamhvc)* * 11 *(rate)* = 18,304€
Costs of energy = (174,14 * 32 * 37,74 *(consumption)* * 0,15 *(rate for energy))*/1000 = 31,55€

Total direct costs of the electric unit at 30% occupancy are 304,69 €. Total costs (direct + indirect) and also the cost calculation of one place for certain occupancy are calculated in Table 3.

Table 3

The summary of costs of the electric unit type 671 (30 % occupancy)

The summary of costs of (30 % occupancy)	**€**
Total direct costs	304,69
Total indirect costs (20% of the total direct costs)	60,94
Total costs of electric unit at 30% occupancy	365,63
Costs of one place at 30% occupancy (93 passengers)	3,93

In the variant with the electric unit type 671 during normal time, the total costs will be 365,63€ for all occupied places and 3,93€ for one place. The carrier's profit is not included in this amount.

According to the conclusions of these two alternatives, costs of the electric unit with 30% occupancy are higher than the costs of the electric unit with full occupancy. The costs of one place at 100% occupancy are 0,82 € while at 30% occupancy are 3,93 €. Costs are calculated for one train. The carrier should take this risk into account if the services are provided in the commercial interest and not in the public interest. Tariff rating is expressed in the final part of this subchapter.

6. Calculation of the Costs of Independent Traction During Rush Hour : Diesel Unit 861 (100% Occupancy Including Standing Passengers)

The diesel unit type 861 is constructed from three parts and is proposed for regional transport on non-electrified railway lines. The manufacturer is ZOS Vrútky. This type of diesel unit is shown in Fig. 2.

Source: Ing. Matúš Dlugoš

Fig. 2 Diesel unit type 861

The basic parameters of the electric unit as important input data for cost calculation are listed in Table 4.

Table 4

Basic parameters of the diesel unit 861

Maximum speed	140 km/h
Engine	MAN
Permanent performance	2x 588 kW
Configuration of the unit	B'2'2'B'
Gauge	1435 mm
Weight	120 t
Length over bumpers	57 590 mm
Width	2 850 mm
Hight	4 300 mm
Wheel diameter	850 mm/770 mm
Places for sitting	168+9
Total number of passengers	317
Wagon class	2.

Important input data for cost calculation

- The model railway line is suitable for driving both types of units (electric and diesel)
- Distance = 32 km
- Type of the diesel unit = DMJ 861.001+061.001+861.001
- Capacity considered for model example and 100% occupancy = 250 passengers (places for sitting and standing),
- Weigh of the electric unit = 126,4t

Based on the previous parameters, it is possible to analyze the total cost which include the calculation of costs of using railway infrastructure, costs of electric unit, costs of train crew and costs of energy.

Costs of using railway infrastructure in SR

Q = (average weight of one passenger number of occupied places) + weigh of the diesel unit* = 0,08*250+126,4 = 146,4 *t*

$U_1 = U_{1i} * L$ = 0,019*32 = 0,608€

$U_2 = U_{2i} * L$ = 0,881*32 = 28,192€

$U_3 = 1/1000 * U_{3i} * Q * L * ke$ = 1/1000*1,261*146,4*32*1,2 = 7,09€

U_{tp2} = *UOj * number of train stops at the tariff points of a particular category*= 0,520 * 2 = 1,04

The legend of variables used in the calculation of the fee for the use of railway infrastructure in the previous section - Variant A.

Total costs of using the railway infrastructure in SR are 36,93 €.

Auxiliary indicators for the calculation of other costs:

∑ *gross tonnage kilometers = (weight of the diesel unit + (average weight of one passenger* number of occupied places))*L* = (126,4+0,08*250)*32 = 4684,80.

∑ *locomotive crew employee hours (zamhrc) = (L/average speed) * number of locomotive crew members ** (1 + *coefficient of secondary performances)* = 0,61 *1 * (1+0,5) = 0,96 *(one member of locomotive crew).*

∑ *train crew employee hours (Zamhvc) = (L/average speed) * number of train crew members ** (1 + *coefficient of secondary performances*) = 0,61 * 2 * (1+0,3) =1,664 *(two members of train crew)*

∑ *unit kilometers (Jkkm) = number of units * L* = 1*32 = 32

∑ *train kilometers (Vlkm) = number of trains * L* = 1*32 = 32

Total costs of diesel unit at 100% occupancy are calculated according to input parameters of transport and input auxiliary indicators. The rates used in the calculation of total costs are model cost rates (the cost rate for driving the diesel unit, the hourly rate for train crew and the rate for energy) which are approximately the same as those used by carriers. The values are rounded for the trade secrets by the methodology of the monograph´s authors.

Costs of electric unit = 32 *(Jkkm)* * 5,4 *(rate for diesel unit)* = 172,8€
Costs of locomotive crew = 0,96 *(zamhrc)* * 14 *(rate)* = 13,44€
Costs of train crew = 1,664 *(zamhvc)* * 11 *(rate)* = 18,304€
Costs of energy = *(*146,4 * 32 * 15 *(consumption)* * 0,85 *(rate for energy))*/1000 = 59,73 €

Total direct costs of the diesel unit at 100% occupancy are 301,204 €. Total costs (direct + indirect) and also the cost calculation of one place for certain occupancy are calculated in Table 5.

Table 5

The summary of costs of the diesel unit type 861 (100% occupancy)

The summary of costs of (100 % occupancy)	**€**
Total direct costs	301,204
Total indirect costs (20% of the total direct costs)	60,24
Total costs of diesel unit at 100% occupancy	361,45
Costs of one place at 100% occupancy (250 passengers)	1,45

In the variant with the diesel unit type 861 during rush hour, the total costs will be 361,45 € for all occupied places and 1,45 € for one place. The carrier's profit is not included in this amount.

7. Calculation of the Costs of Independent Traction during Normal Time: Diesel Unit 861 (30% Occupancy)

All input data needed for the calculation of costs in this variant are the same as in variant C, but the difference is only the occupancy of the diesel unit. The capacity of the diesel unit is 177 places for sitting. In this model example, we consider with 30% occupancy of the diesel unit from the total number of places for sitting (30% occupancy = 54 passengers).

Costs of using railway infrastructure in SR

Q = (average weight of one passenger number of occupied places) + weigh of the diesel unit* = 0,08* 54+*1*26,4 = 130,72 *t*
$U_1 = U_{1i} * L$ = 0,019*32 = 0,608€
$U_2 = U_{2i} * L$ = 0,881*32 = 28,192€
$U_3 = 1/1000 * U_{3i} * Q * L * ke$ = 1/1000*1,261*130,72*32*1,2 = 6,33€
$U_{tp2} = U_{Oj}$ * *number of train stops at the tariff points of a particular category*= 0,520 * 2 = 1,04

The legend of variables used in the calculation of the fee for the use of railway infrastructure in the previous section - Variant A.

Total costs of using the railway infrastructure in SR are 36,17 €.

Auxiliary indicators for the calculation of other costs:

∑ *gross tonnage kilometers = (weight of the electric unit + (average weight of one passenger* number of occupied places))*L* = (126,4+0,08*54)*32 = 5089,25.
∑ *locomotive crew employee hours (zamhrc) = (L/average speed) * number of locomotive crew members* * (1 + *coefficient of secondary performances)* = 0,61 *1 * (1+0,5*) = 0,96 (one member of locomotive crew).*
∑ *train crew employee hours (Zamhvc) = (L/average speed) * number of train crew members* * (*1 + coefficient of secondary performances)* = 0,61 * 2 * (1+0,3) =1,664 *(two members of train crew)*
∑ *unit kilometers (Jkkm) = number of units * L* = 1*32 = 32
∑ *train kilometers (Vlkm) = number of trains * L* = 1*32 = 32

Total costs of diesel unit at 30% occupancy are calculated according to input parameters of transport and input auxiliary indicators. The rates used in the calculation of total costs are model cost rates (the cost rate for driving the diesel unit, the hourly rate for train crew and the rate for energy) which are approximately the same as those used by carriers. The values are rounded for the trade secrets by the methodology of the monograph´s authors.

Costs of electric unit = 32 *(Jkkm)* * 5,4 *(rate for diesel unit)* = 172,8€
Costs of locomotive crew = 0,96 *(zamhrc)* * 14 *(rate)* = 13,44€
Costs of train crew = 1,664 *(zamhvc)* * 11 *(rate)* = 18,304€
Costs of energy = (130,72 * 32 * 15 *(consumption)* * 0, 85 *(rate for energy))*/1000 = 59,73 €

Total direct costs of the diesel unit at 30% occupancy are 300, 44 €. Total costs (direct + indirect) and also the cost calculation of one place for certain occupancy are calculated in Table 6.

Table 6

The summary of costs of the diesel unit type 861 (30% occupancy)

The summary of costs of (30 % occupancy)	**€**
Total direct costs	300,44
Total indirect costs (20% of the total direct costs)	60,08
Total costs of diesel unit at 30% occupancy	360,52
Costs of one place at 30% occupancy (54 passengers)	6,67

In the variant with the diesel unit type 861 during normal time, the total costs will be 360,52 € for all occupied places and 6,67€ for one place. The carrier's profit is not included in this amount.

According to the conclusions of these two alternatives, costs of the diesel unit with 30% occupancy are higher than the costs of the diesel unit with full occupancy. The costs of one place at 100% occupancy are 1,45 € while at 30% occupancy are 6,67 €. Costs are calculated for one train. The carrier should take this risk into account if the services are provided in the commercial interest and not in the public interest. Tariff rating is expressed in the final part of this subchapter.

A summary of the total costs and costs of one place for all four variants is shown in Table 7. Based on the results shown in this table it is understandable that the costs of the carrier are influenced by the occupancy of the train and the capacity of the electric/diesel unit.

Table 7

Summary of the total costs for all four variants

Total costs for all four variants	**Total costs (train)**	**Costs of one place**
Electric unit 671 (100% occupancy - 450 passengers)	370,74€	0,82€
Electric unit 671 (30% occupancy - 93 passengers)	365,63€	3,93€
Diesel unit 861 (100% occupancy- 250 passengers)	361,45€	1,45€
Diesel unit 861 (30% occupancy- 54 passengers)	360,52€	6,67€

Tariff rating of the risk from the use of the dependent / independent traction during rush hour / normal time with respect to the transport price

On the basis of an analysis of own costs, a more advantageous alternative is the possibility of using a dependent (electric) unit. The total costs of the carrier are lowest during rush hour (100% occupancy) and with using the electric unit 671. For elimination of this risk, we suggest that the transport price during rush hour should be higher (by a certain percentage) than during normal time. The other option of a tariff rating of this risk is the average value of the costs of one place for the passenger during rush hour and normal time - in our case, the price for transport in the model distance by the electric unit would be 2,36 € + 20% carrier´s profit surcharge. The final transport price for distance 32 km would be 2,84€.

The proposal of tariff rating by method of average costs for the electric unit 671 during rush hour and normal time is shown in Table 8.

Table 8

Tariff on the model railway line (32 km)

Proposed tariff	Tariff point A (0 km)	Tariff point B (16 km)	Tariff point C (32 km)
Tariff point A (0 km)	**.**	1,33	**2,84**
Tariff point B (16 km)	1,33	**.**	1,33
Tariff point C (32 km)	**2,84**	1,33	**.**

8. Conclusion

The proposal of the optimal tariff, taking into account the risk from the occupancy, is created according to shares of total costs and the number of places for sitting (standing) at the particular occupancy - we calculated total costs of one place on the whole railway line for two types of occupancy. Unit costs were averaged and increased by the surcharge (20%) which represents a reasonable profit for the carrier. The result is the proposal of the section tariff including the transport price for the entire distance (32 km) and analogically derived transport prices in individual sections (0km – 16km, 16 km – 32 km). The tariff proposed in the monograph is simplified for three tariff points but for real practice it is possible to set a tariff for more tariff points as well as for more options of the occupancy of the electric unit (10%, 20%, 30%, ...100%) - costs of the carrier will be taken into account further in the proposed transport prices.

Acknowledgements

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The Concept of Surveillance/Rescue System with a Ducted Propeller for Water Rescue Services

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Abstract

The article presents a description of the concept and implementation of the unmanned water plane system – a search and rescue system with the duplex communication capability. It presents the results of numerical calculations of different propeller duct geometries with a propeller modeled by means of pressure pulse. The results under comparison concerned the calculations of thrust generated by a ducted propeller for several different ducting profiles in order to select the profile characterized with the best performance. In the tests performed, the static thrust gain was approximately 15%. in comparison to open propellers. Good properties of the selected profile were confirmed in practice.
KEY WORDS: *aerodynamics, ducted fan, experimental methods, CFD simulation*

1. Introduction

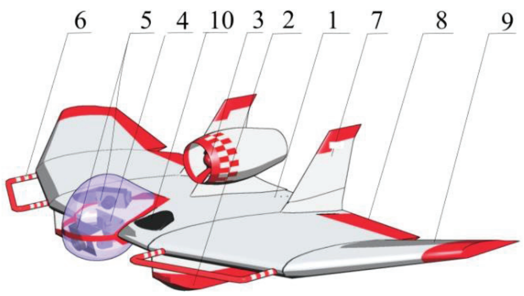
Problems with communication on open waters were revealed on the basis of a survey given to active lifeguards and on the basis of the experience of one of the authors, who is also a lifeguard. On numerous occasions, tourists swim too far away from the shore or to places beyond the range of technical means, where they cannot be contacted or summoned. Covering a distance of 200 m takes a lifeguard more than 160 seconds, and that time is reduced if other means of transport, e.g. boats are used. That time may be reduced even more, if unmanned aerial vehicles (UAV) are used in patrol missions.

The results of surveys were also used for the preparation of a rescue system concept based on a UAV with a duplex communication capability. The platform for the first prototype was a ready-made X-8 airframe which was used for testing electronic equipment (Fig. 1.), i.e. the control, stabilization, and autopilot systems, as well cameras and audio/video transmission equipment. The propulsion comprised two EDF (Electric Ducted Fan) turbines producing 2500g static thrust each. It had a maximum take-off weight of 5.5 kg and was equipped with 1.4 kg of payload including various detection and rescue equipment, and floats providing up to 6 kg of static buoyancy. The first prototype had very good flying characteristics as well as maneuverability on the water, the latter of which was due to the application of thrust vectoring for directional control while on the water surface. The main disadvantage of the prototype was its low flight endurance caused by low efficiency of the EDF turbines and their high energy consumption. The maximum flight time was under 25 minutes whereas the flight endurance of a similar aircraft, powered with an identical power pack, and with an open propeller was approximately 45 minutes.

The objective of the present research studies was to design a ducting profile which would protect people from possible injuries and would ensure similar efficiency to that of the open system, or even higher (Fig. 2.). According to the project, the UAV airframe with a relatively low load per unit of surface will have operational speed in the 10-15m/s range which is an equivalent to 0.2-0.3 propeller advance for a 12-inch propeller. The objective of the studies was to determine the geometry parameters for 0.2-0.3 propeller advance range.

Fig. 1 Rescue UAV with EDF turbine propulsion system manufactured by AeroaAtena and FlytechUAV consortium, photo T. Muszyński

It is commonly known that ducted propellers produce higher thrust for static conditions and low propeller advances in comparison with open propellers. Numerous tests were performed, which confirmed the increased efficiency compared to open propellers for low propeller advances. Sources [1, 4] inform of a considerable static thrust gain in comparison to open propellers. Depending on the particular propeller variant, that gain was from more than 10% to approximately 94%, whereas in order to obtain the same thrust the power could be reduced by as much as 62% [3].



1. Fuselage and wing
2. Floats
3. Engine with ducted propeller
4. Electronic systems
5. Cameras
6. Handles

7,8,9. Flight control surfaces

10. Loudspeaker and microphone

Fig. 2 Water rescue concept developed on the basis of the surveys conducted

New wing-body design was equipped with an advanced, improved propulsion, a variable geometry ducted propeller with an aim to maximize the overall efficiency and flight endurance. What is more, the advanced concept is furnished with floats providing up to 16 kg of static buoyancy and features a rugged structure which is more suitable for rough sea (Fig. 2).

2. Selection of Research Methods

Research studies and development of ducted propellers were present already in the 1920s. In 1920, German Ministry of Transport told the owners of heavy inland-water tugs to install ductings around screw propellers in order to reduce the erosion of channel bottoms.. It turned out that boats equipped with propeller ductings were faster and generated greater thrust. Shortly afterwards, Ludwig Kort commenced research studies with the aim of explaining that phenomenon. At first, the research focused on the maximization of static thrust, and subsequently various ducting profiles of screw propellers were examined and adapted to the propeller speed and load intensity. In 1933, Ludwig Kort was granted the US patent for the Kort nozzle [5]. In 1966, Northrop company conducted quite extensive research in screw propellers, the scope of which was extended both with regard to experimentation and numerical calculation In the research, screw propeller and screw-ducting assemblies were compared, and the calculations utilized a physical model based on the equation of energy conservation and the moment conservation method. In 1923, in another patent, Hamel used a ducted propeller built into the wing of the aircraft [6]. In the 1930s, Luigi Stipa built an aircraft whose fuselage served at the same time as a propeller ducting [7].

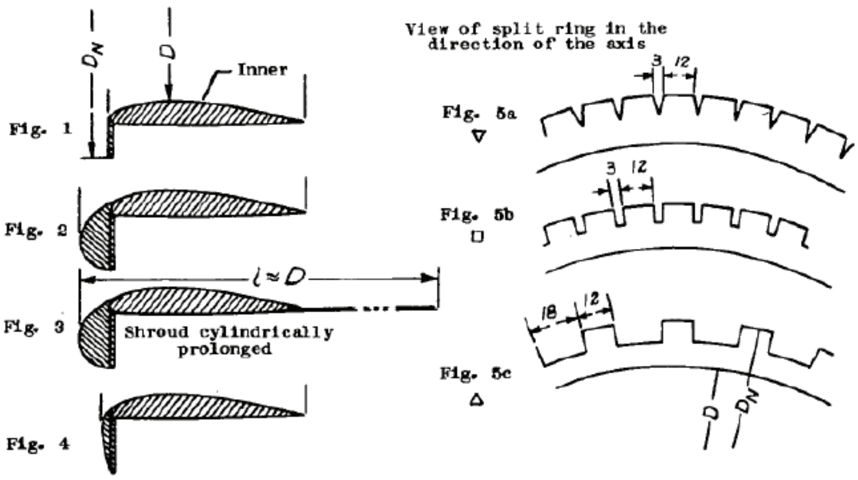


Fig. 3 Ducting profile modifications applied by Kruger [18]

First comprehensive research concerning aircraft ducted propellers was conducted by Kruger, who examined 15 different versions of propeller ducting with diverse parameters, such as the chord length , thickness, chord line angle of attack , and inlet border of attack (Fig. 3). Models were examined at rest and in axial motion. A thinner ducting/ring had lesser drag, but the propeller thrust decreased faster. Owing to additional tabs on the leading edge, it was possible to double static thrust coefficient. Maximum efficiency was 71% for a thin profile with the short chord. One of the conclusions of Kruger's work was that the diffuser flare angle is not a significant parameter, i.e. there are no visible interdependence between the flare angle of the diffuser and the improvement of static thrust characteristics and small propeller advances. Theoretical calculations were conducted with the assumption that the flow is dependent solely on the shape of the ducting profile, and not on the pressure distribution on the airscrew disk. Experimental research confirmed the validity of that statement. Similar conclusion may be found in the monograph of Jarzyna et al. [9].

The development of CFD simulation methods was evolutionary together with the growth of the processing power of computers. Numerical methods used in fluid mechanics calculations may generally be classified as potential, inviscid, using Euler equation, and methods using Navier-Stokes equations describing the motion of viscous fluids. Navier-Stokes equations describe the phenomena occurring in a fluid treated as a continuous medium. Individual terms of the equation describe non-uniform motion of the fluid along the trajectory, the motion of fluid caused by buoyant force, viscous phenomena, and take into consideration external forces acting on the fluid. Panel methods are characterized by low costs of calculation, which frequently compensates for their lower accuracy. In the finite element or finite volume methods, we must have a computer with a great processing power, and those methods require the labor-consuming preparation of a computational mesh [11]. The accuracy of potential methods is usually increased by combining them with the analytical solution of the boundary layer, and such a solution has been used in most programs, both open source XFOIL, XFLR5 and commercial, MSES and PANUKL.

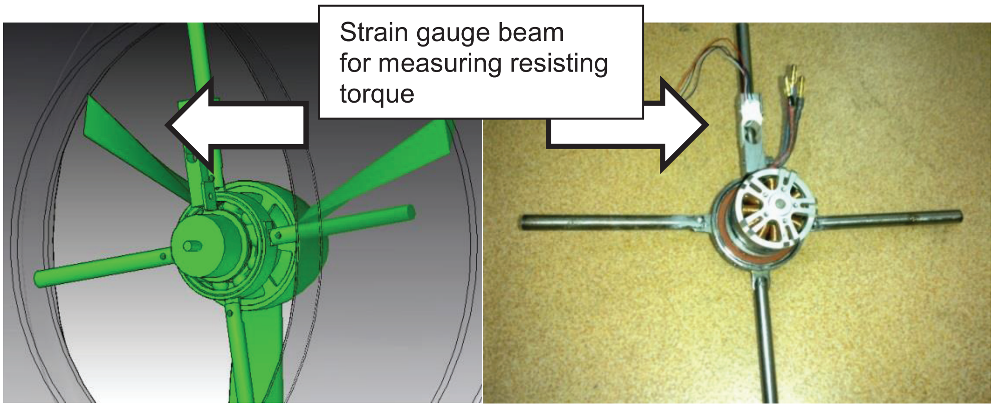
There are many methods differing from one another with respect to the type of boundary elements (vortex sheets), and the type of boundary conditions used, Neuman or Dirichlet. In order to solve the problems in which zero-circulation is expected, it is sufficient to apply the distributions of the sources only, whereas whenever lift is generated, distributions of vortices or doublets have to be applied, at times in combination with the distribution of the sources. The methods which utilize discrete vortex distribution, distributions that are stable or linearly variable are also referred to as Surface Vorticity Methods (SVM). In the panel methods, the surface of the body around which the flow occurs is divided into segments referred to as boundary elements or vortex sheets. The determination of the flow of forces acting on a body placed inside the flow is tantamount to finding the values of the functions which describe the distribution of those singularities (e.g. positive and negative source flow rates, vortex circulation, and moments of the doublets). The condition that is used with that is the impermeability of the profile outer wall. The result is a system of linear equations from which a set of necessary hydrodynamic parameters can be calculated. After that, boundary flow velocities and pressure distributions are determined, the latter from the Bernoulli's Principle. The distribution of potential flow parameters is calculated with great accuracy, which permits the calculation of the boundary layer parameters, and, what it involves, gives the possibility of calculating the profile drag and the characteristics of the boundary layer and its break-off point. The most significant assumptions made at building the physical model of flow around the ducting are: fluid inviscosity and irrotationality (except for the wake vortex) of the circulation. The impact of viscosity is simulated by the Kutta-Żukowski condition which may be interpreted as neutralizing the circulation or creating stagnation zone on the trailing edge per unit of length. Calculation method depends on the manner in which the aircraft body is modeled. Generally, two approaches are adopted. The object is modeled with the use of thin surfaces or the aircraft is treated as a 3D solid. The outer surface of that solid is usually divided into tetragonal flat panels or vortex sheets. It is assumed that the wake vortex is flat and parallel to undisturbed velocity or to the chord [8]. At present, the most commonly used numerical methods in aerodynamic calculations concerning aircraft and propellers are FVM and FEM. Navier-Stokes equations give much greater possibilities of modeling the phenomena occurring in the fluid. Fluid motion in the domain is described by Navier-Stokes equation (4), whose individual parts are equivalent to the description of a non-stationary fluid motion, convection, fluid motion caused by buoyant force, diffusion, and disturbance washout (this part is responsible for modeling viscous phenomena, generation, i.e. taking into consideration the impact of external forces acting on the fluid, e.g. pressure pulse on the propeller). The FVM (Finite Volume Method) was developed to solve problems in which field variable continuity conservation principle in the area under consideration does not have to be fulfilled. This method is based on the analysis of the field variable behavior inside the cells of the mesh, not in its nodes. Pressure distribution in them is determined from the continuity equation and the moment equation, whereas velocity distribution corrected with the pressure is derived from the continuity equation only.

In the FVM method, the value of the average integral inside the cells of the mesh is determined (the value of the integral divided by the cell volume). The values determined are then updated in the subsequent temporal steps, using the function of the stream which flows through the cells. The fundamental problem in the FVM method is the proper definition of the stream function so that it will be the correct approximation of the actual stream, using only the average values inside the mesh cells. The most common program using that method is ANSYS FLUENT. In the finite volume method, accuracy is influenced by the selected computational meshes in which calculations are performed. Moreover, the package has the capability of simulating multiphase flows, tracking molecules with a given density distribution, and the capability of the stationary fan simulation by means of the averaged pressure pulse surface (FAN model). The SIMPLE algorithm solves each equation separately with a single step, that is why convergence of the solution is quite slow. The COPLED SOLVER algorithm solves the same equations jointly, instead of updating, solving individual equations step by step, they are being solved simultaneously. That procedure requires greater processing power but the solutions become convergent much sooner.

The most popular commercially available programs/packages for analyzing the problems using the FEM methods are: ABAQUS, ADINA, ANSYS, MSC/NASTRAN, MSC.Marc, MSC/PATRAN, MSC/FATIGUE, FIDAP, OPERA- 2D. The FEM (Finite Element Method) is, like the finite volume method, a numerical method for finding approximate solution of Navier-Stokes partial differential equations. The structure of the ADINA CFD package is similar to that of the ANSYS FLUENT. In FEM, the calculation area is divided into many subareas. The continuous medium analyzed is represented by those elements "averaging" the physical state of the body. The functions searched for, being the solutions of partial differential equations, are approximated locally in each finite element by means of special tentative continuous functions defined unambiguously by their values in certain points, known as nodes (nodes are situated inside the element or on its surface). The software packages of both the ANSYS FLUENT, and the ADINA, ANSYS, and ABAQUS are able to analyze a very broad spectrum of flow and thermodynamic phenomena. These packages are more and more universal, they support many models of boundary layer, turbulence, chemical reactions, fuel consumption, and many other models useful in flow analyses in commercial applications [12, 13]. Panel methods require many simplifications and, what it involves, do not return credible values of e.g. drag, which is usually determined using Trefftz analytical method. Moreover, numerical differentiation of the velocity potential alone may be a source of numerous errors, especially in points of great irregularity of the computational mesh, e.g. in the corners of its sides. The FLUENT ANSYS package appears to be the most universal and tested tool used for designing aircraft. The cases necessary for us have already been calculated, and the manner of the calculations and their results are commonly available.

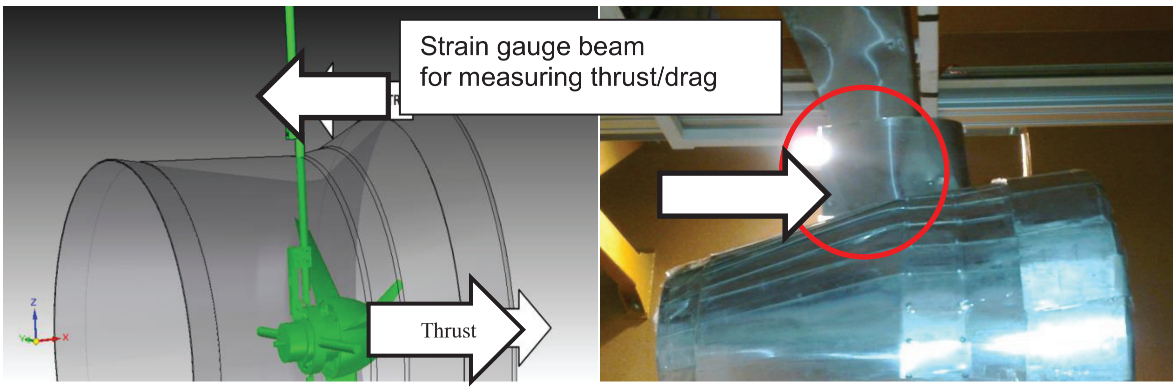
3. Methods and Results

Experimental research was conducted on the basis of the ducted propeller model with a variable ducting geometry and variable flare angle of the inlet and discharge nozzles. They were conducted in the TA 1000 wind tunnel at the Department of Fluid Mechanics and Aerodynamics, Rzeszów University of Technology. It is a free-stream non-return flow wind tunnel. The test section is in the so-called Eiffel chamber being a cube the side length of which is approximately 3000mm. Energy characteristics of non-return flow wind tunnels are slightly less favorable than those of return-flow wind tunnels. On the other hand, a non-return flow wind tunnel is characterized with a much lower turbulence level. Owing to that characteristics and to the lack of walls around which the streams directly flow, in the non-return flow wind tunnel, the interference with the stream boundary is not taken into consideration [14, 15]. In order to conduct the experiments, measuring stand was designed and built. For the purposes of the experiment, computer modular measuring system DaqBook 2001 was used, which was configured for the research problem in question. The measuring process was programmed in the measuring platform environment Dasylab v.11, which was dedicated to supporting professional research, and was performed automatically, with the possibility of freely arranging the parameters of the experiment. The measurement of thrust and torque was made using extensometric method. This permitted conducting the experiment in accordance with the requirements of present metrology. The following parameters were measured: engine torque (Fig. 4), propeller thrust (of the propeller-ducting assembly)/ring-nozzle drag (Fig. 5), dynamic pressure in undisturbed flow, impact pressure ahead of and behind the propeller on the reference radius $r = 0.75r$, and propeller speed.



a b

Fig. 4 Resisting torque measurement: a - schematic drawing; b - the view from the propulsion, photo T. Muszyński



a b

Fig. 5 Thrust/drag measurement: a - schematic drawing; b - fairing of the extensometer used for thrust/drag measuring, photo T. Muszyński

Impact pressure measurement ahead of and behind the propeller with a reference radius $r = 0.75r$ was performed using impact pressure tubes placed ahead of and behind the propeller plane of rotation. Models used in the experimental or numerical tests are characterized with the following geometric parameters (Table).

Table

Basic geometry characteristic of the ducted propeller variants under investigation

	Intake and discharge diameters		Intake and discharge areas compared to propeller area		Profile angle of attack and deflection		Inlet and discharge nozzle flare angle	
No.	Diameter D_{INLET}	Diameter $D_{DISCHARGE}$	S_{INLET} [Sdisch./ Sprop]	$S_{DISCHARGE}$ [Sdisch./ Sprop]	α_{CSO} [degrees]	deflection [%_cord]	Inlet nozzle flare angle [o]	Discharge nozzle flare angle [o]
1.	395	382	1.68	1.57	0.9	-7.1	17	9
2.	270	255	0.78	0.69	1	8.3	-9	-6
3.	395	350	1.68	1.32	3.1	-5.5	17	5
4.	315	252	1.06	0.68	4.3	4.9	0	-6
5.	362	299	1.41	0.96	4.3	-0.7	10	-1
6.	395	318	1.68	1.09	5.4	-4.3	17	2
7.	405	328	1.76	1.16	5.4	-5.5	19	3
8.	362	252	1.41	0.68	7.6	1.8	10	-6

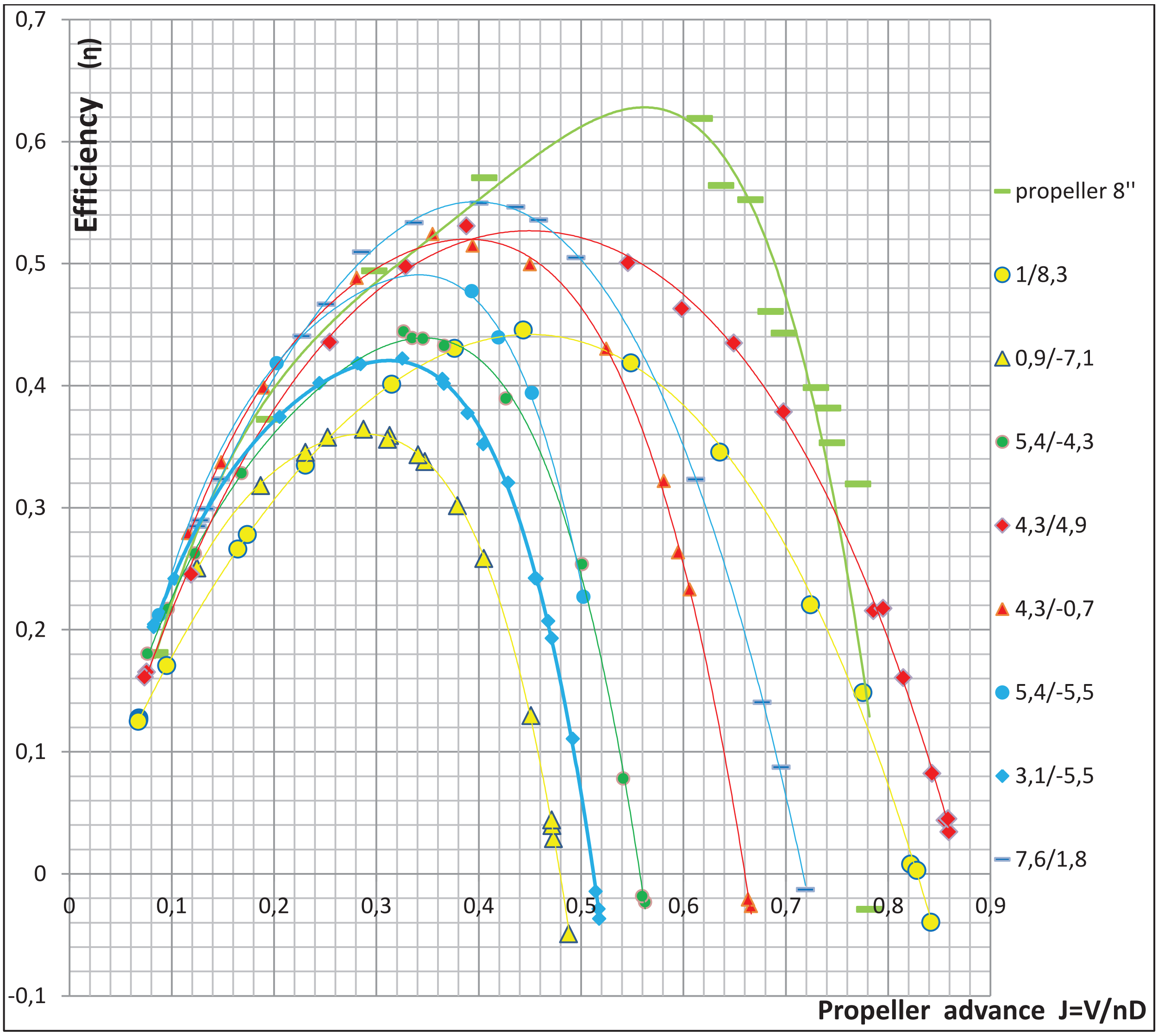


Fig. 6 The efficiency of the most effective geometry settings of the ducted propeller assembly for small advances and open propeller.

According to the expectations, ducted propeller permits obtaining greater thrust and higher efficiencies than open propeller in the small advance range (Fig. 6). In the research studies under consideration, the highest efficiency in the range of advance not exceeding 0.22 was that of the (5.4/-5.5). It is the variant with the greatest inlet diameter and a slightly flared discharge nozzle. According to theory [14, 16], such a configuration permits the local increase of the flow velocity around the nose portion of that profile, and, what it involves, permits the emergence of areas of considerable underpressure, which create a forward resultant force adding to the thrust. The purpose of a slight flare in the duct section behind the propeller plane is to reduce the velocity of air stream discharged from the ducting, which promotes energy loss reduction Within the 0.20 to 0,23 advance range (4.3/-0.7) geometry. For the advances of 0.23 to 0.4 the maximum efficiency was that of the (7.6/1.8) ducting.

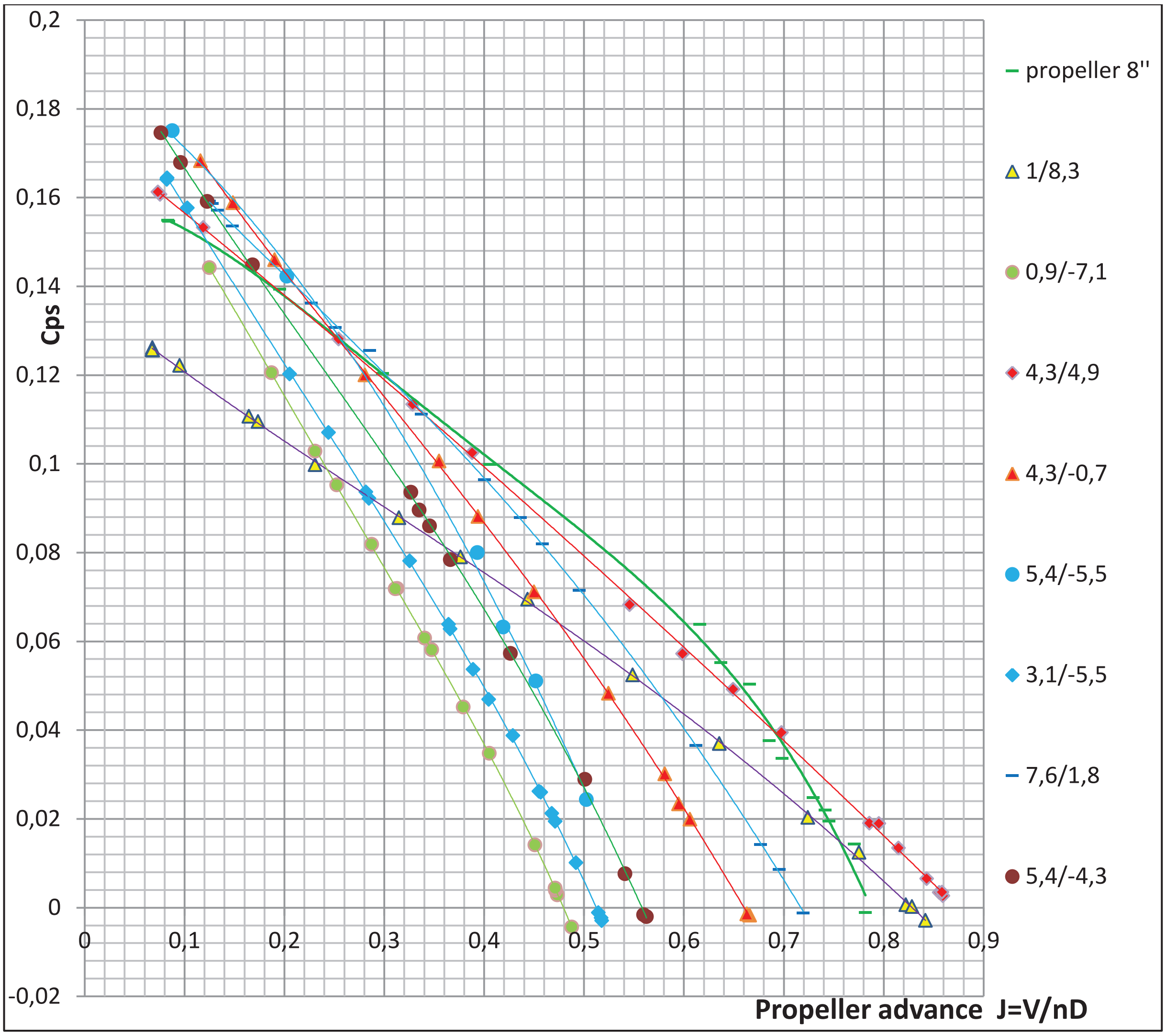


Fig. 7 Thrust coefficient Cp_s of the most efficient geometries of ducted (for small advances) and open propellers

Among the geometries investigated, the greatest values of thrust coefficient in the low advance range were those of the greatest inlet diameter (5.4/-5.5) and (4.3/-0,7). Within the 0.20 to 0,26 advance range it was the (4.3/-0.7) geometry. For the advances of 0.22 to 0.31 the maximum values of thrust coefficient were found in the (7.6/1.8) ducting (Fig. 7).

Because of the fact that the fixed-geometry design can be made without corners inside, in locations where the hinges changing the geometry would otherwise be located – which was the case in the model used in the experiments, it was decided that the typical ducting profile, Wageningen 19A, will be used which is used in aircraft propeller and marine propeller screw ductings. A regularity that can be noticed in the experiments conducted is the fact that the decrease of the discharge nozzle flare angle is accompanied with the considerable increase of the discharge nozzle efficiency in the range of greater propeller advances. In order to check the characteristics of that profile and of its modifications, it was decided that numerical simulations would be carried out in the Ansys Fluent program.

The object of the numerical simulations was to determine the characteristics of the propulsion system using Wageningen 19A profile and its modifications. Modifications were developed on the basis of the experimental studies concerning the ducted propeller with a variable ducting geometry with the aim of improving its characteristics within the 0.2 to 0.3 advance range, i.e. the basic utility range of the prepared surveillance/rescue system with a ducted propeller for water rescue services. Numerical simulations were performed for the Wageningen 19A profile and its three modifications. The essence of Modification 1 was the change of the exhaust nozzle flare angle – cylindrical middle section was lengthened as far as to the trailing edge, which resulted in the zero flare angle of the exhaust nozzle. In Modification 2 and 3, the entire profile was rotated by 1 and 3 degrees around the intersection of the ducting with the propeller plane of rotation.

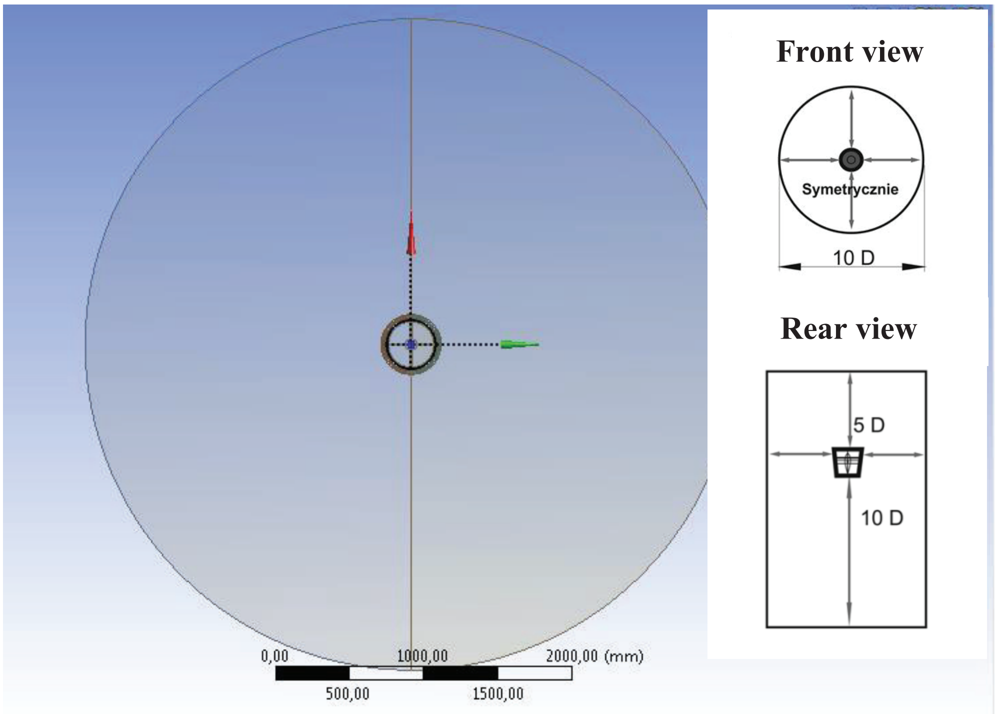


Fig. 8 Frontal view and relative dimensions of the computational domain

The ducted propeller geometry was prepared in the Catia v5 program of the *Part Design and Assembly Design module*, and was then transferred to the *Design Modeler* program of the *Ansys Workbench package* (Fig. 8). In that program the geometry was "smoothed", sharp edges were rounded and radii were increased in the areas where the planes meet. The next phase of developing a model to be used in simulation calculations was the development of the calculation mesh (Fig. 9, Fig. 10). For that purpose, the model with the domain was imported to the *ANSYS Meshing* program. In order to determine the thickness of the boundary layer, the flow type with regard to the Reynolds number was determined, as well as an approximate boundary layer thickness. This mesh required additional modifications connected with the necessity of its densification in the areas of expected large gradients of both flow velocity and pressure.

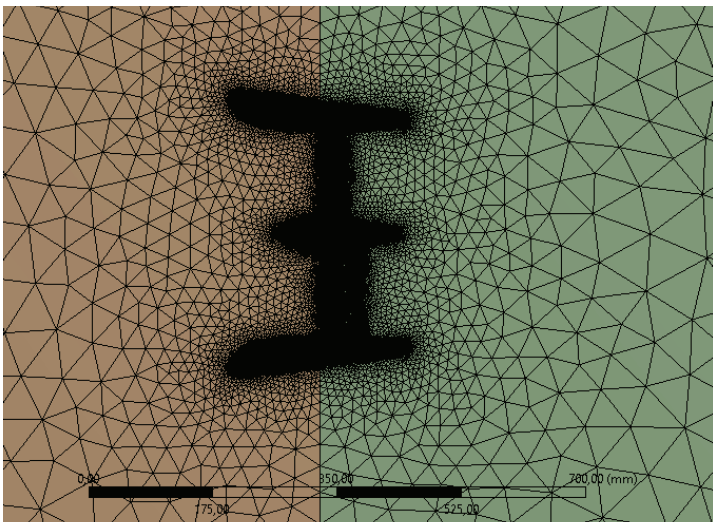


Fig. 9 Division and densification of the Modification 2 geometry mesh

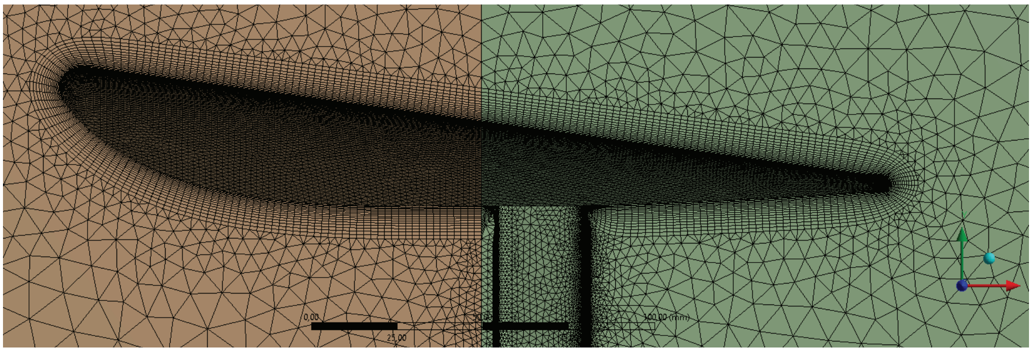


Fig. 10 View of the discretized profile with the boundary layer

For the meshes constructed, parameter Y^+ was also checked, i.e. non-dimensional coefficient describing the height of the first element form the wall of the next (Fig.11). This parameter is defined with the formula:

$$Y^+ = u^* y/\nu;$$

where y -distance to the closest wall (height of the element); ν - local kinematic viscosity; $u*$ - local friction velocity defined by the formula:

$$u^* = \sqrt{\tau_w/\rho}$$

where τ_w - stress on the wall; ρ-air density.

It is recommended that the value of Wall Y^+ should be close to 1 [12], which is a recommended value for each model of turbulence. In reality, however, such a value is difficult to achieve since it requires a very dense mesh with a very small first element in the boundary layer. If such a condition (Y^+close to 1) is hard to fulfill, it is recommended that $Y^+ > 30$, which is also difficult to achieve for a complex geometry (most frequently the $30 < Y^+ < 300$ range is given). Avoidance of meshes with the Y^+ within the following range: $5 < Y^+ < 30$. The Y^+ coefficient of the computational meshes created for the present research is below 1.5, and only for some of their fragments its value is from 1.5 to 3, which is an acceptable value according to most sources. For the RANS model with the model of turbulence k-ω SST the parameter Y^+ should not exceed 5 [8]. The vast majority of the elements fulfills that condition, and only the locations at which individual elements are connected show slightly higher values (Fig. 11).

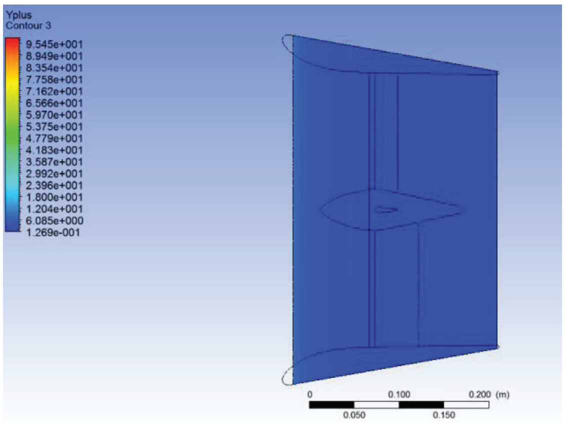


Fig. 11 Mesh quality factor Y^+ for the outer surfaces of the Modification 2 geometry

In thens, static pressure and temperature values were assumed to be the same as on the day when the 7.6/1.8 geometry was measured. The remaining boundary and initial conditions, both for the velocity and pressure field and the boundary values were determined according to the user guide of the FLUENT program and the online guide for using advanced features of that program. In the calculations, the k-ω SST model was utilized [20] As it has already been mentioned, the k-ε model is a good model of free flows and flows in boundary layers, and it has low sensitivity to inlet conditions which are often not precisely known. On the other hand, the turbulence model, k- ω, models turbulent flow in the boundary layer much better but it gives poor results for free flow turbulence.

Pressure pulse was defined on the basis of the results obtained from the experiment for the geometry which had the profile angle of attack and the deflection the most similar to those in source [10]. As only one pressure pulse measurement was available, the manner of its distribution was adopted in accordance with source [1], and then the mean value of the pressure pulse on the airscrew disk was determined.

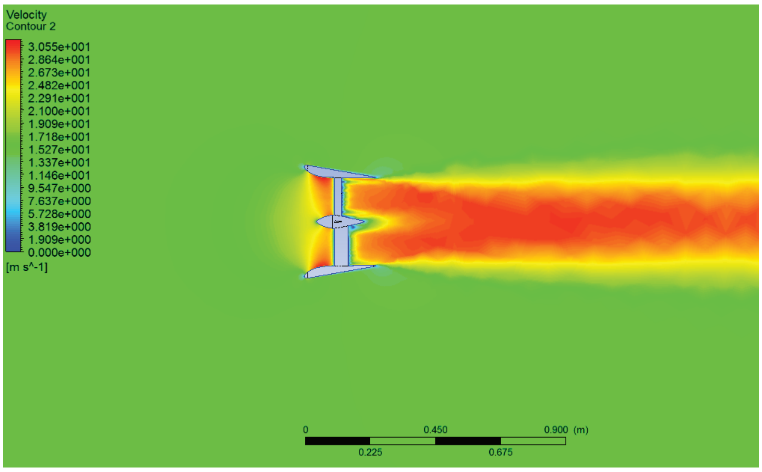


Fig. 12 Velocity distribution, Modification 2

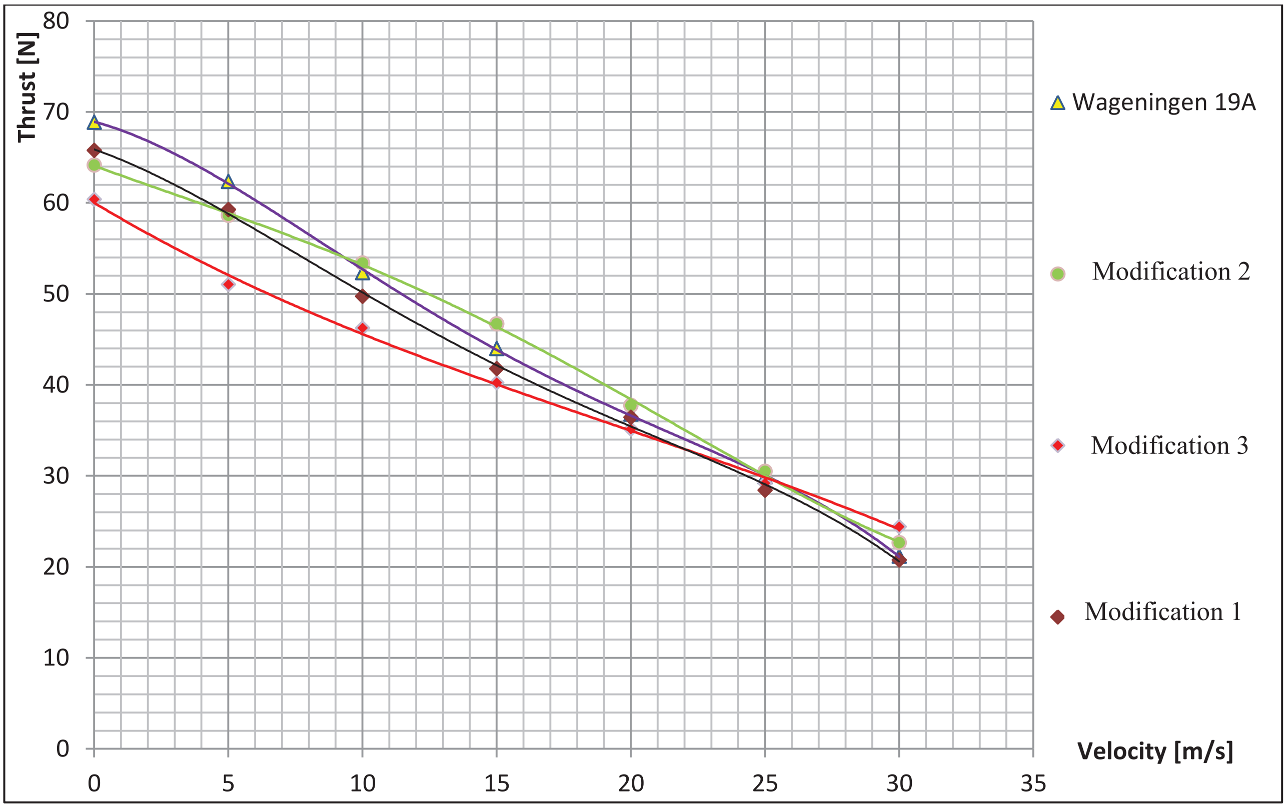


Fig. 13 Comparison of the CFD thrust simulation for the Wageningen 19A profile and its modifications

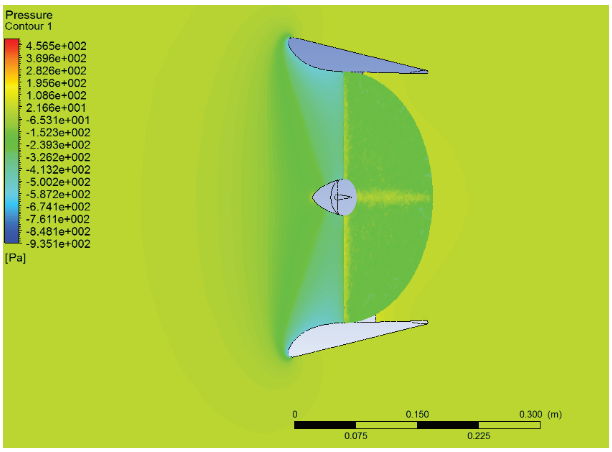


Fig. 14 Pressure distribution for the propulsion unit with the Modification 2 profile at the velocity of 15 m/s and the propeller modeled by means of a pressure pulse

The most favorable characteristics of thrust in the function of velocity for the velocity in the 10-15 m/s (propeller advance $J = 0.2$ to 0.3 - Fig. 13) range were those of the propulsion unit equipped with the Modification2. The propeller ducting of the Robolifeguard UAV was made in accordance with that profile. Simulations also confirmed a regularity that the decrease of the discharge nozzle flare angle is accompanied with the considerable increase of the discharge nozzle efficiency in the range of greater propeller advances (Fig. 13).

It can be noticed in the pressure distribution for Modification 2 (Fig. 14) that there are impact pressures on the airscrew disk (center body) which points out to the fact that the distance between the airscrew disk and the engine bearers. Impact pressures expand from the engine bearers as far as to the airscrew disk, which most likely affects the propulsive efficiency. It is one of the conclusions that were taken into consideration while building the proper propulsion unit for the UAV (Fig. 14).

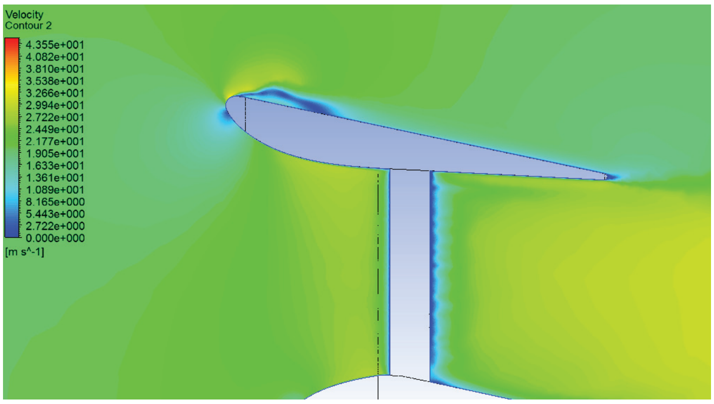


Fig. 15 Velocity distribution for the propulsion unit with the Modification 3 profile at the velocity of 20 m/s and the propeller modeled by means of a pressure pulse

In the velocity distribution for Modification 2 (Fig. 12) and Modification 3 (Fig. 15) there is a visible break-off on the leading edge, which suggests the inappropriate manner of modification (by rotating the entire profile) which led to stream break-off just behind the leading edge.

4. Conclusions

The research studies compared the calculated thrust of a ducted propeller for various ducting configurations to select the profile with the best performance in the designed range of operating velocities of a UAV under construction. Good properties of the selected profile were confirmed in practice. Owing to the application of the ducting, static thrust was increased by 15%, which is a slightly higher value than in the source [10]. Because of that, the profile tested could be applied in practice, yet the thrust increase was quite small in comparison with other research studies [17, 18].

In the simulations, static thrust should be 8% greater than that proved by the experiment. One of the main reasons for the discrepancies may be the assumed method of propeller modeling, as a pressure pulse, as well as assuming the average pressure on the basis of the same function. It should be presumed that pressure distribution changes for each geometry variant and flow velocity As only one pressure pulse measurement was available, some way of determining the mean value of the pressure pulse on the airscrew disk ought to be assumed. Similar problems appeared already in earlier studies [19]. Their solution may be the application of a much more accurate ducting model and the Virtual Blade Method which takes into consideration propeller blade geometry.

Fig. 16 Rescue UAV (technology demonstrator) with the propulsion system designed on the basis of the experimental and numerical studies, Materials Technology Student Research Circle, Polish Air Force Academy, Dęblin, photo T. Muszyński

The UAV with a newly designed ducted propeller (Fig. 16) had a much shorter take-off distance and more than double flight endurance in comparison with the generally available EDF (Electric Ducted Fan) turbine solutions which were used in the first prototype. The ducted propeller unit that was built had greater static thrust than an open propeller with the same diameter while using a propeller with a 2 inches larger diameter compensated for the difference completely. From the perspective of the propulsive unit efficiency and its weight, using the propeller ducting seems in this case unprofitable. Since, however, the aircraft is to be operated near people, their safety is the most important factor here. Owing to the application of the newly-designed propeller ducting, it was possible to achieve the efficiency and flight endurance similar to those of an open propeller with a much higher level of safety.

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Structure of Unmanned Aerial Vehicles Used in Courier Services

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Abstract

A current development of unmanned aerial vehicles has caused that the vehicles gradually find themselves in a field of courier services. This article is focused on defining of a suitable structure for the unmanned aerial vehicles used for the courier services. The first part of the article is about summarizing a current state of this topic. Basic requirements for a consignment transportation are defined in the first part too. These requirements are characteristic of a consignment, transport distance, delivery place and addressee identification. The next part of this article focuses on describing structures of the vehicles (airframe) that are suitable for the courier services and it focuses on describing types of power units. The final part is about presupposed operational requirements to unmanned aerial vehicles operations. These requirements can be for autonomous flight, safety or requirements for a structure of transport boxes.
KEY WORDS: *UAV, RPAS, unmanned aerial vehicle, courier service, logistics, UAV structure*

1. Introduction

Nowadays, there is a growing trend to use unmanned aerial vehicles maximally in non-army areas of a business. This trend is also in an area of a postal consignments transportation. There were several flights that delivered the consignment to an addressee in the world. But these flights were experimental. The flights showed that this way of the consignments transportation is possible under certain circumstances. There are not uniform regulations for this type of the transport in the world. These regulations should define and set conditions for it. The USA has some regulations which are quite good. The European continent has not the uniform regulations and the unmanned flying is regulated by national regulations. The national regulations are very different at each member state of the EU. Nowadays, the uniform common regulations for the EU are preparing. The EASA gives patronage to it. Rules and operation conditions are just searching now on one hand and it is necessary to solve a technical part of the operation on the other hand. The technical part should ensure that the vehicles will be able to fulfil the consignments transportation reliably, safely and economically [1].

2. Definition of Basic Requirements for Postal Consignments Transportation

2.1. Consignments Characteristic

2.1.1. Paper Consignments

The postal consignments are paper consignments, postcards, letters and also packages. The first three consignments weigh several grams and their size is up to B4 format. A standard size is B5 format. The transport of these consignments needs a little power. From the economic point of view, there should be a system which enables a delivery of many consignments to several addressees and after that the vehicle should return to the base. This flight is suitable for a district of for a village, for instance. This type of the delivery needs a special structure of the vehicle. The structure should enable an access to each section of a cargo space separately. This will ensure that only right consignment will be delivered to the owner (the addressee) and other consignments will be protected against an abuse.

2.1.2. Packages

A package transport is more complicated. The most courier services define a maximal weight (up to 20 kg) and size of packages for a standard transport. The maximal size is up to 2.000 mm. Sizes of the package are summarized and the maximal size must not be exceeded. Bigger consignments are oversized and they are delivered according rules for a special transport. It is necessary to change these limits because of technical requirements for the standard package transport realized by the unmanned aerial vehicles. It can be assumed that the limits for the unmanned vehicles should be between 2 and 10 kg and the ground plan size should be up to B4 format (see chapter 2.1.1). Many consignments with similar parameters should have special category, for instance pizza boxes and so on. Other infrequent and oversized consignments should be transported by standard type of the transport, for instance by a car. It is not cost-effective to design and rebuild the unmanned vehicles for the consignments that cannot be unified.

2.2. Transport Distance

Current ground transport systems have almost unlimited options in an area of the transport distance. The most suitable vehicle is chosen based on the transport distance, weight and size of the consignment. It is possible to refuel the vehicle or to load the consignment to another vehicle. These possibilities are very limited in case of using the unmanned aerial vehicle. It is because there is no infrastructure for the unmanned vehicles in the world. It can be expected that the first flight paths will be as long as the maximal range of the chosen unmanned vehicle. The structure itself and also a type of a drive unit could greatly affect the range. It can be assumed that the flight from the base to the addressee will be up to 10 min in case of an electromotor (Fig. 1) and up to several hours in case of a combustion engine (piston or turbine) [2].

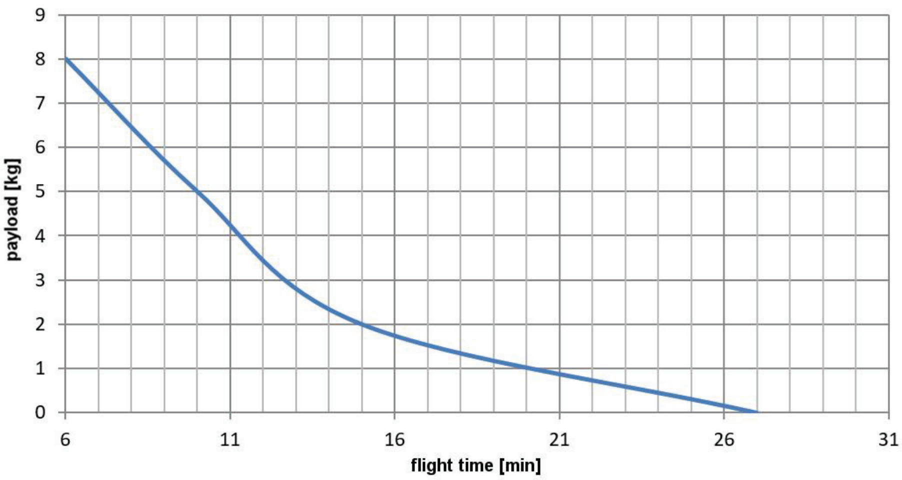

Fig. 1 A dependency of the flight time to the consignment weight. This is for the helicopter series 700 with the electromotor [3]

2.3. Mailing Address

2.3.1. Delivery Place

It can be used several ways how to deliver the consignment to the addressee. The first way is to release it inflight so the consignment can land by parachute or it can fall to a special impact area. The second way is to release the consignment when the unmanned aerial vehicle is hovering. The vehicle is in the air and the addressee can take the consignment from it. This way has several limitations like the type of the unmanned vehicle, energy demands so the flight time decreases because of the hovering or safety aspects so the addressee can have contact with the structure, for instance with a propeller. The last way is to land with the vehicle at a landing area (garden, roof and so on). This way have some risks. These risks can be abuse or damage of the unmanned vehicle.

2.3.2. Addressee Identification

Current transport conditions must define and identify the addressee. This process become very complicated when the unmanned aerial vehicle is used and no deliveryman is there. A multi-level transport system should have been set because of this. The first level would be a "pizza delivery" type. The addressee would be identify by a payment type (payment in advance or by card when receiving). When the vehicle delivers more expensive consignments, the identification can be done by a reader of an identification card, passport or another modern biometric data. The unmanned vehicle should have some instruments for an addressee identification and for an electronic payment.

3. Structure Options of the Couriers Unmanned Aerial Vehicles

3.1. Types of Airframe

Nowadays, the structure of the most common unmanned aerial vehicles are divided into these categories:

1. fixed lifting surface
2. rotating lifting surface
3. mixed structure

The vehicles with the fixed lifting surface (wings) are airplanes. They are controlled by aerodynamic forces. The thrust is created by a drive unit. These vehicles predominantly need runways. They can transport heavy load to long distances. Suitable drive unit is a combustion engine using liquid fuel. An application of these vehicles is between logistic centres or towns.

The vehicles with rotating lifting surface are the second category. These vehicles are controlled by thrust vectorising (helicopter or coaxial helicopter) or by thrust changing done by many motors (x-copter). Their incontestable advantage is vertical take-off and landing. They are very suitable for final delivery because of this. They can land on nonstandard landing surfaces (slope, bad surface quality, landing area contamination and so on). The x-copters are suitable for small and light consignments. The structures similar to the helicopter is suitable for heavy consignments. These structures are suitable for long distances too (Fig. 2). The combustion engine can be used for these structures. It increases a range significantly. So they are suitable for transport to outlying villages (approximately 30 km).

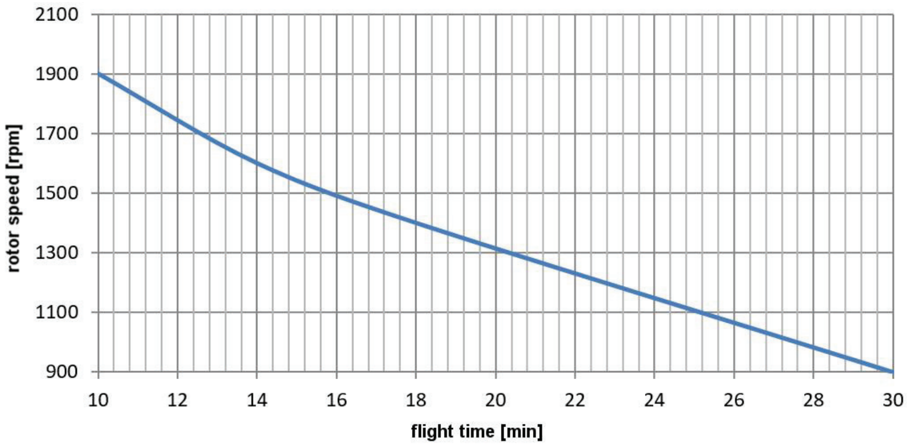

Fig. 2 A dependency of the helicopter series 500 rotor speed to the flight time. The helicopter is without the load and it has an electromotor [3]

The last category combines the previous categories. There are mixed structures in this category. This type of the structure combines advantages and also disadvantages of the previous structures. It can be said that this category is experimental. This is because of technical and operational demands of the unmanned vehicles which have the mixed structure. Only newly built systems and operations show if the mixed structure is applicable. But for now, it is unsuitable to use the mixed structure for the transport.

3.2. Choice of Drive Unit

Present types of the drive units significantly predetermine their use. For instance, if it is necessary to determinate required power or to determinate the flight time, basic assumptions (1) can be used for rotor drive units [4].

$$T = \oint\!\!\!\oint_S p d\vec{S} + \oint\!\!\!\oint_S \left(\rho \vec{V} \cdot d\vec{S} \right) \vec{V} \, , \tag{1}$$

where T is an engine thrust; S is an area of the rotor and ρ is an air density.

A need power P for the hovering can be calculated by using an equation (2) where T/A is a load of a rotor disc [4].

$$P \equiv T \sqrt{\frac{T}{2\rho A}} = \frac{T^{\frac{3}{2}}}{\sqrt{2\rho A}} \, . \tag{2}$$

The most suitable drive units for the unmanned aerial vehicles are:

1.Electromotor – generally, it can be said that this type of the drive unit is one of the best. It is because of its reliability, simplicity and availability. Its basic disadvantage is small power supply in batteries. The batteries have same weight for all flight unlike a liquid fuel. It can be used only for short distances (tens of minutes) thanks to this (Fig. 3). This drive unit is the most suitable for the x-copters. Its big advantage is also a low emission and noise pollution. So it is suitable for the transport above build-up areas [5].

2.Combustion engine – A piston engine has big potential. It can help to transport heavy consignments to medium distances at low altitudes (Figs. 4 and 5). A maintenance of this engine is expensive and it is noisier than the electromotor. The combustion engine produces more emission than the electromotor too. A turbine engine can be place into this category too. The turbine engine can have several configurations: turboprop, jet or turbofan configuration. An efficiency of this engine is smaller than the efficiency of the previous engines. The turbine engine is suitable for long distances (100 km and more) and high altitudes. This engine has demanding maintenance and control system too. An initial costs are much bigger than the costs of other engines.

Fig. 3 A dependency of an electric current consumption at a rotor speed. The vehicle is a helicopter series 500. The green line is the rotor speed. The blue line is the current [3]

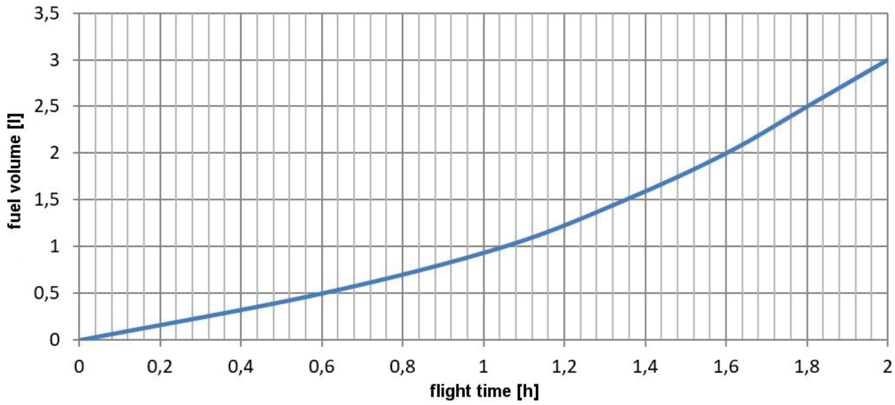

Fig. 4 An influence of a fuel volume to the flight time. It is for a helicopter Radikal G30 V2 [3]

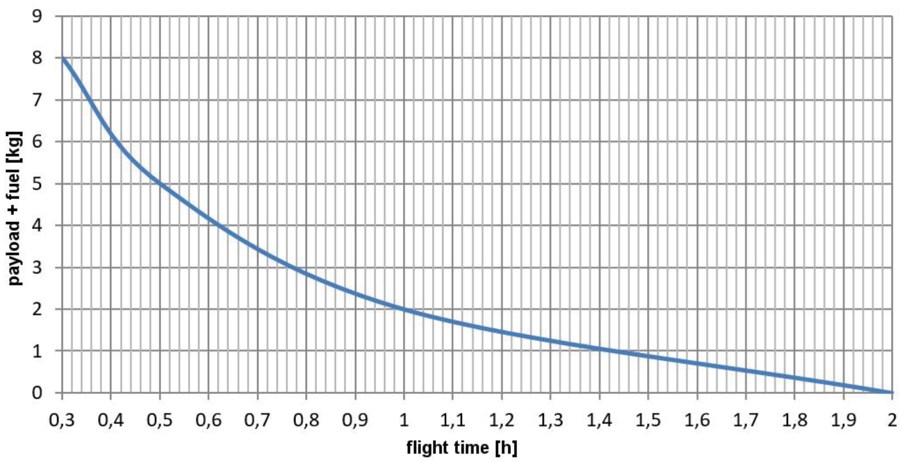

Fig. 5 A dependency of the flight time to the payload and fuel. It is for the helicopter Radikal G30 V2 [3]

4. Presumed Functional Requirements for Unmanned Aerial Vehicles Operations

General requirements for the courier unmanned vehicles can be divided into several categories. A primary category is about autonomous flight requirements. Each consignment should have an electronic mark and there should be written information about flights, addressees and flight priorities in the mark. Next point in this category is about safety and autonomous emergency descending. The unmanned vehicles must flight inside corridors that are clearly defined. When the corridors are known, emergency areas can be predicted. The autonomous system must have some device that can check the landing area. The device could check if the area is suitable for landing or if there isn´t any barrier like person, car or animal [6].

Next category is about a transport space system. It is obvious that the transport process must be realized with special transport boxes. The consignment will be placed into a unified transport box. The consignment will be secured throughout the transport. The box must be suitable for all types of the unmanned vehicles that will participate in the transport.

Secondary requirements are a system for addressee identification, system for doing the cashless payment, online data transfer, system for changing flight parameters, video transfer and so on. The last mentioned systems can be places into the primary category too. It depends on a character of the transport. The regulations should create and regulate this distribution [7].

5. Conclusion

It is very complicated to answer to the question how will the transport system by the unmanned aerial vehicle look like. An international development in the area of the regulations for the unmanned aerial vehicles will have the major impact to this transport. Nowadays, it can be found that the regulations oversleep so the aviation technique outruns it. Newly prepared regulations will probably be outdated before they come into force. The goal of this article is to describe a probable form of the consignment transport by the unmanned aerial vehicles. Nowadays, it is impossible to describe technical solutions more precisely. Nevertheless, it shows what the technical progress enables or will enable in the nearest future.

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Vehicle Fire Safety of the Static Traffic

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Abstract

Parking motor vehicles and their safety shutdown presents a risk of fire, theft of property or the whole vehicle. The article deals with fire safety vehicles and fire transfer from vehicle to vehicle taking into account the parking spaces and distances to between them due to radiant heat. Presents results achieved in experiments, simulations of fires in different environments with varying separation distances vehicles. To a large extent reflecting the fire safety of towns and villages in parking lots and parking areas.
KEY WORDS: *safety, paring areas, fire, parking spaces, fire tests*

1. Introduction

Parking in the open air is a common situation in the city. Parks in open spaces are commonly found at shopping centres, housing estates, and residential areas. In [1], the basic requirements for designing parking spaces for each vehicle category are stated. Particular dimensional parameters of parking and parking areas in Slovakia can be found in STN 73 6056. Various standards on the width and length of parking spaces are used in the world. Some towns and villages have these dimensions adjusted separately. The size of parking spaces is devoted to various studies.

For example, the following are standard space requirements of some typical vehicles. These may be used as basic minimum reference values but different layouts such as parallel, herringbone and in-line, have slightly different overall space requirements and detailed layout of parking spaces will be site specific.

- Car 2,4 m x 4,8 m;
- Light vans 2,4 m x 5,5 m;
- Rigid vehicles 3,5 m x 14,0 m;
- Articulated vehicles 3,5 m x 18,5 m;
- Coaches (60 seats) 3,5 m x 14,0 m.

These dimensions refer to standing space only and do not take account of access, manoeuvring space or space required for loading/unloading [3].

The basic dimensions of the vehicles from which the dimensions of the parking area (car park) are based are shown in Table 1.

Table 1

Basic dimensions of vehicles for the design of the parking area [**Error! Reference source not found.**]

Vehicle type	Length (m)	Width without rear-view mirrors (m)	Height (m)
Personally	4,75	1,75	1,80
Dellivery	6,00	2,00	2,80
Truck	18,75	2,50	4,20
Bus	15,00	2,50	4,00
Motorbike	2,50	1,10	1,20
Bike	1,80	0,60	1,10

When comparing the table with the basic dimensions of the vehicles and the selected parking space requirements, the minimum standards set out in the following table are not met.

Table 2

Smallest distance values from the fixed obstacle and between the vehicles in the Slovak [2]

Length of distance (m)		Vehicle type				
		Personally	Dellivery	Trucks	Bus	Motorbike
Between the fixed obstacle and the side of the vehicle on the driver's side, between the vehicles side by side	A	0,75	0,75	1,00	1,00	0,50
Between the fixed obstacle and the side of the vehicle on the opposite side of the driver	B	0,40	0,40	1,00	1,00	
Between the front of the vehicle and a fixed obstacle	C	0,25	0,25	0,50	0,50	0,25
Between the end of the vehicle and a fixed obstacle	D	0,25	0,50	1,00	1,00	0,25
Between two vehicles at longitudinal standing	E	1,00	1,00	1,00	1,00	X
Between two vehicles behind	F	0,50	1,00	1,00	1,00	0,50

These standards have been in force since 1987. Due to developments in the automotive industry, some passenger cars exceed the standard values in Table 1, reducing the distance between two vehicles and creating space for faster fire spread from vehicle to vehicle. [2, 5]

When planning the construction of car parks, it is necessary to focus on the fire safety of wearing vehicles in the context of fire and the spread of fire. The environment in which the vehicle is found will have a significant impact on the external fire and, last but not least, the amount of damage incurred.

2. Fire Tests

Fires of passenger cars are almost everyday road traffic events. The number of car parks and garages also increases proportionally from the increase in the number of vehicles. Vehicles in these objects often stand side by side at distances smaller than those required by fire safety and, in particular, possible fire on one of the vehicles and its further development. Also, based on these, we have carried out several flame jump experiments from vehicle to vehicle. The aim of the experiments was to confirm or rebut the hypothesis that, at a lesser distance, there will be an initiation next to the standing vehicle when the vehicle is in the transverse state. As a fire-exposed object, the doors of a passenger motor vehicle (both front and rear) were chosen on which the temperatures were measured by radiant heat or the whole motor vehicles.

In experiments on the doors, we placed the radiometers at a distance of 50 and 70 cm from the heat source, two pieces at each distance. One was located in the axis of the source and the other at the level of the edge of the tank with a flammable liquid (Fig. 1).

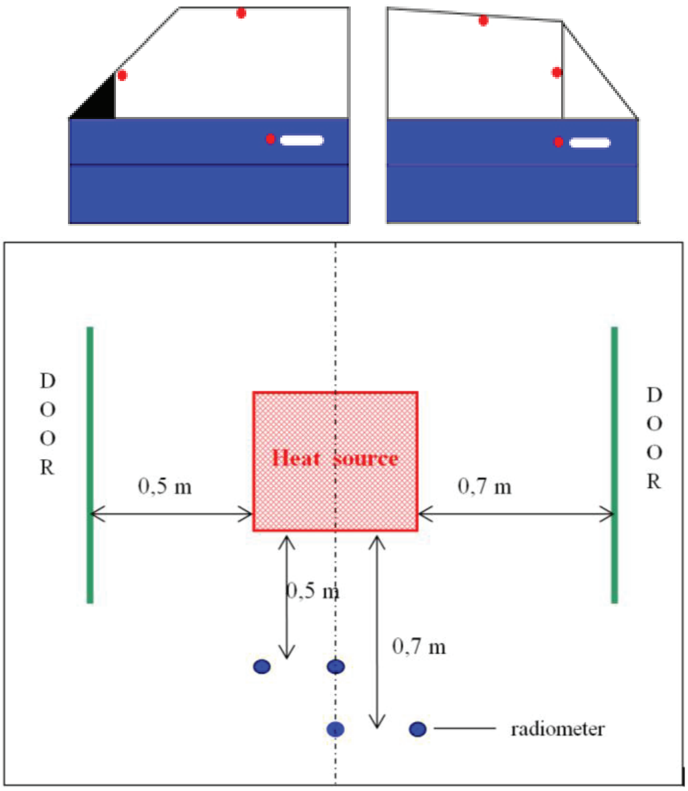

Fig. 1 Layout of the measuring devices [1]

During the experiments, changes and measured values were examined according to the test methodology developed prior to the test and adjusted according to the real situation after the individual real tests. The status of individual devices and samples was recorded before and after the test. The 60 × 90 × 20 cm bathtub filled with automotive gas was used during the test. The tray was positioned so that the top edge was at the bottom edge of the door. Temperature ranges ranged from 192° C to approximately 30° C in the radiometer range. By heating the petrol the temperature gradually dropped. The maximum heat flow rate was 33.98 kW.m-2. The thermal effect of the fire was reflected on both doors. The rear view mirrors and window seals were covered. Doors at a distance of 50 cm showed greater signs of damage than those at a distance of 70 cm. The temperature flow over time is illustrated in the Fig. 2.

In the second case, we did a fire test on complete vehicles. The location of vehicles and thermocouples is shown at Fig. 3.

These tests studied also skipping the flame from a burning vehicle standing next to non-burning vehicle. After initiation of the passenger compartment were left open a window to the burning vehicle by another vehicle. During the fire was ignition of another vehicle, but not radiant heat, but by breaks piece of plastic strip doors at the front door of another vehicle. Thermocouple temperature measured at B-pillar during the measurements amounted to max 63° C, which is insufficient for ignition temperature. The measured temperature can be seen at Fig. 4.

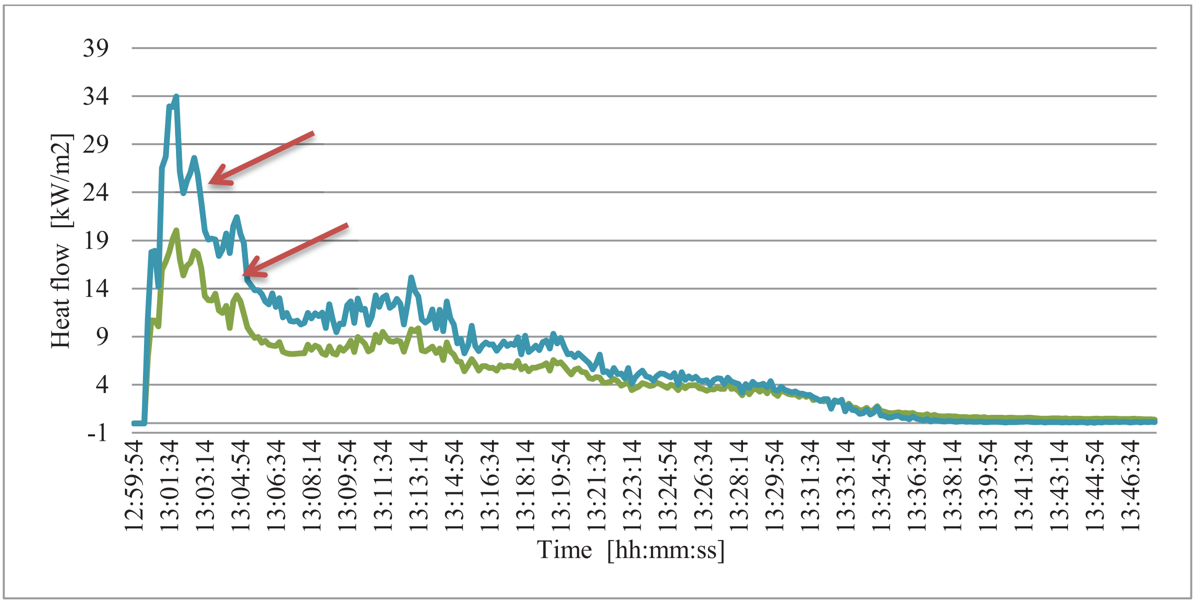

Fig. 2 Graph of the heat flow of the burning door in the experiment

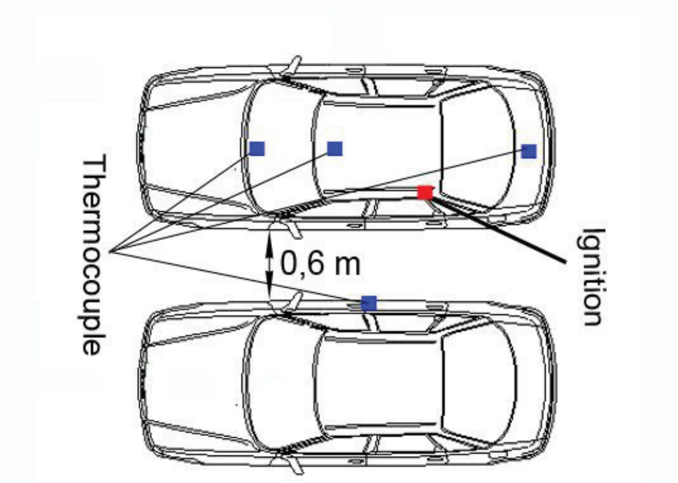

Fig. 3 Position of vehicles in the experiment

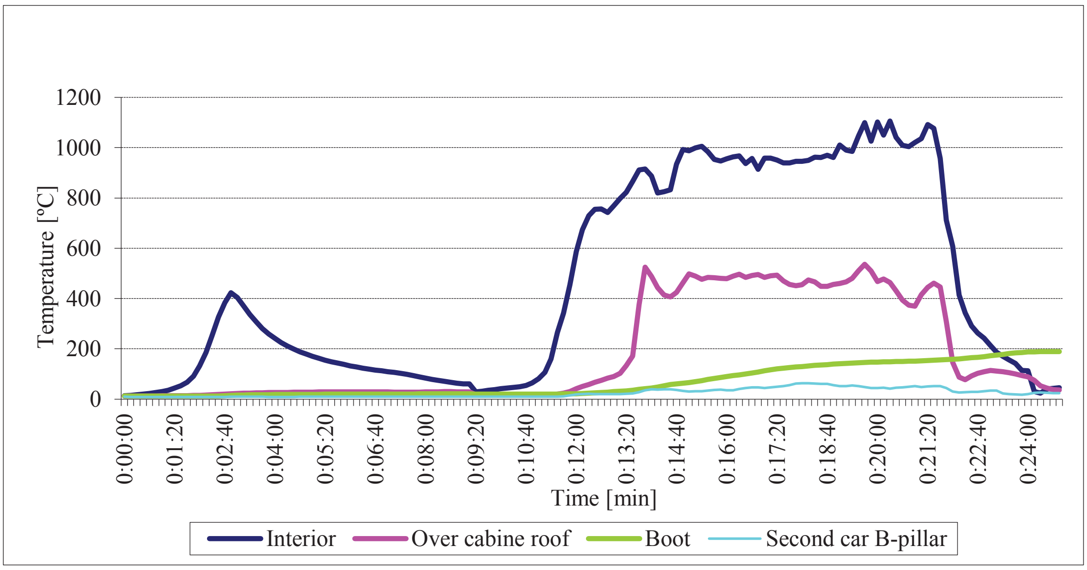

Fig. 4 Graph of the temperature gradient of burning vehicles in an experiment [4, 6, 7]

3. Conclusion

Temperatures and heat flux at both fires were high. With vehicle distances up to 50 cm, it can be argued that the fire will be transferred from the vehicle to the vehicle due to radiant heat. However, the 70 cm test did not explicitly confirm the flame from the vehicle to the vehicle and the automatic spread of the fire. In practice, the fire spreads by fouling the fuel underneath the floor standing vehicle or by leaving flammable parts - Plastics, rubber and the like. To achieve unambiguous 100% fire safety of the vehicle when parked and fire-extinguished, it is necessary to ensure a wide range of factors that cannot realistically be achieved in land transport.

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Using HIL testing for Differential Lock Control

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Abstract

The paper deals with the testing of a control algorithm for locking differential of the truck. This algorithm is applied to hardware for HIL testing. Connection and communication between sensor, actuator, and hardware is described. In conclusion, a Real-time testing of the mechatronic system is created to verify the functionality of the assembled control algorithm of the differential. Moreover, a reaction on the real sensor is monitored.
KEY WORDS: *control algorithm, NI VeriStand, differential, HIL*

1. Introduction

Mechatronic systems are an integral part of each vehicle. Their development is constantly accelerating and therefore, different tools are needed for development and testing. To verify mechatronic systems before the first prototype of the ECU (Electronic Control Unit), HIL (Hardware-in-the-Loop) testing is used. This is the special hardware used as an ECU replacement. The hardware has a processor where the control algorithm is implemented and the hardware has input and output modules for connecting sensors and actuators. Therefore, the development of the control algorithm and the ECU prototype can proceed in parallel.

This article deals with the use of such hardware to test the developed mechatronic system. An important factor is the processing of input signals and the control of actuators. Therefore, the possibility of the laboratory testing of sensors and actuators, the concepts of the developed control algorithm, the possibilities of its MIL (Model-in-the-Loop), and HIL testing will be described in this article.

The developed control algorithm is designed to automatically lock the differential on a truck. The basic concept is based on the ZF ADM system [6] which mainly monitors the signals from the speed sensors and evaluates the slip between the individual wheels of the vehicle. According to slip values, the algorithm determines signal sent to the actuator to lock the differential. Therefore, special hardware for HIL testing is used to test the control algorithm on a vehicle. The advantage of this device is the possibility to use it for different applications and its flexibility.

The article describes the basic principle of the function of the developed control algorithm. In the first phase, it is necessary to test it using MIL testing. For this purpose, a custom library with blocks for assembling the computational model of a vehicle is used. Then the control algorithm can be connected to computational model and can be tested. This test shows most of the errors that could occur during development.

Subsequently, the use of HIL testing is described. The control algorithm will be placed in special hardware. This serves as an ECU replacement and we can test the algorithm on the vehicle in parallel with the development of the ECU prototype. Itis important to correctly evaluate the input signals of the sensors. Therefore, the following chapters describe the steps of development of a control algorithm of the differential lock and laboratory testing of the sensor signal.

2. Control Algorithm

The development of the control algorithm takes several steps. In the first phase, a concept of mechatronic system function was prepared. In this case, it is the automatic control of the differential lock of the truck. The basic concept is based on the ZF ADM system [6]. ECU evaluates the slip between the individual wheel speed sensors and determine the lock of the different differential. Other used sensors are sensors of the pedals position, steering wheel, pressure sensor, switches of the pneumatic cylinders and CAN communication. The obtained signals are evaluated by the control algorithm and limits are set. The basic scheme of the control algorithm is shown in Fig. 1. In this case, there is a partially independent differential lock. This means that there is no preferred sequence for turning on all-wheel drive, the lock of the rear axle differential and the lock of the front axle differential. The diagram shows the procedure for activating the all-wheel drive, subsequent independent locking of the inter-axle differential, and axle differentials.

During development, different concepts were tested, one of them is presented in this article. The schemes differ according to the type of the powertrain, as shown also in Fig. 1. After evaluating the position in the diagram, the control algorithm sends the signals to the actuators. These are electrovalves that control the air supply to the pneumatic cylinder. Each differential has a special dog clutch that is controlled by a bracket of the pneumatic cylinder. If the electrovalve opens, the air flows into the pneumatic cylinder and acts on the piston. This piston with the console starts to move and creates the force to connect the dog clutches in the differential. When the dog clutches are fitted, the relevant differential is locked and there is no slip between the wheels of the axle. Subsequently, the switch in the pneumatic cylinder is switched on and signals a successful differential lock. It serves to control and diagnose the proper function of sensors and actuators. If the slip conditions do not continue, the algorithm will send a signal to open the appropriate differential. If all the differentials are locked, signals are not available to determine whether to remain in this state or to start opening the differentials. Therefore, a test loop is included in the algorithm. It sets the low-level state in the algorithm after a specified time and checks conditional to re-lock or gradually open other differentials. For example, everything is repeated until the vehicle drives out of the mud.

To verify the basic functions of this mechatronic system, it was necessary to test the correct function of sensors and actuators. Therefore, the control algorithm has been simplified to lock one differential and signals from sensors were monitored in the laboratory. For this the hardware for HIL testing was used. Therefore, the control algorithm had to be compiled into a file that is supported by NI VeriStand software. The control algorithm was created using C language.

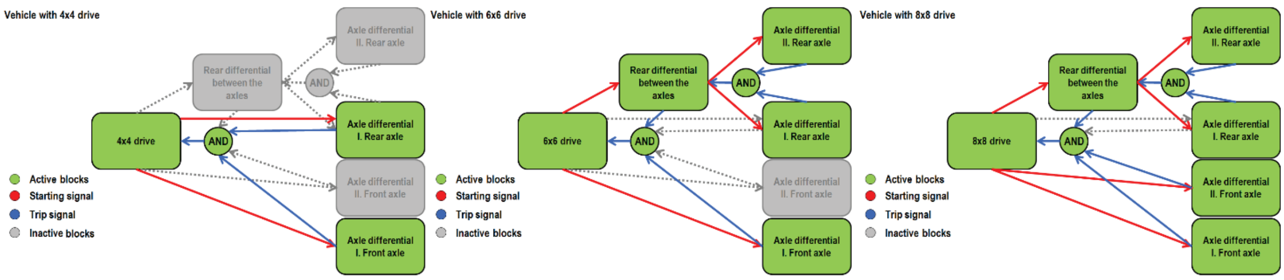

Fig. 1 Scheme of control algorithm – vehicle with 4 × 4, 6 × 6 and 8 × 8 drive

3. MIL Testing

During development of the control algorithm, it is important to verify its function. Therefore, it is appropriate to use MIL testing. This means that the control algorithm was designed and computational vehicle models were assembled for its testing. The computational model of the vehicle simulates the signals from the sensors and sends them to the control algorithm. This evaluates the situation and sends the signal to a computational model of the differential.

To assemble the computational model of the vehicle, own libraries with blocks [4, 5] have been used to describe the behaviour of individual parts of the vehicle. These blocks describe the behaviour of engines, clutches, transmission, axles, differentials, vehicle dynamics, brakes, tyre models, to name but a few. Blocks are created in Simulink software using literature [1, 2]. From these blocks, the user is able to assemble a vehicle with 4 × 4, 6 × 6 and 8 × 8 drive and simulate different manoeuvres, analyse vibrations, or just test mechatronic systems.

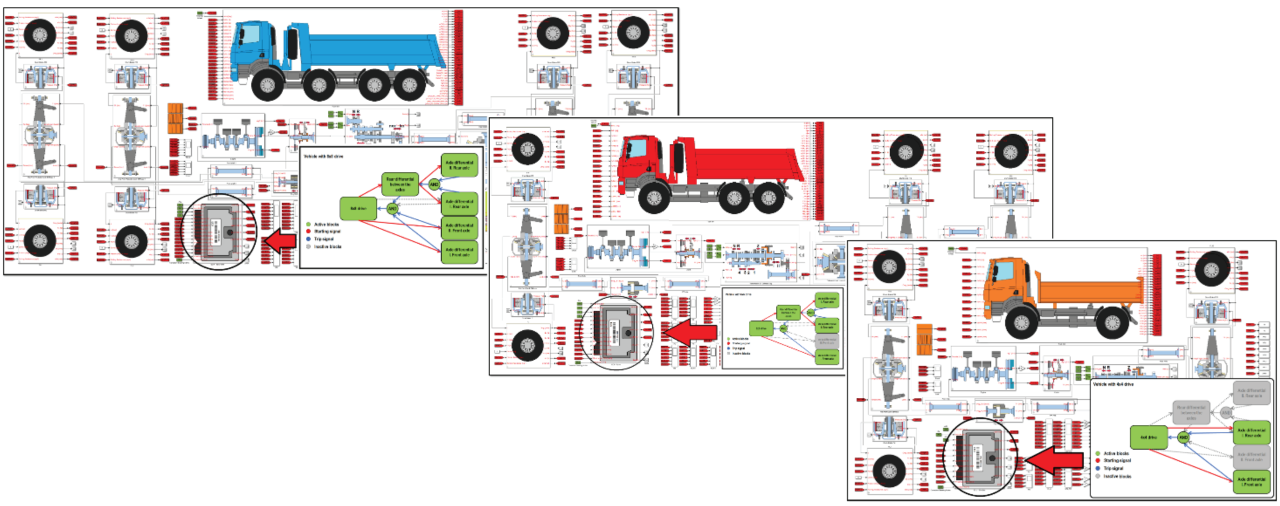

Fig. 2 Computational model of the truck with 8 × 8, 6 × 6 and 4 × 4 drive

In this case, the control algorithm is tested on three computational models of vehicles with 4 × 4, 6 × 6 and 8 × 8 drive. They are shown in Fig. 2. Computational models are assembled of engine blocks, clutches, transmission, axles, differentials, tyre model, drum brakes, vehicle model, road model and ECU with a control algorithm. During simulation, it is important to create a slip of the individual wheels and the control algorithm must solve these situations. Therefore, road block describes adhesive properties depending on the location of the individual wheels of the vehicle. The adhesion characteristics are sent to the tyre model. In the case of adhesion, properties correspond to muddy, snow, or sand, this makes possible to simulate wheel slip. During simulations, the drive within an area with unfavourable adhesive properties is controlled and reaction of the control algorithm is also monitored. Different simulations are described in [3, 4]. In these simulations, the main part of the control algorithm is not only controlled but also it partly controls the faults of individual sensors or actuators. In this phase of development and testing, most errors could be detected and this prevents the occurrence of failures or unexpected situations while testing on an actual vehicle.

4. Laboratory HIL Testing

The hardware for HIL testing is used to apply the control algorithm to the vehicle. In this case, National Instruments - NI 3110 RT hardware is used where a processor with implemented control algorithm is located. The slots for modules with input and output connectors are linked to the main part of the hardware. The NI 9159 slot and the NI 9229, NI 9477 and NI 9425 modules were used. The slot contains FPGA (Field Programmable Gate Array) that communicates with the modules and transfers data between the sensors and the processor.

Two speed sensors, a brake pedal position sensor, a throttle pedal position sensor, an electrovalve and a pneumatic cylinder with a position switch were tested in the laboratory. The test circuit is shown in the Fig. 3. Individual sensors and actuators were powered by voltage sources of 24 V.

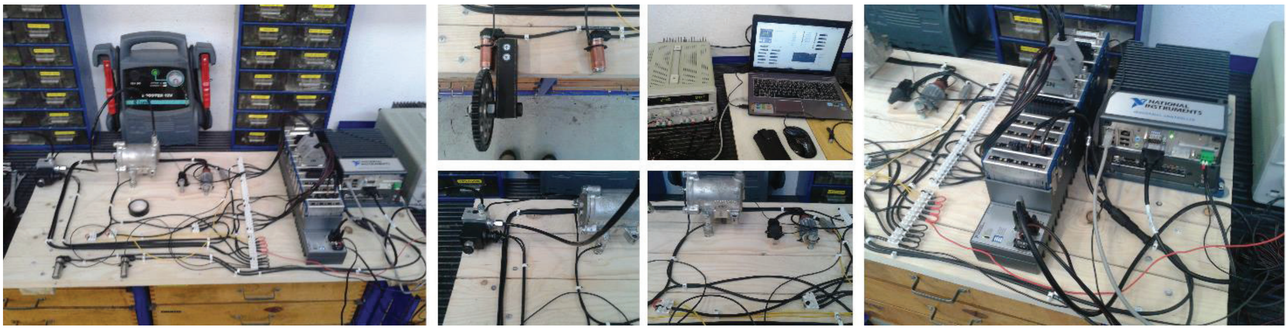

Fig. 3 Testing of the sensors and actuators

In terms of used speed sensors, they are inductive and generate sinusoidal waveform. Therefore, it was necessary to program a function for processing this signal and evaluate the wheel speed. This was programmed for the FPGA in the NI 9159 slot. The period between the segments was monitored when the signal exceeded the set voltage limit. Furthermore, control mechanisms have been programmed to avoid misinterpretation of the period. From period value, wheel speeds were calculated and were sent to the control algorithm in the processor. For simulation of the slip between wheels of one axle, two speed sensors were used. It was possible to simulate the slip by turning the gear before one of the sensors. This generated the speed of only one sensor and by evaluating these values, the algorithm determined that there was a slip. These sensors were connected to the NI 9229 module and in the FPGA, their signals were evaluated and recalculated to wheel speed. The pedal sensors and the switch in the pneumatic cylinder have been connected to the NI 9425 module. This is a digital input module.

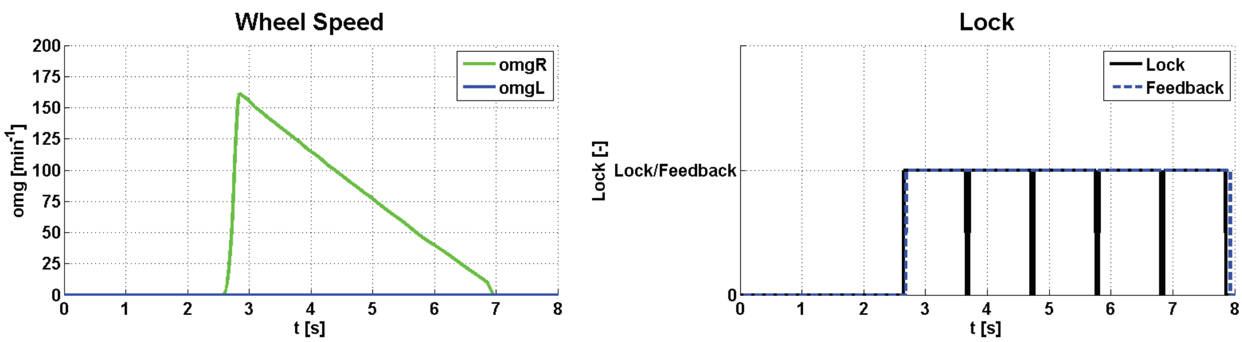

Fig. 4 Testing of the sensors and actuators

A 0-24V signal of pedal sensors was an input to the module. When a certain voltage level was exceeded in the module, signal 0 or 1 was sent to the processor. For example, value 1 means that the pedal is pressed. In the case of the throttle pedal or feedback (switch in the pneumatic cylinder), the ground is switched. Therefore, the electrical circuit is supplemented with a pull-up resistor. After evaluation of the input signals, the algorithm sends the signal to the NI 9477 module which switches ground pin of the electrovalve. Air flows from the pneumatic circuit into the pneumatic cylinder and the piston moves. It means a lock of the differential. At the same time, the switch of the pneumatic cylinder is switched on and this signifies the lock of the differential. This simplified mechatronic system tested the functionality of sensors, control algorithm and system failure under laboratory conditions. Fig. 4 shows one of the tests in the form of the graphs. The first graph shows the wheel speed of the two speed sensors on the vertical axis and the time is on the horizon axis.

As mentioned earlier, wheel speed was simulated by rotated gear before one of the sensors. The sinusoidal signal was connected to the NI 9229 module and recalculated to wheel speed in the FPGA. This value was sent to the control algorithm and this is shown in the graph. The second speed sensor generated zero speed at all times. This was simulated at the start of vehicle drive with a slip of one of the wheels. From the input data, the algorithm evaluated differential lock and a sent signal to electrovalve. This is shown in Fig. 4 on the right and it is marked as the Lock. Time loop is also included, it controls the situation when it is not possible to evaluate a slip. In this case, the cycle is repeated for 1s. The algorithm sends a signal to open the differential and checks again if a slip occurs. If the slip does not exist the differential stays opened. This is shown at the end of the graphs. These and various other tests of the sensors, actuators, the programmed FPGA and the control algorithm were verified. The development will continue with HIL testing on the vehicle. The overall control algorithm will be placed on the processor and all the sensors and actuators will be connected to the hardware.

In general, NI VeriStand software is used to implement the control algorithm on the processor. Compiled files of the control algorithm and the FPGA are placed into the software menu. Additionally, there are set inputs and outputs of the hardware, saved data and displayed online data. To control the mechatronic system settings, it is possible to program Workspace. This is a graphical interface. In this case, a control panel for displaying the feedback of differential lock (pneumatic cylinder switch) and bottoms for the setting of the automatic and manual control has been programmed.

5. Conclusions

To accelerate the development of mechatronic systems, it is necessary to use different tools. They include hardware for HIL testing. This allows parallel testing and development of individual parts of mechatronic systems, control algorithm, mechanical elements, sensors, actuators and ECU prototype.

This article deals with the use of the hardware for HIL testing and own tools for MIL testing. A control algorithm for automatic differential lock was programmed during the development. The basic principle is a monitoring of the slip between the individual wheels of the vehicle and evaluation of lock of the individual differentials. In the first phase, the algorithm was linked to the computational model of the individual vehicle and tested in the MIL loop. In this simulation, the correct behaviour of the control algorithm was checked and programming bugs were traced. The computational model of the vehicle was assembled from own blocks describing individual parts of the vehicle. By this individual models, different adhesion conditions weresimulated to generate the slip of each wheel. From the results, the correct reactions of the control algorithm were evaluated and appropriate adjustments were made.

Parallel testing of the sensor and actuators was performed using hardware for HIL testing in the laboratory. The control algorithm responded to real sensor signals and it was monitored. The actuator (electrovalve) was controlled and the functions programmed in the FPGA were checked. Modifications and combinations of commercial and custom tools and the control algorithm will be ready for vehicle testing and it will be the next phase of the development of the mechatronic system for an automatically differential lock of the truck.

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Crisis Solution of Fire Situations in Mobile Assets

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Abstract

Mobile assets are special ones dealing with a problem of confined areas that might be connected with a danger of a fire rising in task meeting. The equipment must be mobile with a high ability to pass through a terrain. The paper addresses approaches for designing mobile assets with a built-in protection against fire through a system of auto detection of an increased heat with an automatic launching of firefighting devices. Increases requirements for reliability and operational capability are laid on these assets working in non-standard operational conditions.
KEY WORDS: *Crisis situation and accident, fire situation, detectors of increased heat, water pumps, reliability of means, mobility of assets*

1. Introduction

Crisis solution of fire situations requires deployment of special equipment. Generally, it is needed that this deployed special equipment is mobile or embedded into mobile transportable means.

The Slovak Republic attains a need level in theory and practice in work with special equipment. Deployment of forces and means of crisis management, operating in crisis situation ,e.g. in fires, in engineering areas, in field health service, research, have proved in the past, and showed, that Slovakia has suppositions to contribute in the future to development, production and operation of selected kinds of special equipment. It is necessary that this equipment is used and operated not only in a military area, but also for so called humanitarian purposes as: rescue works in fires, floods and industrial accidents, normalizing situations in places and areas affected by disasters or catastrophes, protection of environment in large scale accidents and disasters etc. [9]. These new approaches in thinking at work with special equipment bring a need of common exchange of views of employees working in such branches on an international level.

One of the main requirement for such equipment is its mobility and transportability. [2].

2. Approaches to a Mobility of Working Places for Special Equipment and their Hardening

The activities relating containers have been still updated by customer´s requirements, which can be shown on a changing requirements for their dimensions, quality and equipment. [6].

With a view on a containerization grow in a global distribution of goods, its penetration was expected into military area and in crisis management and even requested by many states. Use of a transportation unit having standard dimensions is useful from many views, mainly in cooperation of alliance forces in oversea missions. Logistics of NATO container systems, with regard to transport means, is based on air or on vessel shipments and consequently on a wheel transportation. There are high demands laid on these vehicles with regard to a driving range, load capacity, speed on hardened roads, crossing capacity through a rugged terrain etc. Modern special wheel vehicles for transportation of container systems must be equipped with a hydraulic equipment for an autonomous loading and unloading and a ballistic protection by a requested level of protection [1, 3, 4].

All containers are designed by standard ISO 830 and they have defined dimensions and a loading capacity. The standard defined a container platform as well. In terms of special equipment, the ISO 1C and 1D containers are mostly used, or their variants with a different high and special containers as well – especially in NATO armies so called. „Flat rack“ that is a welded platform with ISO 1C dimensions specified by STANAG 2413 [4, 5].

Container shipment to a destination is often complicated, it requires a logistic support. It is ensured though different kinds of moves on the road, railway or through water and air transport. Trans-shipment points, called as terminals are needed for that end.

Transportation of a container to its destination, or to its maximum approach is convenient on a road. There are available all kinds of ground communications within driving ability. We use vehicles with a special superstructure, as in Fig. 1 and Fig. 2. Disadvantage of such transportation is a less amount of containers [2].

Advantages of a railway transportation consist in a possible transportation of large amount of containers by a single transportation means that is not feasible on a road transport. It results in lower transportation costs and a better price. There is a possibility to transport very heavy shipments. Disadvantages include a need for an available railway, transportation in a more complicated terrain is inconvenient, transportation to a destination takes longer time, low flexibility, possible violation of timetables and a slow handling. This mode requires a place for loading and unloading

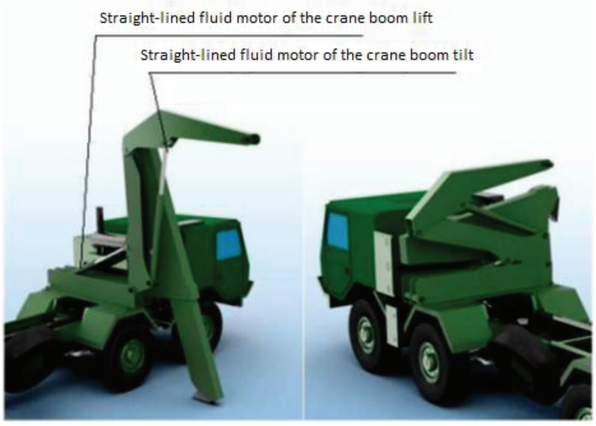

Fig. 1 An example of a chassis of a container carrier with a manipulator for loading or unloading of containers in a field [6]

Fig. 2 An example of a container carrier on TATRA 815 8 × 8 equipped with a side container loading and unloading [1]

that means that costs increase. Railway transport is connected to a road transportation, therefore there are places called as combined transportation [2]. There are two kinds of water transportation dealing with container transportation – a river and sea transport. Transportation of containers on a river is not as common as transportation on a sea. Use of transportation at sea and oceans is more effective. Sea transportation is a bearing system within intercontinental transportation of goods and its application is related mostly with container freights. Shipment between continents can be carried out with acceptable costs only by a maritime transport. Road and railway transports do not allow this possibility except for Europe and Asia, where a possible railway transportation has recently been considered. A significant advantage is a possible transportation of large shipments and a large amount of goods. A distinct disadvantage of a water transportation is a long time period for transportation, you need to count with, when planning a transport solution. [2]. Air transport of containers can be considered in such arrangement – container located in a cargo plane, in a transport aircraft, e.g – of C 130, AN 124, IL 76, A 400M type and a slung container under a helicopter. The both are used in work with special equipment, e.g. freight of spare parts and delaborated equipment to the deployment area, which is equipped with an airport, air field e.g. Kandahar or transportation of repair shop container, source sets container, water treatment plant underslung container directly to an area of deployment in terrain.

Faculty of special technology has been solving two fields of problems within its scientific and research activity – hardening of containers through a ballistic protection and transportation and loading containers for a transportation with a wheel equipment.

The Faculty (FST) solved a container arrangement and its loading on a TATRA 815-7 10 × 10 truck. The chassis of Tatra 815-7 was designed as a heavy truck applied with military as well as civil sectors [3]. A frame is based on an original Tatra 817 concept, i. e. that it is based on a central bearing tube combined with a transversal frame. Axle suspension is very similar with older models, i.e. to tilting semi-axles with an independent suspension. The chassis was enlarged with the fifth axle, whereby the fourth and the fifth axle can turn. The suspension system was updated, in this case, through pneumatic packs. So the height of a vehicle can be adjusted as needed. At the same time the chassis is equipped with a central inflating of wheels, with a possible pressure adjustment, controlled from a driver´s place. All these elements together enable crossing a demanding terrain. In this case the cab was adjusted as well, it was lowered. Transportation of the truck by C-130 Hercules aircraft is possible due to this solution [11].

For manufacturing purposes for special equipment there have been made the adjustments shown in Fig. 3 based on above mentioned experiments.

Fig. 3 Implementation of a container system on a TATRAPAN 8x8 container carrier. [7]

3. Safety Requirements on Handling of Hazardous Substances

Solution of firefighting situations requires transportation of chemical agents and their deployment. Therefore it is necessary to pay attention to these agents due to their possible fusion and resulting self-ignition. Common incompatibility of some chemical agents creates problems during handling and storage. Chemical agents might show some risky features in combination with other agents. At present the cards on safety data often do not provide complex information on specific features of chemical agents and fixtures as common incompatibility at routine handling.

Chemical agents themselves represent a danger, or they signify special risks when mixed with other ones. This feature is generally called as chemical reactiveness and it is a potential source of various threats when handling these agents. A significant amount of energy can be released during a chemical reaction. If this energy does not dissipate into ambient reaction system, the chemical reaction could run out of control. Other products, as gases or other pollutants might release in these reactions [7].

In practice there is a commonly used system for a safe handling with incompatible chemicals based on UN classification. It is an international valid system, classifying dangerous agents into nine classes and several subclasses. These ones include in broader terms main groups of chemicals agents. Physical characteristics as inflammability and explosiveness have been chosen as a base for development of this classification (Table) [8].

Table

Incompatibility of chemical agents by UN system

1	Class 1	1													
2	Class 2.1	N	2												
3	Class 2.2	N	A	3											
4	Class 2.3	N	A	A	4										
5	Class 3	N	A	A	N	5									
6	Class 4.1	N	N	A	A	A	6								
7	Class 4.2	N	N	N	N	N	N	7							
8	Class 4.3	N	N	A	A	A	A	A	8						
9	Class 5.1	N	N	A	N	N	N	A	A	9					
10	Class 5.2	N	N	N	N	N	N	A	A	N	10				
11	Class 6	N	A	A	A	A	A	A	A	A	A	11			
12	Class 7	N	N	A	A	N	N	N	N	N	N	A	12		
13	Class 8	N	A	A	A	A	A	A	N	N	N	A	N	13	
14	Class 9	N	A	A	A	A	A	A	A	A	A	A	A	A	14

A – safe combination, N – dangerous combination

The following recommendations are to be observed relating separate storage of incompatible chemical agents:

1. To store only minimum needed amounts of chemical agents.
2. Larger amounts are to be stored on a different premises.
3. Chemical agents to be stored at appropriate temperature and air humidity. Do not store chemical agents at heat sources and on a solar light.
4. Date of receipt and opening should be marked on a wrapper.
5. Chemical agents must not be stored on hardly accessible places and on a floor.
6. Inflammables must not be stored in refrigerators, being used in households. Refrigerators made of non-flammable materials resistant to explosion are to be used for such storage. Nowadays in dwelling environs there are many chemical agents and fixtures, which could present a danger to health if handled non-appropriately. Handling with chemical agents imposes increased claims for safety of workers as well as safety of property. Observance to instructions defined for particular systems creates premises for a safe handling with incompatible chemical agents.

Knowledge about physical-and-chemical firefighting technical features of dangerous materials contributes to reduction of threat to employees as well as inhabitants.

4. Computer Forest Fire Simulation as a Tool for Fire Progress Prediction and Back Analysis of Fire Origin

Advances in computers and information technologies in the last decades stimulate the development of various useful program systems for firefighting. The existing fire behaviour predicting systems are capable to simulate the forest fire front growth after the fire detection. They describe not only the spatial and temporal behaviour of forest fires (fire spread rate and direction), but can quantify and display various fire characteristics (e.g. fire intensity, flame length, etc.), which can be useful for the purposes of fire effects analysis. They can be used for simulation of various fire scenarios in a certain region under different conditions to test the fire management response for the fire event (prevention).

The fire behaviour models are also used for the reconstruction of previous forest fire events (post-suppression). Such simulations are particularly useful to understand the circumstances that led to human incidents due to firefighting [9]. Fire behaviour predicting systems can also be useful for operational training. Current generally little use of the forest fire decision support systems in operational fire management in the European Union is a great challenge for scientific and development activities within current fire research [10].

5. Example of an Intervention in a Fire Fighting Situation from Air

Image of special technology generally evoked the context of military engineering, or weapon technology. From historical aspect is this conventional title connection of image and object comprehensible. Evidently, that actual technical and technological level of Mankind is in a great measure like implication of research and development results at ambit oriented to the defence and warfare too. Conflict seasons in our history are coming in ordinary cycles. In this periods was (almost ever) detect substantial progress at ambit of techniques and technology that is related with tactical and technical domination and with results of military conflict. Post-war quiet times in history are marked like time, when results of primary military research was applied in common life and they are coupled with economic, and social development of society. For example: existence and development of computing technology has been directly connected with "secret" technological war, which determined WWII results. Military aviation, cryptography and development of nuclear bomb they were main marks of this. Fact, that (today already) we could flying by transoceanic airlines, that we have (today already) at our tables personal computers and our houses (today already) make use of energy produced by nuclear electric power plants is paradoxical implication of our past wars.

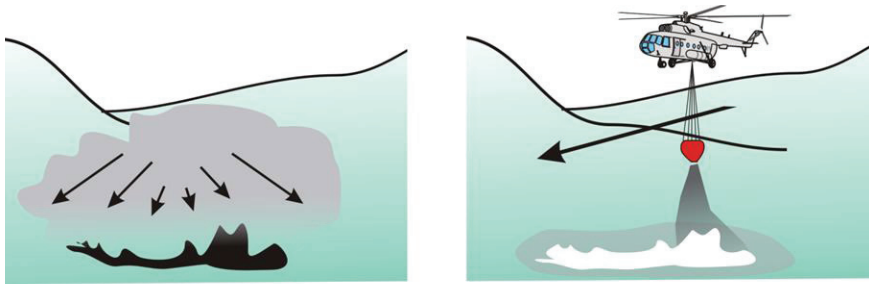

Fig. 4 Preparatory phase of extinguishing – application of extinguishing powder

Development of special technology depends on requirements of armies and warfare, but in final implication is technological breakthrough applied in all of sectors of industry, economics and social connections. Proof, that special engineering may not be all the time fixed at the killing and destructive uses, is complex of today "ordinary" technologies and currently also project, that is prepared as in Fig. 4 by technical universities at Zvolen (Technical University in Zvolen), in Trenčín, shown in Fig. 5 (Trencin University of Alexander Dubček in Trenčín) and in Bratislava (Slovak Technical University Bratislava) in cooperation with organs of environmental department (Ministry of Environment of Slovak republic and State Nature Protection of Slovak republic in Banská Bystrica). [9]

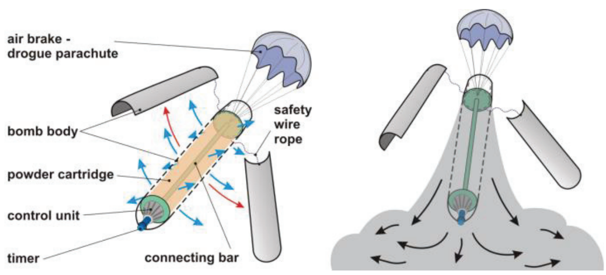

Fig. 5 Principal scheme of container – powder “bomb” and application technique of powder extinguishing medium

Project POWDER BOMB is actually in position of main research and development lines definition. These corresponding with professional orientation of coupled scientific workplaces. The lines are:

1. Ecological extinguishing powder medium
2. Tactics of extinguishing
3. Ecological aspects of extinguishing
4. POWDER BOMB technologies

Actually we could not exclude, that with project POWDER BOMB will not be realized some discrete parallel projects pointed on related problems.

6. Conclusion

Need for science, research and education in area of special equipment is obvious. We can prevent from effort to rename special equipment through its complex definition corresponding with current needs of science, research and practice. Consequently through a development and publishing a relevant publication of a monograph type, this would fully characterize a special equipment issue. Cooperation of Trencin University called by Alexander Dubcek in Trencin with schools and institutions in Slovakia and abroad is a presumption for a development of special equipment in a complex term. An issue relating materials and technologies for special equipment has historical roots in abroad as well as in Slovakia and in the past also a successful history of cooperation. [7, 8, 10]. It is a base to start solving other, new projects being solved on an international level.

Preconditions of work in areas related to special equipment are rather wide and it is obvious, that authors as well as the Faculty they have been working for, will find a place of their materialization

At present time the Trencin University of Alexander Dubcek, Faculty of Special Technology pays great attention with a great feedback to reconnaissance mean, which are remotely able to solve a catastrophic crisis situation and to make a real decision for intervention. There are great efforts in research and development of appropriate transportable means in this stage.

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Accidents on Railway Crossings of Slovak Republic

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Abstract

Safety and speed of road and rail transport are very closely linked. In terms of safety on railway tracks are critical points crossing of the railway line and road (railway crossing). This is virtually the only place in direct physical contact between the otherwise relatively insulated transportation modes. This shows the statistics of accidents on railway crossings and analysis of its causes. The main negative impact of accidents on railway crossings plays the human factor. Many road users does not respect the rules while getting along. An article contains prepared statistics on the railway crossings, traffic accidents and their consequences. Briefly are outlined the possible measures to improve the existing conditions.
KEY WORDS: *road transport, road traffic, traffic accidents, over-level intersection, secured crossing, rail transport, railway crossing*

1. Introduction

The increasing share of road transport in the transport market and the increasing demands on the safety and speed of individual traffic flow requires a comprehensive solution that, in addition to the factors mentioned, will also take into account the requirements for improving the quality of the transport system, fluency, ecology and economy. One of the most risky places in road and rail transport are rail crossings. A comprehensive solution for securing safety on the railway crossings of the situation in the adoption and realization of interconnected measures of investment, organizational, regime, educational and legal character, which will compensate selected crossings by over-level intersection of road and railway communications, equipping the most frequent unsecured crossings with security equipment, locking of crossings used only seasonally, as well as the cancellation of the least frequented crossings, which are not necessary to ensure the traffic service of the site. Considering the wide range of arrangements, the article's authors have focused only on some factors that increase human safety on railroad crossings.

2. Railway Crossings on the Railway Network of the Slovak Republic

One of the risky places are railway crossings regardless of whether they are secured or unsecured. This is evidenced by the fact that, according to long-term statistics, fatal accidents occur in Europe on 1 % of fatal accidents in road transport, but more than 25 % of fatal accidents in railway transport; 555 accidents in Europe in 2012 (322 killed, 364 with severe injuries [1].

From the point of view of security, railway crossings can be divided into:
- secured (active) which are equipped with crossing security device,
- unsecured (passive), which are marked with the appropriate tags only.

The main task of the crossing security device is to increase the traffic safety in the place of the level intersection of the two traffic routes, what are two different modes of transport - road and rail.

Crossing security device is a device on a railway crossing which informs the user about the state of the railway traffic on the crossing, in particular, warns the road users solidly, clearly and in time that the train is approaching the railway crossing.

At present, in order to improve the road safety but also railways safety is the effort to reduce, modernize and replace the number of railway crossings and to replace them by over-level intersection of the road with the railroad. For comparison in 2000, were on the territory of the Slovak Republic (hereinafter referred to as the "SR") 2 486 railway crossings, in 2016 they were reduced to 2 105.

Železnice Slovenskej republiky (ŽSR) have registered to 31st of December 2016 total number of 2 105 railway crossings in SR, of which [2]:

- 1 067 secured (active) crossings which are equipped with crossing security equipment in the structure:
  - 48 crossings secured by mechanical barriers (without light signalling);
  - 2 crossings secured by mechanical barriers (with light signalling);
  - 511 crossings with light security devices with barriers;
  - 457 crossings with light security devices without barrier;
  - 41 permanently locked crossings;
  - 8 mechanical crossings devices;
- 1 038 crossings unsecured (passive), which are marked with traffic signs only (A25, A26, A27a-b, A28a-b, A29a-b, A30a, A30b, P2).

As can be seen from the overview of railway crossings, most of them are controlled automatically. The operation of the alarm device (alert and light signalling and subsequent launching of the gate) will be launched automatically after the train enters the track circuit (usually at a distance of several hundred meters before the crossing). The warning sound (80 decibels) and the light (red flashing light) are set so that even the smallest and largest vehicle can pass safely through the crossing (for example a 22 meter-long truck and a speed of 5 $km.h^{-1}$). Only after that time the barriers will fall. The operation of the alarm device terminates automatically when the last carriage leaves the track circuit.

Railway crossings are also a source of serious traffic accidents, which have fatal consequences. Only in the last 5 years 62 people died on the railway crossings. An overview of the number of traffic accidents and their consequences on railway crossings is given in Table 1.

Table 1

Statistics of traffic accidents and their consequences on railway crossings

Year	No. of crossings	No. of accidents	No. of dead	No. of severe injured
2000	2486	46	9	5
2001	2486	67	13	6
2002	2481	75	14	8
2003	2479	41	6	15
2004	2479	59	10	5
2005	2479	71	7	16
2006	2322	60	12	9
2007	2307	69	6	14
2008	2307	69	17	17
2009	2265	51	26	14
2010	2220	50	11	7
2011	2205	50	12	14
2012	2160	50	21	15
2013	2155	46	10	12
2014	2131	49	11	20
2015	2115	55	14	12
2016	2105	38	6	10
Total		946	205	199

Source: Annual reports of ŽSR, 2000-2015 [3, 4]

The state and evolution of accidents on railway crossings are influenced by a number of factors. Objective factors are, in particular, the traffic-transport parameters of rail transport (numbers and types of trains, the spatial and time management of their routes on the railway network, etc.), as well as the intensity of road transport on the roads crossing over railways.

Objective factors include:

- number of railway crossings;
- types of railway crossings (secured and unsecured);
- the total length of railway lines.

The basic safety features on railway crossings are, in addition to the overall number of accidents, their consequences, particularly on the lives and health of the accident victims. The trend of development of the number of the dead and severely injured on the railway crossings of the SR over the last 16 years is illustrated in Fig. 1.

In both files considered, the most probable is polynomial regression curve even if the reliability value is low.

Trends development of the total number of railway crossings and the number of accidents on the railway crossings of SR between the year 2000 and 2016 are shown in Fig. 2.

Both of the considered parameters have a downward trend, with a decrease in the number of crossings being possible with a high accuracy with a linear regression line. The trend of accident rate falls according to the regression curve expressed by the polynomial equation with a relatively low confidence value.

The correlation coefficients given in Table no. 1 were found between the individual sets of values given in Table 2.

The results shown in Table 2 show a very low to negligible dependence between the observed values.

The total number of crossings has a certain amount of alertness, but the more detailed trends in this area are illustrated by separate tracking of secure and unsecured railroad crossings. The graphic representation of these trends is shown in Fig. 3.

The graph in Figure no. 3 indicates that, in addition to the decreasing total number of crossings, the ratio of secure and unsecured crossings is also changing. From 2011-2012, when the equilibrium occurred, the number of secured crossings in relation to unsecured is still increasing slightly.

Although railway crossings are properly marked, road users (drivers, cyclists, pedestrians) do not respect rules very often. Investigation of the competent authorities has revealed that the most frequent cause is:

- non-compliance with road traffic rules by drivers of motor vehicles, bicyclists and pedestrians;

– deliberate damage to the crossing security devices (broken warning light, broken lashings, damaged, damaged racks, but also theft of components of the security equipment, etc.).

In the modern history of SR, the most serious misfortune occurred the 21st of February 2009, when a personal train on Červená Skala – Banská Bystrica line crossed to the left middle part of the bus on the Polomka railway junction, turning it to the right side and derailing the motor wagon. The bus was thus pushed 26 meters until the train stopped. The accident killed 12 people, six people suffered severe injuries, 19 light [5].

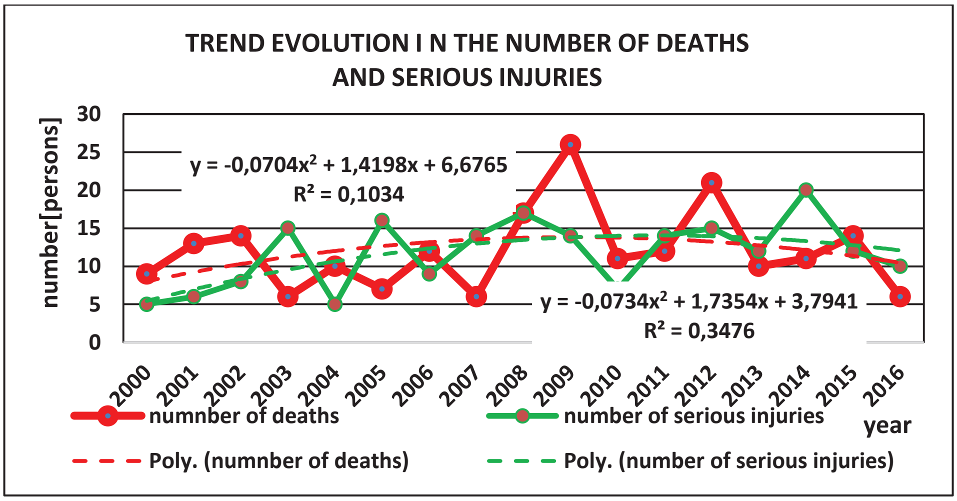


Fig. 1 Trends development of the number of traffic accident victims on railway crossings in SR

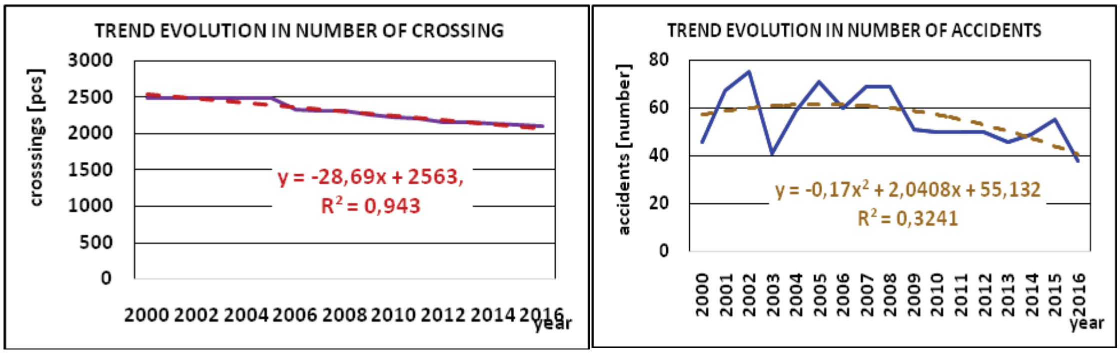


Fig. 2 Trends development of the number of traffic accidents on the railway crossings in SR

Table 2

Correlation coefficients of selected files

Evaluated files		Correlation coefficient
number of crossroads	number of accidents	0,481500
	number of dead	-0,214872
	number with severe injuries	-0,408889
number of accidents	number of dad	0,093902
	number with severe injuries	-0,038365
number of dead	number with severe injuries	0,156279

Source: own processing

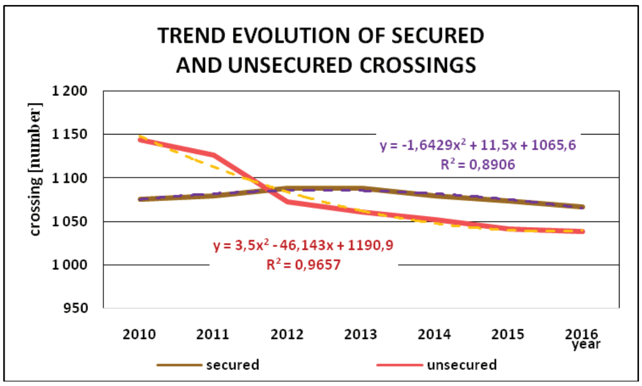


Fig. 3 Comparison of development directions of secure and unsecured railway crossings

3. Actions to Reduce Accidents on Railway Crossings

Although railway crossings are properly labelled, drivers, cyclists and pedestrians do not respect, who do not realize that, in accordance with the law of the National Council no. 513/2009 Coll. about tracks that, in the case of a level crossing of the road with a road, runway traffic is preferred over road traffic [6]. This also entails the obligations of a road user stipulated by the road act.

Every accident on a railway crossing is investigated by the competent Police Corps authorities in close cooperation with the ŽSR authorities. It can be said that, on the basis of the specific causes and reasons for the accident, specific actions are taken immediately and gradually.

The most important action, as has already been stated, is to reduce the number of unsecured rail crossings and to replace them with crossing security devices (for example replacement of warning crossings for lighting and light signalling represents funds on average 250 000, - up to 300 000, - €.) [7] Or an over-level intersection.

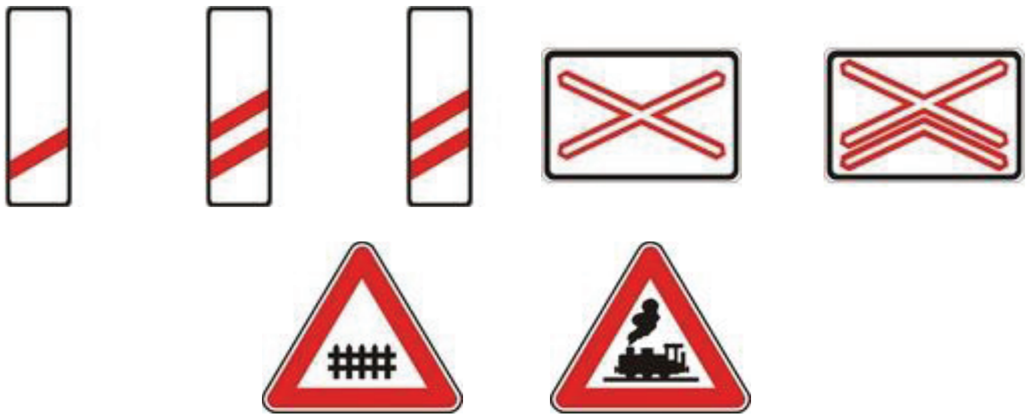
An important role for safe overtaking of the railway crossing by road users is also the marking of the railway crossing by the following [7]:

– traffic signs A 27 to 29 Signboards, which are gradually placed at a distance of 240, 160 and 80 meters from the road crossing the road (Fig. 4);

– traffic signs A 25 Railway crossings with barriers, A 26 Railway crossing without barrier, A 30a Warning cross for single-barrier crossing or A 30b Warning cross for railway crossing are located in front of railroad crossing (Fig. 4);

– by means of crossroads safety devices with red intermittently illuminated lights indicating „Stop" or white intermittently illuminated lights indicating „Free", that warn the driver is obliged to drive at a distance of 50 m in front of the railway crossing and during its passage by the speed (in this case it must not unnecessarily prolong the crossing time):

- not more than 30 $km.h^{-1}$, if the white light is not working on the crossing safety device;
- not more than 50 $km.h^{-1}$, if the white light is interrupted.



Source: [4]

Fig. 4 Traffic signs highlighting the crossroad [7]

The conclusions of the accident investigation on the crossings show that the most important factor in accidents on the railroad is the man and his failure. For this reason, it is necessary that the road user in front of the railway crossing should be extremely cautious and convinced that he can pass safely through it even if the red intermittently illuminated lights do not turn on. In Act no. 8/2009 Coll. about road traffic it is stipulated that the driver and the pedestrian must not enter the railway crossing if:

- a warning is given by two red intermittently interrupted lights of a crossing security device;
- a warning is given by the intermittent sound of the horn or bell of the crossing safety device;
- are triggering, or if they are triggered or if the barriers are lifted;
- already seeing or hearing an incoming train or other track-based vehicle or, in particular, hearing or hitting or whistling;
- the person assigned to ensure the safe operation of the railway crossing gives a sign to stop the vehicle by twisting with a red or yellow flag, and under reduced visibility by red-tangling in the upper half;
- the situation on or behind the railway crossing does not allow him to pass safely and continue to ride or walk.

Another significant action to increase road and rail safety, as well as to provide rapid and effective assistance to railway accident victims by the ŽSR and in cooperation with the Ministry of the Interior of the Slovak Republic and the Integrated Rescue System (IRS) in the SR, was on national and regional railways ownership of the state by the unique identification number (JIN). The JIN sticker (for example SP2727) measuring 43 mm × 160 mm, black lettering 33 mm (total length 150 mm) on a white background is preferably glued to the side of the warning cross (Traffic signs A 30a, A 30b) from rail track side or on the side of the alert box from the side of the track (Fig. 5).

Source: authors

Fig. 5 Railway crossing SP0171 in line 2601 Žilina - Teplička

The essence of this system is the allocation of JIN to each railway crossing (secured and unsecured), which is in the administration of the ŽSR. The data base is assigned to each crossing: the dispatcher's and train dispatcher's telephone number and the dispatcher's (or sinker's) name, the track and section name, the rail crossing position in kilometers, the electrification data, the class and the landmark number, the road position and the crossing track, local pass name, longitude and latitude, altitude, note. These data are provided in case of need of IRS and police [8].

4. Conclusion

The safety of the traffic on the railway crossings and in their immediate environment by road users is one of the prerequisites for reducing accidents on them. These trends in the number of road accidents and their consequences are only indicative. In particular, for the purpose of establishing precautionary actions, it is necessary to follow these trends in relation to the place of the occurrence of accidents, their causes and their specific responsibilities. In addition to the ŽSR, in order to increase the safety of overtaking of railway junctions, road managers must also participate in the road traffic that these passes overcome, and last but not least, road users. It is these road users who, in compliance with the legislation, can make a significant contribution to the reduction of accidents on secured or unsecured railroads.

Acknowledgments

This work was supported by Project VEGA No.1/0240/15 Process model of safety and protection of critical infrastructure in the transport sector.

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Analysis of Tendencies of Freight Wagon Axle-Box Temperature Mode Formation

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Abstract

The determinant factors of freight wagon axle-box temperature modes during rolling-stock exploitation are analysed. These factors are axle-box mileage, axle-box operating time, defects of the rolling surface of wheel and ambient temperature. The temperature of freight wagon axle box considering registered data the consist patterns and reasons of axle-box temperature alteration are defined during the monitoring. The dependences of freight wagon axle-box failures, fixed by rolling-stock automatic control equipment, on axle-box running mileage and lifetime are analysed. Finally, basic conclusions are given.
KEY WORDS: *axle-box mileage, axle-box heating, axle-box failures, temperature mode, automated trackside equipment*

1. Introduction

The continuity and safety of modern railway traffic is ensured by means of automatic monitoring (remote) devices for the technical condition of travelling trains. Rail vehicle axle-box is one of the most important parts for ensuring the safety of railway traffic [1]. Trackside Automated Control Equipment (TACE) is used for monitoring of technical condition of axle-boxes of travelling trains, which are arranged in Lithuania at the distance of (30-40) km. Using TACE devices, axle-box faults that threaten traffic safety, and their causes at early stages can also be timely detected. When analysing the monitoring data of TACE devices on the axle-box temperatures, the possibility of developing a methodology for prediction of residual resources of axle-boxes are also analysed. One of the signs of the faults of the axle-box is increased temperature of axle-box housing. TACE stations are equipped with infrared thermometers to measure the temperatures of axle-box housings and pins. The information about the temperatures measured vehicle axle-boxes and axle pins at TACE stations is collected, recorded in databases and submitted to the railway company departments that carry out maintenance of stock. If TACE devices has detected increased heating of axle-box, the train is stopped at the nearest station or plain line. After the train driver or wagon inspectors check the technical condition of the axle-box, the decision on the further operation of the rolling stock is made. The examination of this axle-box reveals that it does not usually have any external signs, testifying about its faults, so wagon inspector is not able to predict for sure relating to further operation of the axle-box. After TACE devices have determined the heating of axle-box and suspended the train, in all cases the carrier incurs losses. One way to avoid this is to determine or predict failures of the axle-box before the temperature has reached the limiting values during the trip.

The European standard EN 15437 deals with interface and design requirements for Axle box condition monitoring. The standard is divided in two, Part 1 describing bearing temperature measurement by trackside Hot Axle Box Detectors (EN 15437-1 ….) [2]. Part 2 describes the monitoring of hot axle box bearing temperature by on-board systems (EN 15437-2 ….) [3]. Molodova et al (2014) described preliminary results towards an automated monitoring system for the quality assessment of insulated rail joints based on axle box acceleration measurements [7]. Attachments for monitoring of hot axle box bearing temperature by on-board monitoring system is presented in Fig. 1.

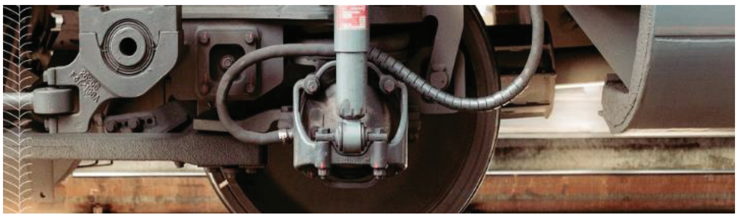

Fig. 1 Monitoring of hot axle box bearing temperature by on-board monitoring system

The noncontact detection system based on uncooled InfraRed Focal Plane Arrays (IRFPA) detector is proposed by Zhang et al (2011) [9]. Combining an embedded signal processing system and the infrared images of axle boxes, the temperature of axle boxes can be analysed and calculated; image local storage and measurement results transfer can be achieved as well.

The Hot Axle Box Detection (HABD) systems are placed on the tracks. They measure the temperature of the axle box bearing boxes and often also wheels and brake discs when the train passes over them. The system uses infrared beams to measure temperature then send the measured values wirelessly to the depot, fleet management team or even the train (Fig. 2).

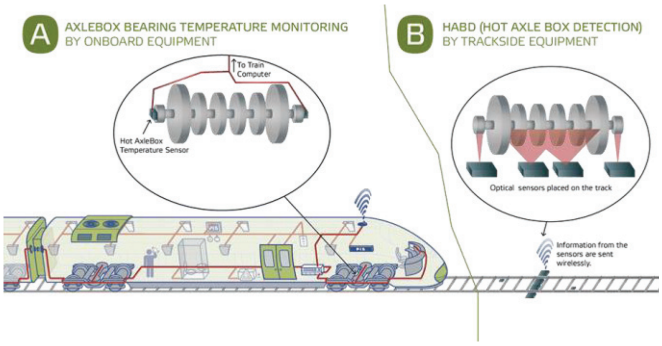

Fig. 2 Axle-box bearing temperature monitoring

If the on-board method was developed to improve the bearing temperature monitoring, the 2 methods (A) and (B) can well be used together for optimal and redundant control.

In the article Lunys et al (2012) [6] examines the variations of temperatures of rolling stock axle-boxes during the entire travelling route of the train from the start to the end station. The authors conducted their study examining the data collected by TACE software on temperatures of rolling stock axle-boxes. It has been found that the operating temperature of axle-boxes is reached after travelling about 50 km. When analysing the variation rate of axle-box temperature, the hypothesis that the each temperature failure of the axle-box has a characteristic rate of temperature variation was made. The results of variation rate of technically unsound axle-boxes are presented in Table 1.

Table 1

Variation rates of temperatures of axle-boxes found during the study

Sign	Temperature variation rate, °C/min.
Locomotive axle-box	0.060
Axle-box of loaded freight wagon	0.030
Axle-box of empty freight wagon	0.016
Passenger carriage	0.014
Axle-box with faulty external bearing ring	0.660
Insufficient amount of lubricant in axle-box	1.020
Water in lubricant	0.920
Rear ring crack	0.820

After conducting the research, O. Lunys *et al* (2015) found that the cooling conditions depend on the sequence of wheelset in the carriage [4]. Due to the influence of blowing air on the first wheelset of the rolling stock (along the travelling direction of the train), the axle-box temperature is by 3.1°C lower than the temperature of the second wheelset axle-box. The temperature in first pin of wheelset axle is higher than the axle-box housing, and in second wheelset, the temperature of axle-box housing is higher than the axle pin [5].

2. Methodology for Monitoring of Temperature Mode of Axle-Boxes

For the monitoring of temperatures of the axle-boxes of freight wagons, a freight train travelling from station "Kalij 3" (Belarus) to the "Draugystė" railway station (Lithuania) was chosen. The relevant train consists of 64 equally loaded wagons of the same structure designed for the transport of mineral fertilizers, belonging to the Belarusian potassium company "Belaruskalij" (see. Fig. 3). These wagons travel within a closed route, i.e. "Kalij 3" – "Draugystė" – "Kalij 3". The trains loaded with 70 kg of freight travel to the station "Draugystė", and return empty. Tracking of these wagons is favourable, for their mileage is recorded. In addition, these wagons overcome a long distance within in a relatively short period - an annual mileage is about 90 thousand km.

TACE system is used for the monitoring of temperature mode of train wagons (see. Fig. 3). Axle-box temperatures were monitored from the entry of wagons to the Republic of Lithuania to Radviliškis railway station. Temperatures of 536 axle-boxes were monitored. There are seven TACE stations from the State border to Radviliškis railway station are equipped with control system of axle-box temperatures. In order to assess the dependence of axle-box temperature mode on the mileage and the running time, it is necessary to identify the mileage of each axle-box and service life since the last medium repairs. These data are determined in accordance with the data of operational freight information system OPKIS used by JSC "Lithuanian Railways".

The determination of the mileage of all train wagons showed that the lowest mileage of the wheelset was 539 km, and the maximum - 339 283 km. Minimum wheelset service life is one week, maximum - 4 years and 10 months.

Fig. 3 Investigated freight wagons of OAO "Belaruskalij"

3. Research Results

After collecting and processing the data on temperatures of train axle-boxes determined at the TACE station State border - Stasylos, the data obtained are presented in Figs. 4-7.

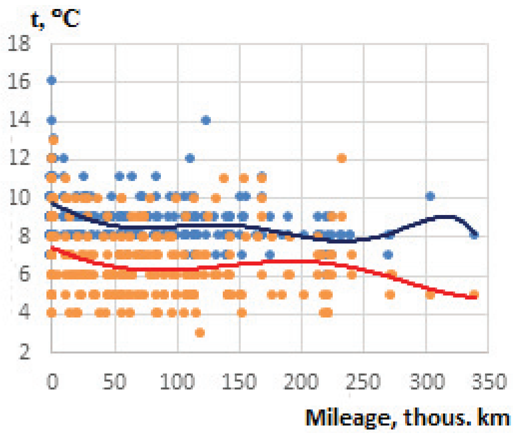

Fig. 4 Distribution of axle-box housing temperatures by mileage

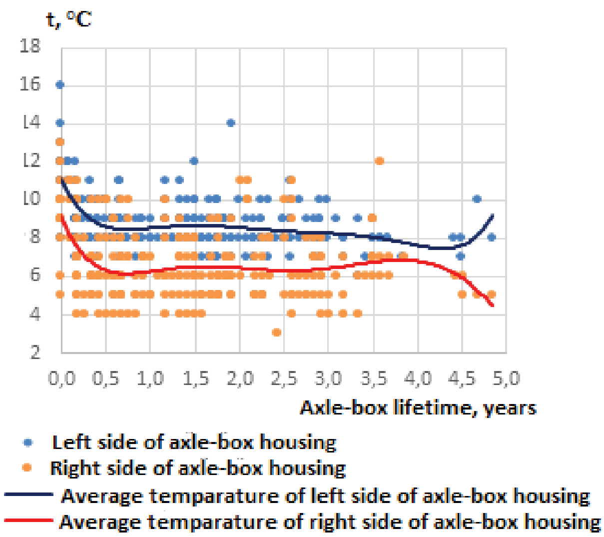

Fig. 5 Distribution of axle-box housing temperatures by the date of wheel-set medium repairs

The chart on the distribution of axle-box housing temperatures according to the mileage in Fig. 4 shows that at the beginning of the axle-box operation, a significant part of the axle-boxes heat up more, and the temperatures decrease during their further operation. The curves of temperature distribution in Figs. 4 and 5 show that the axle-box on the right side heated up more. This could be determined by the curves dominant on the right side, where vertical load of axle-boxes was bigger due to centripetal force. Watching axle-boxes with mileage exceeding 300 thousand km, it was found that the temperatures of latter strongly correlate with a vertical load, i.e. the temperatures of axle-boxes in internal part of curves increase more compared to other axle-boxes, and the axle-boxes on external side heat up less compared to others.

The charts of distribution of axle-box temperatures according to the service life of wheelset in Fig. 5 show similar consistent patterns like the distribution of axle-box temperatures according to the mileage in charts (Fig. 4), i.e. higher temperatures are seen during the start of operation. In the first half of the axle-box operation, their operating temperatures decrease and remains constant for 3.5 years. It was observed that the temperature of axle-boxes in operation for more than 4 years strongly correlates with the vertical load on the axle-box.

In order to assess the dependence of variation rate of axle-box temperatures on the mileage, the variation rate of axle-box temperatures of the train travelling between stations TACE State border–Stasylos and Jašiūnai–Valčiūnai was calculated. The data obtained are presented in Fig. 6.

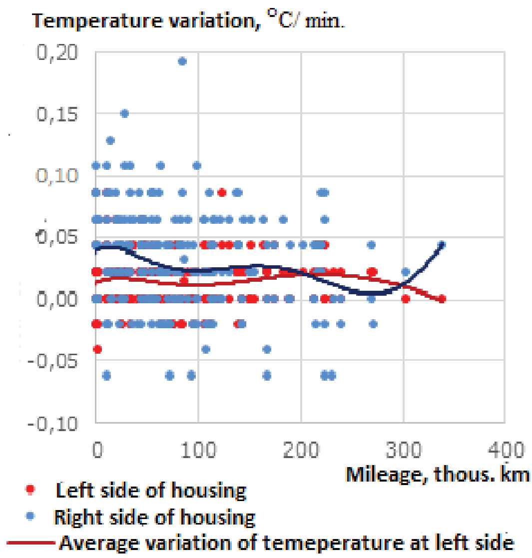

Fig. 6 Distribution of the variation rate of axle-box temperatures by axle-box mileage

Assessment of variation rate of axle-box temperatures travelling between TACE station State border - Stasylos and Jašiūnai - Valčiūnai, no clear dependence on the wheelset mileage was found. The chart of distribution of variation rate of axle-box temperatures according to the mileage in Fig. 6 shows that the variation speed of the temperature is higher - the temperature rise is determined in axle-boxes with low mileage.

The dependence of the axle-box temperature mode on the ambient temperature was investigated at TACE station State border - Stasylos. The values of differential temperatures of 80 axle-boxes with worn bearing surfaces in varying ambient temperatures from minus 22 to plus 20°C were compared. Results of research are presented in Fig. 7.

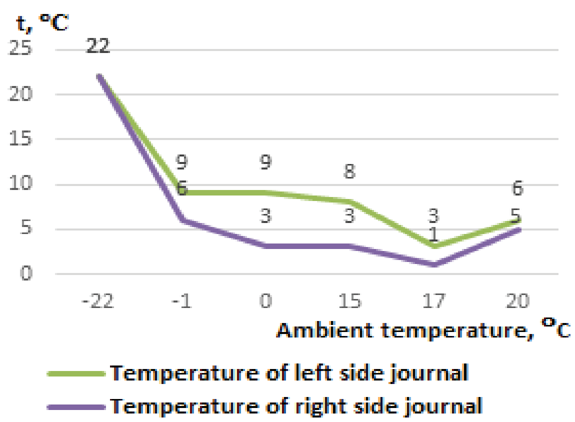

Fig. 7 The dependence of differential axle-box temperature on the ambient temperature

The research found that the differential axle-box temperature strongly depends on the ambient temperature. Fig. 7 shows that the rise in the ambient temperature to +17°C leads to the decrease of differential axle-box temperature. Later the opposite phenomenon is observed: the rise in ambient temperature leads to the rise of differential axle-box temperature as well.

4. Conclusions

No consistent pattern of the influence of wheel rolling surface defects (wheel flats, out-of-round, pitting, cracks, attrition, etc.) on the axle-box temperature mode was found.

After axle-boxes have travelled 50 thousand km or 6 months after the start of operation, raised axle-box grind-in operating temperature tends to decrease gradually by 5°C.

When the mileage of axle-boxes exceeds more than 300 thousand km and they are operated for more than 48 months, their operating temperatures strongly correlate with the axle load.

The increase of ambient temperature to +17°C leads to the decrease of differential axle-box temperature. Further increase in the ambient temperature above + 17°C, opposite phenomenon is observed, i.e. differential axle-box temperature also starts to increase. The increase in differential temperature at temperatures higher than +17 °C is determined by the properties of lubricants.

The analysis of the distribution of axle-box failures by operating time found that 10 axle-boxes broke down after less than a year after the beginning of operation. The least amount of faults occurred within 3-4 years of operating period.

The increase in differential temperature in winter (at sub-zero ambient temperature) is determined by higher tightness resulting from contraction of external bearing rings and density of lubricants.

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Organization of Technical Equipment Operation in the Planned and Preventive System

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Abstract

The aim of the article is to analyze and measure planned-preventative system of military equipment's exploiting and to develop the conception of perfecting the organization of an exploitation system. To that end, the models of technical equipment's exploitation, built based on a theory of independence, were used.
KEY WORDS: *planned-preventative system, military equipment's, exploitation system*

1. Introduction

The effective functioning of economic and non-profit organizations (budget and non-budgetary) is dependent on the possession of operating skills, which are the functions of technical potential. Maintenance and restoration of technical potential depends on the amount of equipment, technical condition and the operation strategies.

In the armed forces, the operating systems of essential technical equipment are built on the strategy based on the amount of work done. In addition to the armed forces there are economic organizations in which these technical facilities are operated by the same strategy.

The basic principles of the strategy based on the amount of work done: fixed range of specific type of maintenance, period of implementation of fixed services and repairs and hierarchy of technical services and repairs. The essence of this strategy is to prevent the operating and maintenance equipment before reaching the limit of wear. Strategy based on the amount of work done is ineffective. Planning and implementation of technical services and repairs in the area of standard quality may result in a reduction in the level of consumption of consumer equipment.

Based on the strategy by the number of work performed in the functioning of the armed forces, there is a planned, preventive maintenance system. A variant of the mentioned system is the planned and preventive system with diagnostics.

If assuming that such an organization of the operation system is appropriate in the conditions of the armed forces, then in time of peace one should strive to prolong the duration of the target service life. In the author's opinion there is a possibility of modifying the functioning system of planned and preventive exploitation. This could be achieved through a specific way of organizing the operation of the technical equipment.

The aim of the study is to analyze and evaluate the planned and preventive system of operating military equipment and to develop the concept of improving the organization of the operation system. For this purpose, models used in the operation of technical equipment based on the theory of reliability.

2. Organization of Technical Equipment Operation Modelling System

The theory of reliability, based mainly on the theory of probability and the theory of stochastic processes is a formal discipline with an extended mathematical apparatus [1].

The reliability function is described by the probability of reliable operation in the interval (0, t) under certain operating conditions:

$$R(t) = P(\tau > t) = 1 - P(\tau < t) = 1 - F(t). \tag{1}$$

The use of the probabilistic model involves the choice of a suitable probability distribution that will largely reflect the processes taking place in the real operating system. This distribution is determined by the function *f (t)* being the distribution function and the function *f (t) = F '(t)* being its density. For exponential distribution function reliability:

$$R(t) = \exp[-\int_{t_0}^{t'} \lambda(t)dt] \tag{2}$$

The function *R*(*t*) is a conditional probability of a defect of a technical object belonging to a given set *t* provided that it has worked without failure until then. In the case of exploitation, it is important to assume that there is no variation in the defect function $\lambda(t)$. It is usually determined by examining the number of defective technical objects within a specified period of time. The function $\lambda(t)$ may have different mileage depending on the nature of the dominant defect. Most often, it is similar to a bathtub and is referred to as the bath curve [4].

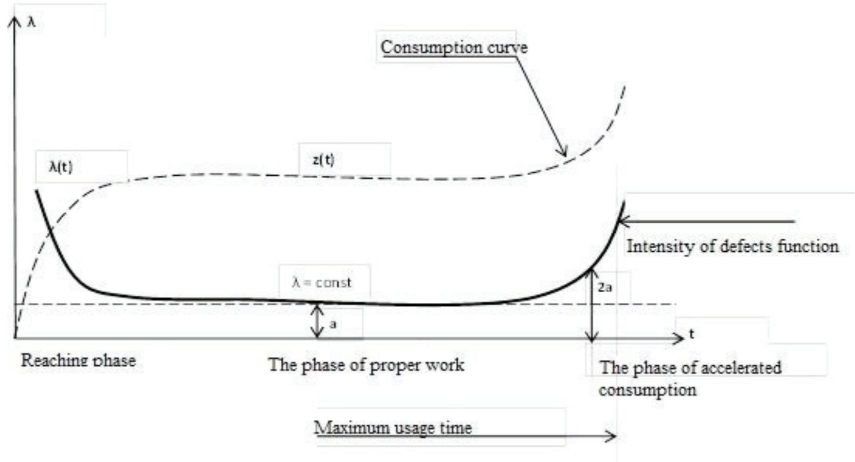


Fig. 1 The course of the intensity of defects function $\lambda(t)$ in the life cycle of a technical object

The intensity of defects function λ *(t)* consists of the following phases:
1. Reaching - intensity of defects is high but rapidly decreases;
2. Proper work - intensity of defects is almost constant and random.

Accelerated consumption - intensity of defects increases until the potential is exhausted.

In the reaching phase there is a process of mutual matching of the cooperating parts. It depends on the technology of production and therefore may vary for each type and model. The reaching process is inevitable but it should be strived to be the shortest. This may be more likely to be implemented by the manufacturer, so that the user's reaching time will be shortened. In the reaching phase technical objects have not only lower reliability but also functional parameters. Intensity of defects decrease exponentially until stabilization and transition to the proper working phase. In the proper working phase the intensity of defects is relatively constant throughout the period is *a*. When the double value is reached, the technical object enters the accelerated consumption phase. This phase continues until the maximum service life specified by the manufacturer.

In situations where the intensity of defects is a monotonous function, a Weibull distribution can be used to describe a given phase, which is more general than exponential and can be applied to any phase of the military equipment existence.

$$\lambda(t) = \begin{cases} \alpha_1\beta_1 t^{\alpha_1-1}, & \text{gdy } t<t_1 \\ \beta_2, & \text{gdy } t_1 < t < t_2 \\ \alpha_3\beta_3 t^{\alpha_3-1}, & \text{gdy } t > t_2 \end{cases} \tag{3}$$

where $\alpha_1 < 1, \alpha_3 > 1;$ t_1 - the contractual time of transition from the phase of reaching the proper working phase; t_2- the contractual transition from the proper phase to the accelerated consumption phase.

Assuming a Weibull distribution as a distribution of reliability, the remaining functional and numerical characteristics of the reliability of the operating system in each phase of the technical equipment existence: reliability function *R(t)*, the probability of density function *f(t),* cumulative intensity of defects (leading function) $\Lambda(t)$, expected expiry time (average durability of technical equipment $\hat{t}$ is shown in Table 1).

Table 1

Dependencies that determine the basic operating system parameters for each phase of vehicle life

	Reaching phase	**The phase of proper work**	**The phase of accelerated consumption**
$\boldsymbol{\lambda(t)}$	$\alpha_1\beta_1 t^{\alpha_1-1}$	β_2	$\alpha_3\beta_3 t^{\alpha_3-1}$
$\boldsymbol{R(t)}$	$\exp(-\beta_1 t^{\alpha_1})$	$\exp(-\beta_2 t)$	$\exp(-\beta_3 t^{\alpha_3})$
$\boldsymbol{Q(t)}$	$1 - \exp(-\beta_1 t^{\alpha_1})$	$1 - \exp(-\beta_2 t)$	$1 - \exp(-\beta_3 t^{\alpha_3})$
$\boldsymbol{f(t)}$	$\alpha_1\beta_1 t^{\alpha_1-1}\exp(-\beta_1 t^{\alpha_1})$	$\beta_2\exp(-\beta_2 t)$	$\alpha_3\beta_3 t^{\alpha_3-1}\exp(-\beta_3 t^{\alpha_3})$
$\boldsymbol{\Lambda(t)}$	$\beta_1 t^{\alpha_1}$	$\beta_2 t$	$\beta_3 t^{\alpha_3}$
$\boldsymbol{\hat{t}}$	$\Gamma(1+\frac{1}{\alpha_1})\beta_1^{-\frac{1}{\alpha_1}}$	$\frac{1}{\beta_2}$	$\Gamma(1+\frac{1}{\alpha_3})\beta_3^{-\frac{1}{\alpha_3}}$

When creating the operating system model, it is important to determine the contractual transition times between the phases. In order to determine the time t_1, it is necessary to analyze the reaching process and the changes that occur in the facility until then. If a technical object does not need to be reached after commissioning, theoretically $t_1 = 0$, then for practical purposes it is necessary to adopt a non-zero value t_1. The intensity of defects in the proper working phase can be determined by analyzing the actual operating system of a particular technical facility. In turn, time t_2 is the moment in which the intensity of the defects $\lambda_3 = 2\,\lambda_2$.

The problem of organization of the operation of technical objects is related to determining the influence of the operation on the reliability and intensity of defects. This is a non-trivial issue because of the complexity and variety of handling processes. Each operation increases the reliability of the facility while reducing the intensity of the defects. For this purpose, the renewal factor δ, which represents the degree of impact of periodic maintenance (00-1, 00-2) and repair for the renewal of the facility, shall be specified.

Taking into account the renewal factor δ, the formula for the intensity of the damage takes the form:

$$\lambda(t) = \frac{\alpha\beta t^{\alpha-1}}{\delta} \tag{4}$$

In turn, the renewal factor δ can be determined from the following relationship:

$$\delta = \begin{cases} \Pi_{i=1}^{k} A_1 \Pi_{i=1}^{l} A_2 \Pi_{i=1}^{m} A_s \Pi_{i=1}^{n}, \text{gdy } k \neq 0 \vee l \neq 0 \vee m \neq 0 \vee n \neq 0 \\ 1, \qquad \text{otherwise} \end{cases} \tag{5}$$

where k - number of serviced operations 00-1 until time t; l - number of serviced operations 00-2 until time t; m - number of average repairs *NS* until time t; n - *A*2 - renewal factor for maintenance 00 - *A*2 - renewal factor for maintenance 00 - A2 - renewal factor for maintenance - *A*2*, As, Ag)*> 1.

Due to the introduction of the renewal factor δ, the dependencies determining the basic parameters of the operating system in each phase of the technical life take the form shown in Table 2.

Table 2

Basic operating system parameters including renewal factor

	Reaching phase	**Phase of proper work**	**Phase of accelerated consumption**
$\lambda(t)$	$\frac{\alpha_1\beta_1 t^{\alpha_1-1}}{\delta}$	$\frac{\beta_2}{\delta}$	$\frac{\alpha_3\beta_3 t^{\alpha_3-1}}{\delta}$
$R(t)$	$\exp\left(-\frac{\beta_1 t^{\alpha_1}}{\delta}\right)$	$\exp\left(-\frac{\beta_2 t}{\delta}\right)$	$\exp\left(-\frac{\beta_3 t^{\alpha_3}}{\delta}\right)$
$Q(t)$	$1 - \exp\left(-\frac{\beta_1 t^{\alpha_1}}{\delta}\right)$	$1 - \exp\left(-\frac{\beta_2 t}{\delta}\right)$	$1 - \exp\left(-\frac{\beta_3 t^{\alpha_3}}{\delta}\right)$
$f(t)$	$\frac{\alpha_1\beta_1 t^{\alpha_1-1}}{\delta}\exp\left(-\frac{\beta_1 t^{\alpha_1}}{\delta}\right)$	$\frac{\beta_2}{\delta}\exp\left(-\frac{\beta_2 t}{\delta}\right)$	$\frac{\alpha_3\beta_3 t^{\alpha_3-1}}{\delta}\exp\left(-\frac{\beta_3 t^{\alpha_3}}{\delta}\right)$
$\Lambda(t)$	$\frac{\beta_1 t^{\alpha_1}}{\delta}$	$\frac{\beta_2 t}{\delta}$	$\frac{\beta_3 t^{\alpha_3}}{\delta}$
$\hat{t}$	$\frac{\Gamma(1+\frac{1}{\alpha_1})\beta_1^{-\frac{1}{\alpha_1}}}{\delta}$	$\frac{\delta}{\beta_2}$	$\frac{\Gamma(1+\frac{1}{\alpha_3})\beta_3^{-\frac{1}{\alpha_3}}}{\delta}$

An analysis of the intensity of defects function shows that a planned and preventive strategy that foresees constant service intervals in each phase of a facility's life is incorrect. A separate strategy would have to be designed for each phase of the existence of a military motor vehicle. Especially in the accelerated phase, service intervals should be lower than for the proper working phase [2].

3. Analysis and Evaluation of Military Equipment Operating System

The model presented in the previous section based on the theory of reliability can be used to analyze and evaluate the organisation of military equipment operating system.

The analysis used data from the actual operation of 144 tanks (PT-91) used for training soldiers in the certain period of time- 1174 days. During this time the total number of defects was 510. They have been relatively new tanks in service for several years. It was assumed that each tank consumes the service life 1 000 km in a year, while the target of the tank is 38,000 km.

Basing on the data and assumptions from above, the intensity of defects λo (t) was calculated.

$$\lambda o(t) = \frac{\frac{number\ of\ damages}{number\ of\ tanks}}{\frac{number\ of\ days\ of\ operation}{number\ of\ days/y}} \cdot mileage\ km/year \qquad (6)$$

hence $\lambda o(t) = 1{,}10 \cdot 10\text{-}3$.

Since the tanks are operated on a planned and preventive system, the maintenance and repair of the military equipment is carried out after a certain course of operation. This effect will vary depending on the type of planned service. The estimated impact coefficients on the increase in technical equipment reliability are shown in Table 3.

Table 3

No.	Type of service	Impact factor on reliability of technical equipment
1	00-1	$A_1 = 1{,}10$
2	00-2	$A_2 = 1{,}15$
3	NS	$A_S = 1{,}25$
4	NG	$A_g = 1{,}140$

At the same time, it was assumed that the calculated intensity of defects *λo (t)* would be the same in the proper phase of the life cycle of the tested tank *λ2 (t)*, that is:

$$\Lambda o\ (t) = \lambda 2\ (t) = \text{const.} \qquad (7)$$

The calculated intensity of defects *λo (t)* concerned relatively new tanks but it is to be expected that, due to the aging of the tanks, the increase in intensity of usage will occur in subsequent years of operation. Based on the experience, it was estimated that it could be up to 50% higher. In this case:

$$\Lambda 2\ (t) = 1.5\ \lambda o \qquad (8)$$

For the remaining phases of the tank life cycle, the intensity of defects λ1*(t)* - reaching phase and λ3*(t)* - the phase of accelerated existence were determined using the relationships shown in Table 1. The intensity of defects in the wave function is shown in Fig. 2.

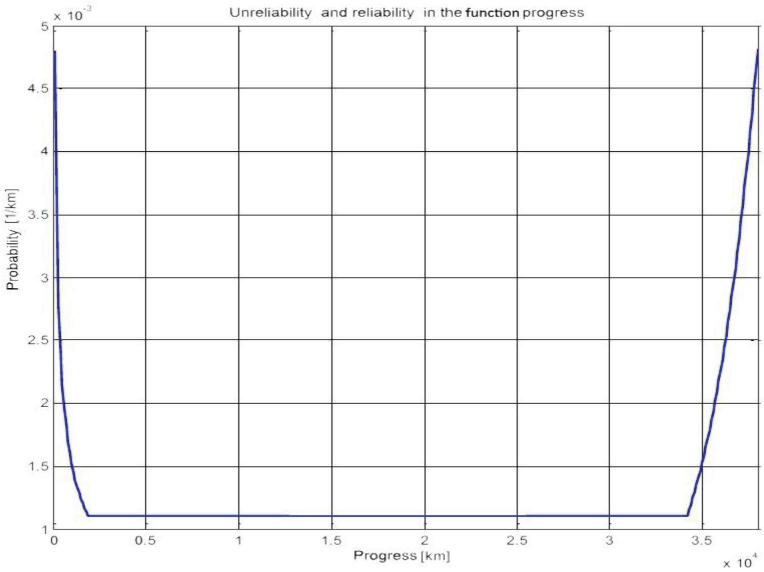


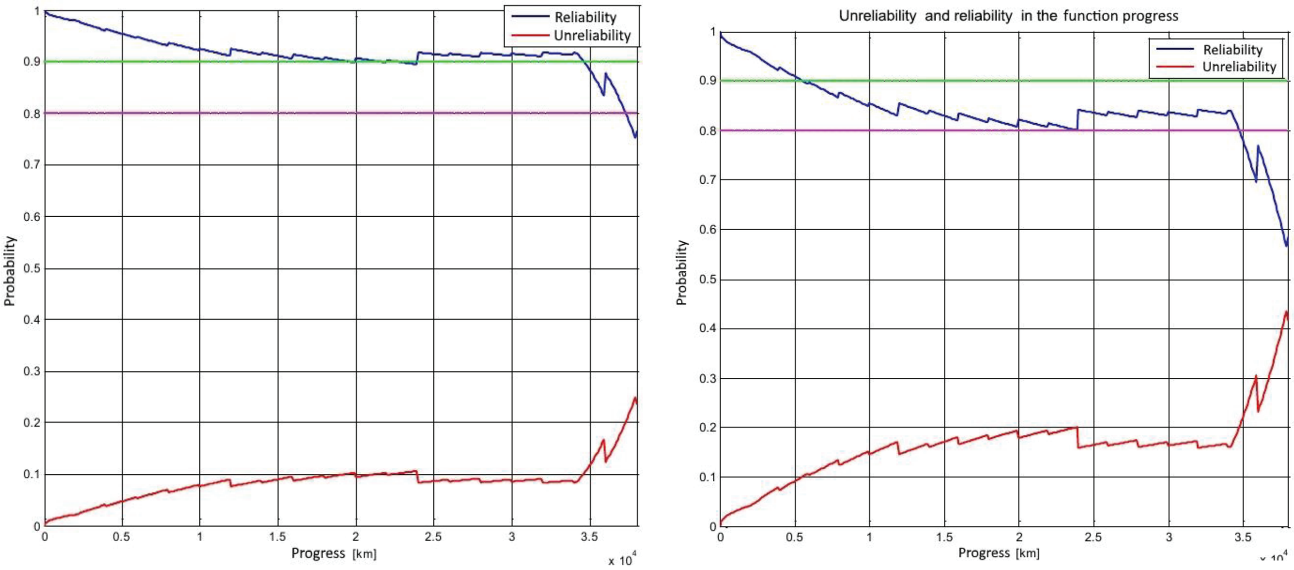
Fig. 2 Unreliability and reliability in the function progress

Analysing the course of the damage intensity of the PT-91 tank in the course of the run, you can determine the ranges of the various operating phases. The break-in phase is about 1,700 km, the proper working phase to about 34,000 km, and the intensity of the damage is rapidly increasing.

The reliability function was then determined as the probability of failure of the technical equipment at time t and the probability of failures for *λo (t)* and *λ2 (t)* = 1.5*λo (t)* - a planned and preventive system; Fig. 3 and in service and repair system; Fig. 4.

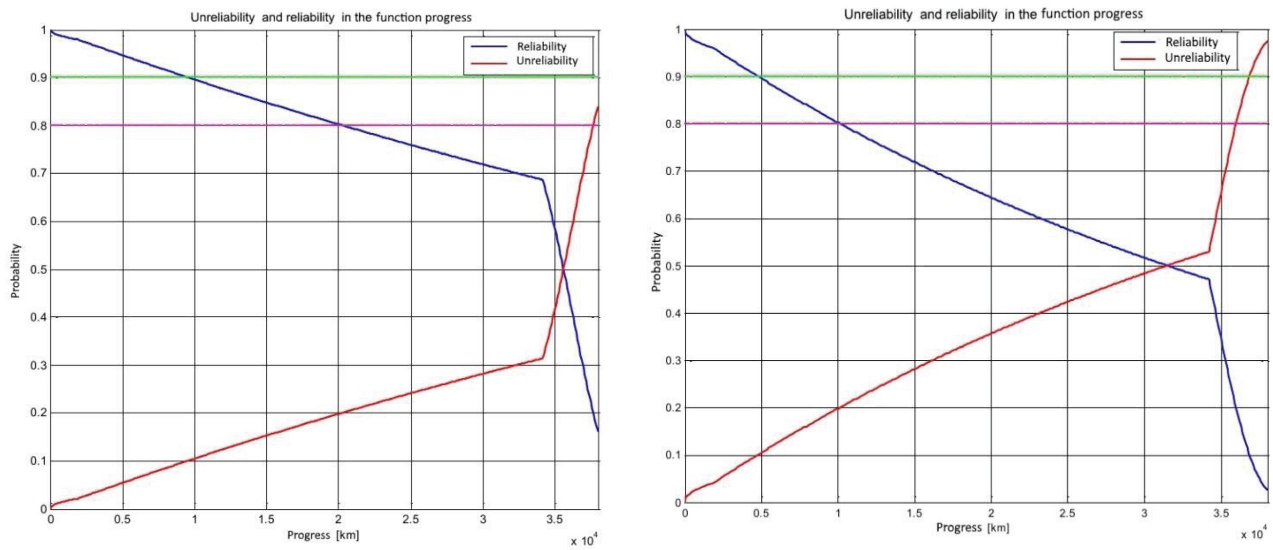
In the figure, the dashed lines indicate the minimum values of the reliability function (green), where the technical equipment can be considered as working and valid (violet).

From the diagram shown in Fig. 3, a, for the intensity of defects *λo (t)*, it can be seen that nearly 90% of the service life of the tanks will be in the state of technical efficiency. This is due to the fact that it is operated in a planned and preventive system, which makes it exist longer in technical condition and even longer in the state of fitness. In case the intensity *λ2 (t)* = 1.5*λo (t)* - Fig. 3, b, the tank after 5,000 km will be in the state fitness but will not meet technical conditions. It is, however, advantageous that even with the target service life the probability of failure is less than the probability of correct operation of the tank.



a b

Fig. 3 Unreliability and reliability as an operating function of the PT-91 tank in a planned and preventive system: a - with less damage intensity; b - with higher wear intensity



a b

Fig. 4 Unreliability and reliability in the operating function of the PT-91 tank in service and repair system: a - with less wear intensity; b - with higher wear intensity

4. The Concept of Improving of the Operating System Organization

Analysis of reliability parameters confirmed the validity of the planned and preventive use of military equipment. According to the authors of this work, during the operation of military equipment in the time of peace, apart from providing the correct technical parameters, a significant issue is also the reduction of operating expenses.

One of the ways to improve the economy of the military equipment operating system in the time of peace could be prolonging the target service life. For this purpose, the intensity of physical aging in the third phase of operation can be slowed down by increasing the frequency of technical maintenance while maintaining the first two phases of frequency resulting from the standardization of technical service in the planned and preventive system.

For this purpose, simulation studies were conducted to determine the reliability and unreliability of the PT-91 tank as a function of the waveform for two variants of technical service frequencies: double and quadruple, and the results are shown in Fig. 5.

The analysis of the curve shows that only a fourfold increase in frequency of technical service in the third phase of equipment life will increase reliability and maintain the equipment in a state of fitness and thus create the possibility of prolonging the target. Fourfold density of technical service in phase three will result in twofold decrease of the cumulative intensity of defects – Fig. 6 (a,b,c), thus significantly reducing the service life, that is characteristic for the third phase of operation.

This will result in the possibility of extending the target range of the PT-91 tanks by about 1,000 km. However, one should also be aware that increasing the frequency of technical operations will increase the cost of their execution and increase the time of stoppage of the tanks in service. Therefore, the correctness of the proposed solution should be proceeded by a detailed analysis of operating costs [3].

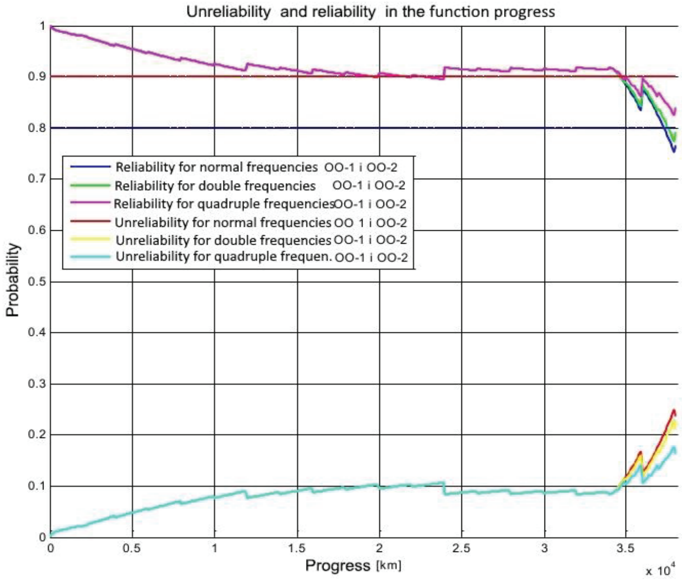
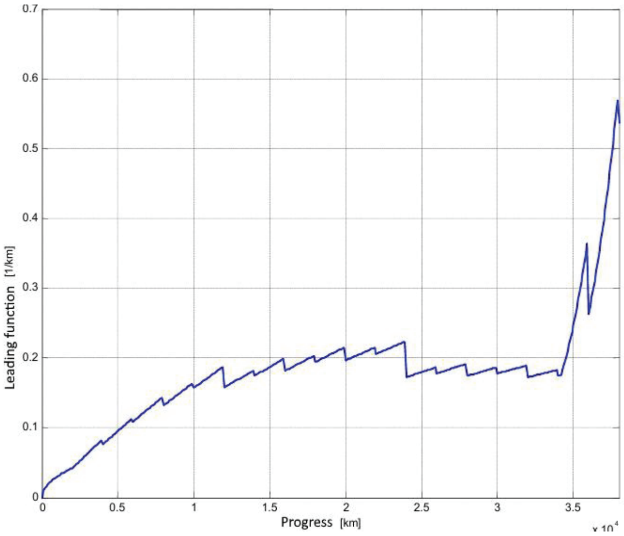
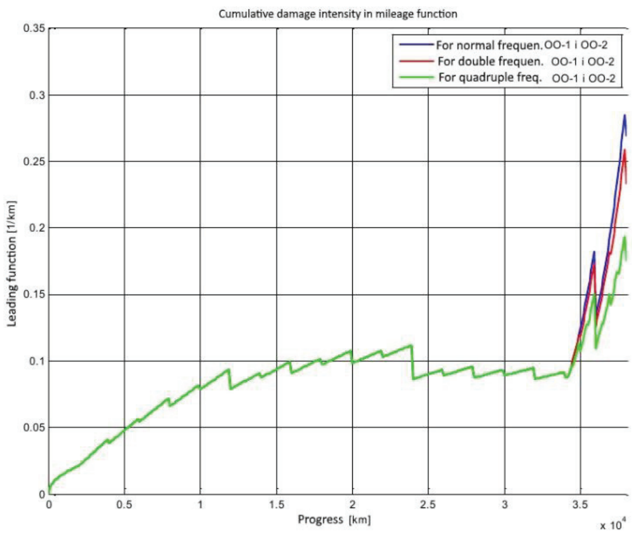


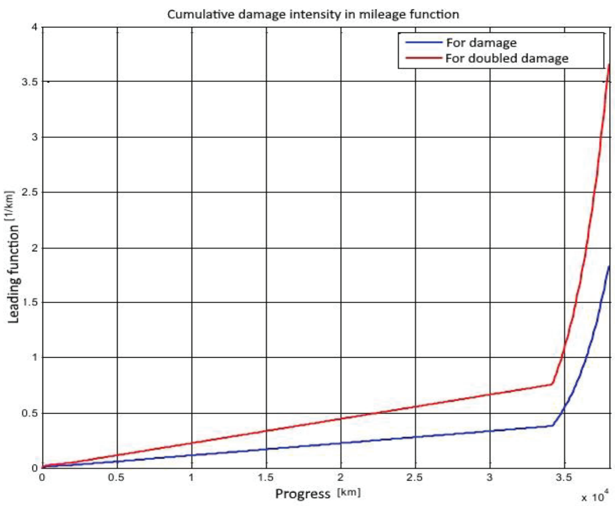
Fig. 5 Cumulative damage intensity in mileage function for normal, double and quadruple frequencies



a



b



c

Fig. 6 Cumulative damage intensity in mileage function for normal, double and quadruple frequencies

5. Summary and Conclusions

The purpose of this study was to analyze and evaluate the organization of the planned and preventive system of operating military equipment and to develop the concept of its improvement. The organization and operation of the PT-91 tank were analyzed and evaluated. For this purpose, a model of the technical equipment operating system based on the theory of reliability was built. The right to use in the armed forces of the planned and preventive operation system was confirmed. At the same time, it was stated that there was a possibility of prolonging the target service life in the time of peace. The reduction in the intensity of physical aging can be achieved by fourfold increase in the frequency of technical service in the third phase of life cycle of military equipment. Making a decision of modifying of the organization of the planned and preventive maintenance system will require a detailed analysis of operating costs.

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Design of the Tracked Chassis Module

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Abstract

This paper deals with conceptual design and the creation of a real tracked chassis. It briefly describes the process of designing a tracked chassis from the initial conditions, a description of the structure and a critical comparison with the real model. The resulting design is patented as a utility model. The prototype is tested under real conditions.
KEY WORDS: *tracked chassis, module concept, rubber track, bogie arm, tensioning*

1. Introduction

Designing a tracked chassis of a mobile forestry machine is a very complex process. The difficulty of the process is increased by the fact that the tracked chassis is designed for a real wheeled machine. The chassis must be designed as a replaceable module. However, the original concept of the machine did not include this option. We can count on many problems with the differences between the track and wheel chassis before the design. These are issues such as dimensions, weight, speed and drive.

2. Initial machine concept

The design of the tracked chassis module was based on several known design solutions. Schematic diagrams of the design solutions are shown in Fig. 1. An important parameter for the selection of the tracked vehicle due to the specific pressure on the soil, is the length of track "l_w" in contact with the ground [3].

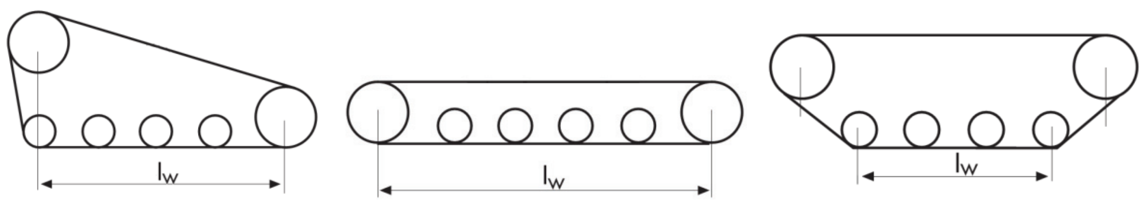

Fig. 1 Types of designs for the tracked chassis; Delta tracked chassis (left), Standard tracked chassis (center), Tracked chassis with increased passage (right) [5]

The following parameters and design requirements have been specified for the track chassis construction:

- Attachment of the tracked chassis module - use of the axle attachment of the original axle (wheel chassis – bogie) [1];
- Use of a rubber track. Enables the machine to move over the roots of trees without damage. Belt is solved by subcontracting [2];
- The specific pressure between the track and the forest soil must be less than 100 kPa [2];
- The structures of the angle of the track when approaching and crossing terrain obstructions, such as a tree trunk or trench [4].

3. Conceptual Parameters of the Tracked Chassis Module

The exact values of the parameters were then calculated or selected from the requirements. The resulting solution:

- The belt type was selected with metal core and steel cords (Fig. 2) [5].
- The rubber track was selected with a width of 450 mm [2, 5]. This is the most commonly used width of rubber tracks for construction machinery.
- The construction type of the tracked chassis module was selected according to the Figure 2 Type B [5].
- The minimum contact length l_w = 1,635 m [3, 5] was determined from the required minimum pressure on the soil.
- The tracked chassis with increased passage was selected for the construction type of the tracked module (Fig. 1 – right) [2].

Fig. 2 Construction of the rubber track with a metal core and the steel cords (left); Types of track construction for the different options, A – Internal side of the track, B - External side of the track, C – External side of the track with the metal trackline. [5]

4. The Module Design of a Tracked Chassis

The resulting design is shown in Figure 3. The track chassis meets the specified parameters and requirements [3].

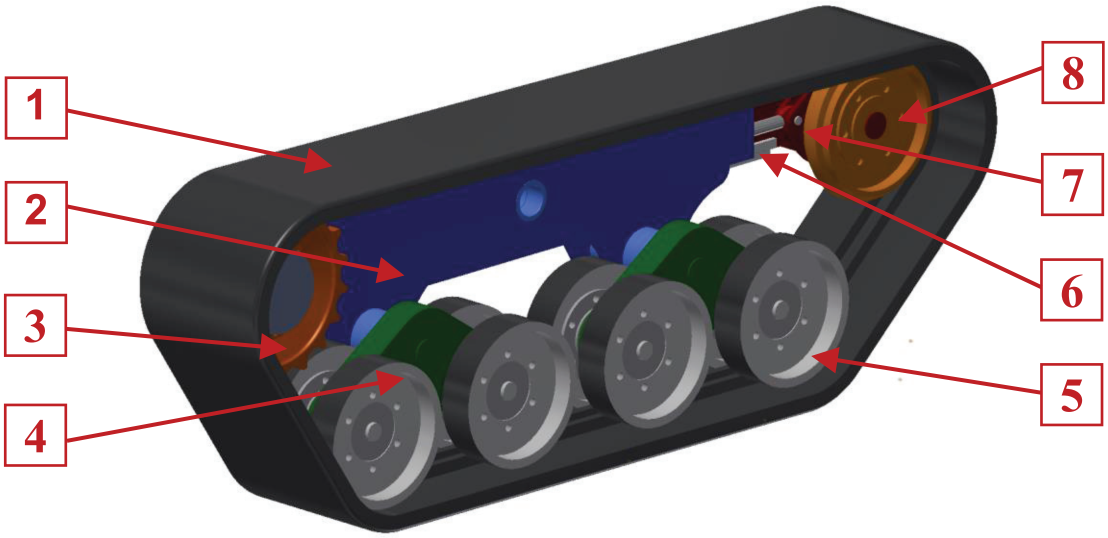

Fig. 3 The resulting concept of the track chassis module; *1* – rubber track, *2* - frame of the track module, *3* - drive wheel with hydraulic motor, *4* – bogie arm frame, *5* - wheels, *6* - tensioning hydraulic motor, *7* - tensioning telescopic device, *8* – tensioning and lead wheel [3]

4.1. The Frame of the Track Chassis Module

The frame of the module is of welded box construction (Fig. 4 - A). The frame is mounted on a plain bearing (B) - the same way as the axle wheel bogie. In the lower part of the frame there are bearings for bogie wheels (C). Mounted on the front part of the frame there is a hydraulic drive motor (D). At the rear of the frame there is a mounting for the tensioning device (E).

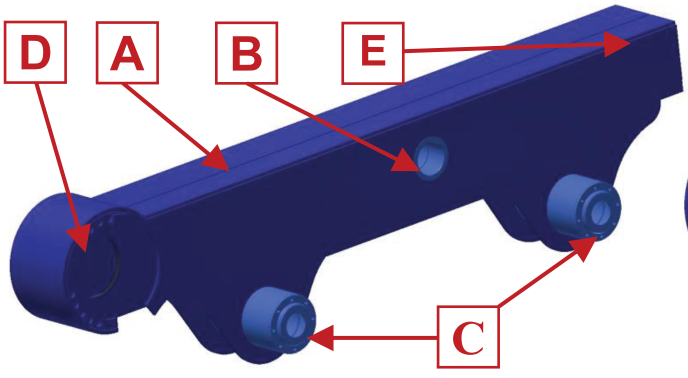

Fig. 4 The frame of the track chassis

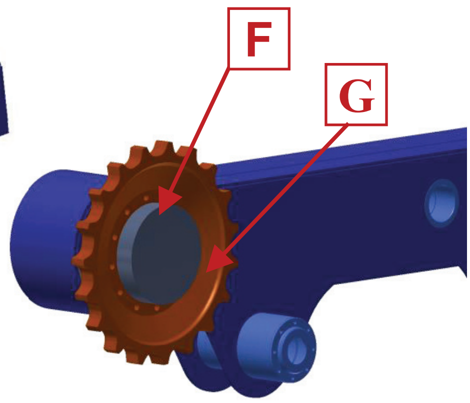

Fig. 5 The track drive sprocket

4.2. The Track Drive Sprocket and Hydraulic Motor

The track drive sprocket (Fig. 5 - F) is mounted on the front side of the track chassis module. It is of an unusual design. The track drive sprocket is attached to a rotary radial hydraulic motor (G).

4.3. The Bogie Arm

The bogie arm frames are welded boxes. At the top there is a shaft for the bogie arm attachment to the frame (H). In the lower part of the bogie arm are the bearings (I) for the rotary joint (J).

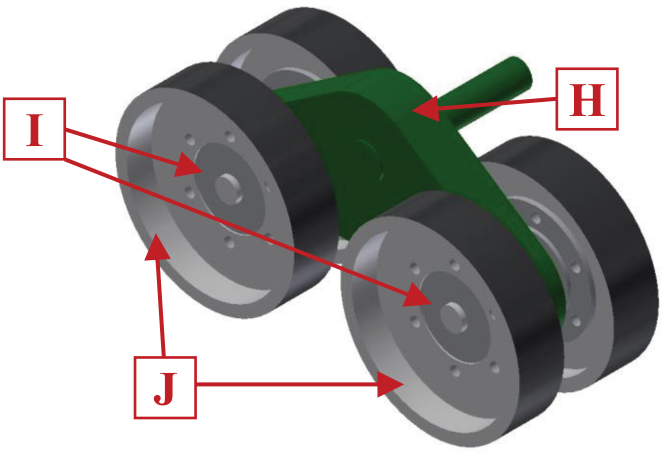

Fig. 6 The bogie arm with wheel sets

4.4. The Tensioning Telescopic Device

The tensioning telescopic device is at the rear of the frame (K). The device is in the chassis frame placed in the inner part and guided by sliding plates (L). The length is determined by the mounting length and the length of shortening or stretching of the track when the machine is moved. The value was determined from the simulation. In the rear part of the tensioning device is a track idler (M). The bracket is for the piston of the tensioning device (N).

4.5. The Hydraulic Motor of the Tensioning Device

The linear hydraulic motor is located between the frame (O) and the tensioning device. (N). The tensioning hydraulic motor is connected to a specific independent hydraulic circuit for proper track tensioning.

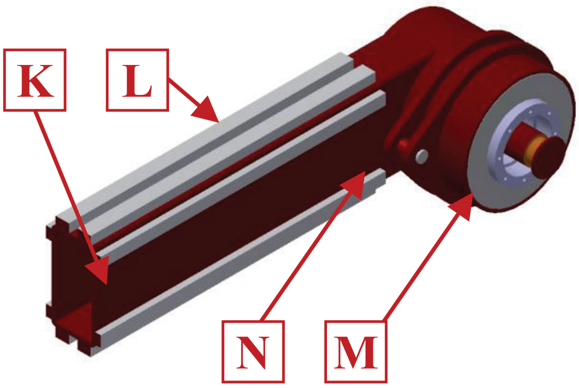

Fig. 7 The tensioning telescopic device

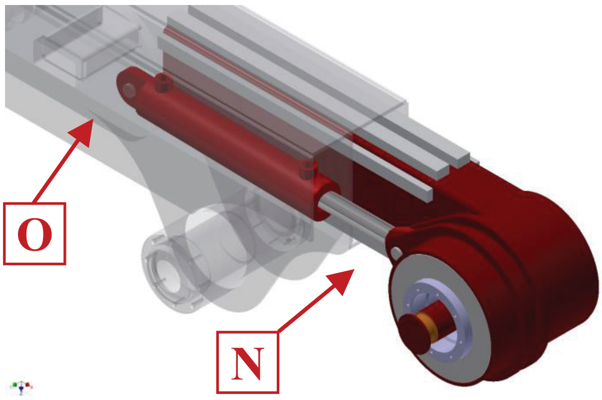

Fig. 8 The linear hydraulic motor

The resulting positioning of the tracked chassis modules on the forwarder is shown in Fig. 9. There are four tracked chassis modules on the machine, two are right-handed and two left-handed. The difference is only the design of the frame and the tensioning device. Other subgroups of the module are interchangeable.

Fig. 9 The virtual prototype of the forwarder with a tracked chassis

5. The Real Prototype of the Tracked Chassis

When making the prototype of the forwarder (see Fig. 10 and Fig. 11), a few problems were encountered, especially concerning delivery of the parts from subcontractors and implementing the parts into the construction:

- A rubber track can be found in the catalogue as [5] and it has a catalogue number, however the distributor does not know the catalogue number or the parameters. The distributor is only interested to know the type of the machine where the rubber track will be build in. Subsequently there are issues with returning unwanted rubber tracks.

- The hydraulic motors designed for the machine were replaced by more powerful ones. Due to this replacement there was a problem in assembling the parts as a result of the existing construction. Furthermore there was an issue with connecting the hydraulic motors to the hydraulic system. Additionally the frame of the construction was amended.

- The tension device of the track was set up for a lower pressure than originally was calculated. The reason was the length of the contact surface and the soil.

Fig. 10 The real prototype forwarder with tracked chassis - loading

Fig. 11 The real prototype forwarder with tracked chassis - drive

6. Conclusion

The forwarder is designed as a machine with the possibility of changing the wheel chassis for the tracked chassis. Basic design and utility parameters have been designed with respect to the environment which the forwarder will work. Emphasis was placed on the terrain skills of the machine, stability and the value of the contact pressure between the track and the subsoil.

Acknowledgement

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Water Treatment Facilities on a Vessel

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Abstract

There are different methods of treating sewage available. For crews and passengers it is important to generate fresh water, in one of the important machinery on a ship board. Fresh water produced from fresh water generator is used for drinking, cooking, washing and even running other important machinery which use fresh water as a cooling medium. The sewage generated on the ship cannot be stored on the ship for a very long time and for this reason it has to be discharged into the sea. Discarding sewage produced onboard on a ship is one of the few tasks on a ship which should be taken utmost care if one wants to save him and his shipping company from heavy fine.
KEY WORDS: *active suspension, fresh water, bilge water, damping*

1. Introduction

The discharge of untreated sewage (Fig. 1) in controlled or territorial waters is usually banned by legislation. International legislation is in force to cover any sewage discharges within specified distances from land. As a result, and in order to meet certain standards all new ships have sewage treatment plants installed. Untreated sewage as a suspended solid is unsightly.

Fig. 1 Ship discharging ballast water

In order to break down naturally, raw sewage must absorb oxygen. In excessive amounts it could reduce the oxygen content of the water to the point where fish and plant life would die. Pungent smells are also associated with sewage as a result of bacteria which produce hydrogen sulphide gas. Particular bacteria present in the human intestine known as E, coli are also to be found in sewage. The treatment of oily wastes for the purpose of meeting marine discharged standards requires various oil pollution abatement systems. The methods commonly used throughout the world for the treatment of oily waste water (including bilge water) can be categorized (Tab.1) as the traditional: coalescence, coagulation, filtration, adsorption and modern methods based on the membrane technologies such as reverse osmosis, nanofiltration and ultrafiltration. The oxidation process is as follows:

$$COHNS + O_{2\ (\text{Organic matter})} + \text{Bacteria} \rightarrow CO_2 + NH_3 + _{\text{Energy}} + \text{Other end products} \quad (1)$$

Table 1

Water treatment procedures on a vessel

Water treatment on a vessel by its application and contamination			
1.Bilge water, sewage waste water :	2. Ballast water, sea water	3. Utility water	4. Potable water treatment
Chemical method	Filtration	Chemical method	Fresh water generation
Biological method	UV irradiation	Brackish water	Evaporation and cooling, vacuum, desalination
Separation	Zooplankton method	Demineralization	Reverse osmosis
Ultrafiltration	Phytoplankton method	Ultrafiltration	Forward osmosis
Sedimentation	Bacterial method	Electronic water purification	Capacitive deionization
Coagulation		Photocatalytic oxidation	Ozone water treatment

Two particular types of sewage treatment plant are in use, employing either **chemical** or **biological** methods. The chemical method is basically a storage tank which collects solid material for disposal in permitted areas or to a shore collection facility [1].The biological method treats the sewage so that it is acceptable for discharge inshore [2].

Chemical sewage treatment

This system minimizes the collected sewage, treats it and retains it until it can be discharged in a decontrolled area, usually well out to sea. Shore receiving facilities may be available in some ports to take this retained sewage.

This system must therefore collect and store sewage produced while the ship is in a controlled area. The liquid content of the system is reduced, where legislation permits, by discharging wash basins, bath and shower drains straight overboard. Any liquid from water closets is treated and used as flushing water for toilets. The liquid must be treated such that it is acceptable in terms of smell and appearance. Various chemicals are added at different points for odour and colour removal and also to assist breakdown and sterilization. A comminutor is used to physically break up the sewage and assist the chemical breakdown process [3].

Tests must be performed daily to check the chemical dosage rates. This is to prevent odours developing and also to avoid corrosion as a result of high levels of alkalinity. Chemical physical plant is specially designed and developed to treat wastewater containing non-biodegradable dissolved pollutants such as inert mineral substances; organic substances; mineral oils; detergents and solvents; paint or debris in suspension.

Biological sewage treatment shown in Fig. 2 utilizes bacteria to completely break down the sewage into an acceptable substance for discharge into any waters. The extended aeration process provides a climate in which oxygen-loving bacteria multiply and digest the sewage, converting it into a sludge. These oxygen-loving bacteria are known as aerobic.

The treatment plant uses a tank which is divided into three watertight compartments: an aeration compartment, settling compartment and a chlorine contact compartment.

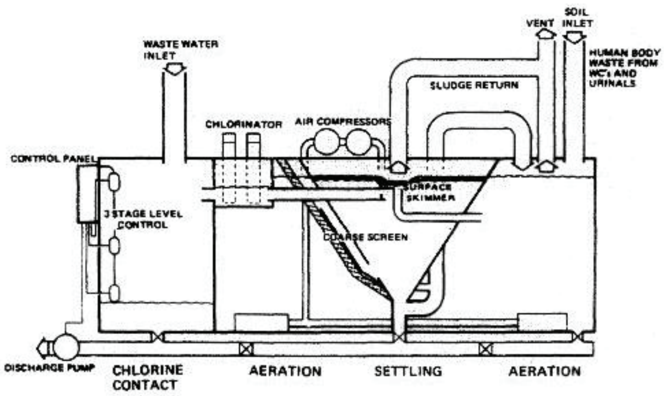

Fig. 2 Biological sewage treatment plant

2. Bilge Water

Bilge water characteristics shown in Fig. 3 and generation rates depend on ship type and ship operating mode. Bilge water is a two-phase dispersive system in which the continuous phase is water, and the dispersed phase is oil. In bilge water both a mixture of water and dispersed oil clusters and oil-in-water emulsion occur, as well as systems with a colloidal dispersion [4]. The oily waste waters can be grouped into three broad categories: free-floating oil, unstable oil/water emulsions and highly stable oil/water emulsions. Oil-in-water emulsion exhibits a natural tendency to undergo separation of the oil phase from the water phase, however, the rate of separation is dependent on the degree of oil dispersion. Therefore, two types of emulsion are distinguished: coarse-dispersed with a droplet size above 50 μm and fine-dispersed with a droplet size in the range 0.2 - 50μm. The coarse-dispersed emulsions exhibit low stability, therefore at favourable conditions, e.g. during ship berthage, the separation of emulsion proceeds relatively quickly [5].

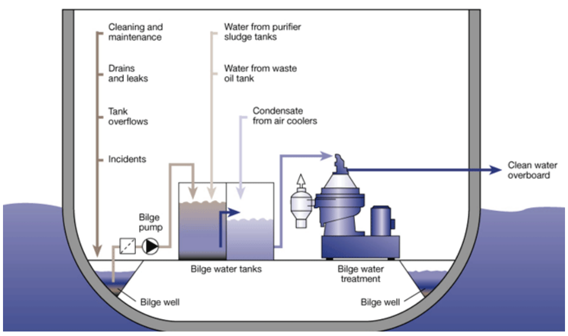

Fig. 3 Bilge system

The gravimetrical separation of course-dispersed bilge water occurs within 12-24 hours and, as a result, the three phases can be distinguished. Phase I- superficial (oil phase) with oil contents about 80-100%, phase II – aqueous with oil concentration 100 – 1000 ppm and phase III – oil sludge.

2.1. Ballast Water

Shipping moves over 80% of the world's commodities and transfers approximately 3 to 5 billion tonnes of ballast water internationally each year [6]. A similar volume may also be transferred domestically within countries and regions each year. Ballast water is absolutely essential to the safe and efficient operation of modern shipping, providing balance (Fig. 4) and stability to un-laden ships. However, it may also pose a serious ecological, economic and health threat.

Fig. 4 Optimarin Ballast System (OBS) [2]

Optimarin Ballast System is based on filtration as pre-treatment and high doses of UV irradiation for inactivation of marine organisms, viruses and bacteria, without affecting the normal operation of the ship. Ballast water is UV treated both during ballasting and de-ballasting to ensure the dual UV effect. Ballast water is only filtered during ballasting. The OBS is one of very few treatment options that does not use or generate chemicals or biocides in its treatment or cleaning processes. It is based on the idea that such systems should be environmentally sound, simple, flexible and easy to install, and capable of operating on both new builds and existing vessels. The OBS is certified to operate in all salinities (freshwater, brackish and seawater). It accommodates a wide range of ballast water capacities and can handle flows up to 3.000 m³/h. The Optimarin Ballast System is normally installed in the pump or engine room and in close proximity to the ballast pumps.

2.2. Filtering

Microfiltration membranes allow water and dissolved ions, to pass through, but stop suspended solids down to particle sizes as small as 0.1 microns. This process clarifies water and removes virtually all suspended solids. Ultrafiltration produces water free of virtually all suspended solids and turbidity as well as removing suspended and emulsified organic chemicals

2.3. UV Treatment System

The type approved Optimarin Ballast System is based on filtration as pre-treatment and high doses of UV irradiation for inactivation of marine organisms, viruses and bacteria, without affecting the normal operation of the ship. Ballast water is UV treated both during ballasting and de-ballasting to ensure the dual UV effect (Fig. 5). Ballast water is only filtered during ballasting.

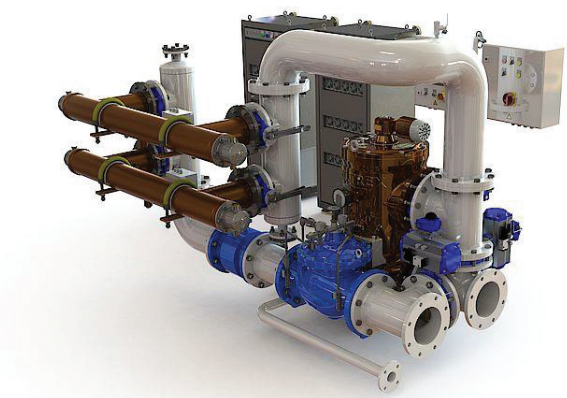

Fig. 5 UV treatment system [7]

2.4. Phytoplankton Methods

The samples are to be collected for the phytoplankton analyses. The sampling consists of collecting three replicate samples of the ballast water before (control) and after treatment for two types of analyses: chlorophyll a analysis and direct cell counts. The cell counts are carried out using standard counting procedures based on the sedimentation method and using an inverted microscope. The phytoplankton is to be identified to the level of a particular class and enough of the sample must be examined to ensure that a minimum of 100 cells from each class was counted.

2.5. Bacterial methods

The samples for bacterial analysis are to be collected in sterile polypropylene bottles filled either from the tube flushing the water over the zooplankton sieve (30 samples) or from a tap immediately prior to the heat exchangers. The samples are to be kept cool until they could be processed further (usually within a few hours). The concentration of viable bacteria is determined by a most probable number technique.

The tank water assessment is to be treated as originating from the same ballast water, and used as replicates for assessing the effect of the treatment temperature and the age of the ballast water as well. We have to bear in mind that the pumps will contribute to the mortality of organisms for any ballast water and it is the treated water that has passed through the pumps that has to meet the IMO discharge standard, so any treatment will likely have a pump effect contributing to the mortality.

3. Utility Water

3.1. Ultrafiltration

Ultrafiltration is a pressure-driven membrane process which can separate, concentrate, and fractionate macromolecular solutes and suspended species from water. UF provides nondestructive separation without causing any change of phase. In addition, UF can be operated at relatively low pressures (70–700 kPa) because of the negligible osmotic pressures exerted by the higher the high molecular weight solutes the membranes are designed to treat. In general, UF is a hydraulic pressure-activated process which is dependent upon molecular size and shape to provide separation of solute(s) and solvent. UF separates dissolved solutes in the range from 0.005 to 0.1 mm. Although UF is a useful separation technique, it has several inherent limitations.

3.2. Photocatalytic Oxidation Process

Photocatalytic Oxidation Process (Fig. 6) uses a semiconductor catalyst such as titanium dioxide (TiO_2) in conjunction with near UV light to generate strongly oxidizing and reducing species. When the solid is illuminated with energy equal to or higher than the band gap energy, electrons are promoted from the valence to the conduction band, leaving behind positive holes. These charge carriers migrate to the semiconductor particle surfaces.

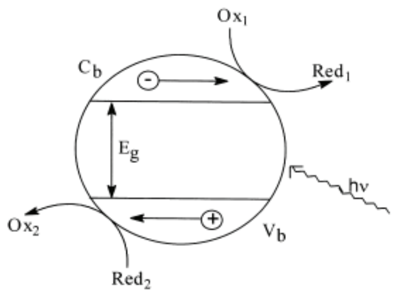

Fig. 6 Photocatalytic process on illuminated semiconductor particle: V_b = valence band; C_b = conduction band; E_g = band gap energy

4. Potable Water

4.1. Fresh Water Generator

Fresh water generator is one of the important machinery on board of a ship [7]. Fresh water produced from fresh water generator is used for drinking, cooking, washing and even running other important machinery which use fresh water as a cooling medium. Fresh water is generally produced on board using the evaporation method. There are two things that are available in plenty on ship to produce fresh water – seawater and heat. Thus fresh water is produced by evaporating sea water using heat from any of the heat source. The evaporated sea water is again cooled by the sea water and the cycle repeats. Generally the heat source available is taken from the main engine jacket water, which is used for cooling the main engine components such as cylinder head, liner etc. The temperature available from this jacket water is about 70^o C. But at this temperature the evaporation of water is not possible as we all know that the evaporation of water takes place at 100^o C under atmospheric pressure. Thus in order to produce fresh water at 70^o C we need to reduce the atmospheric pressure, which is done by creating a vacuum inside the chamber where the evaporation is taking place. Also, as a result of the vacuum the cooling of the evaporated sea water will also take place at lower temperature. This cooled water is collected and transferred to the tank.

The main body of a fresh water generator (Fig. 7) on the ship consists of a large cylindrical body with two compartments. One of the compartments is the condenser and the other is the evaporator. The fresh water generator also consists of an educator which helps in generating the required vacuum. The fresh water pump and ejector pump helps in transfer of water to and from the fresh water generator.

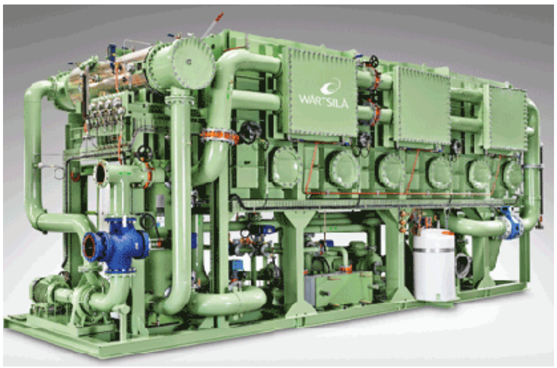

Fig. 7 Fresh water generator [7]

4.2. Reverse Osmosis

Reverse osmosis is a separation process that uses pressure to force a solvent through a semi-permeable membrane (Fig. 8) that retains the solute on one side and allows the pure solvent to pass to the other side, forcing it from a region of high solute concentration through a membrane to a region of low solute concentration by applying a pressure in excess of the osmotic pressure. RO is appropriate to demineralize salty water sources removing all the colloids, and most of organic and ionic species. However, reverse osmosis is susceptible to fouling. Fouling is a major problem in operation of RO plants and can have several negative effects: reduced membrane flux, increased difference pressure, and decreased salt rejection necessitating periodical cleaning. RO permeate is water with a changing electrical conductivity and content of total organic carbon depending on its filthiness. RO membrane elements family consists of spiral-wound, thin-film composite membrane elements designed specifically for water treatment applications.

Nowadays, reverse osmosis is one of the methods which are used on board for generating fresh water. Generally this is used on passenger vessels wherein there is a large requirement of fresh water production. However, in merchant ships the evaporation method is used as reverse osmosis is costly and includes large maintenance cost for membrane.

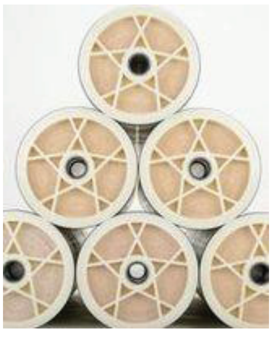

Fig. 8 Reverse Osmosis membrane

New RO elements are recommended for brackish and low salinity feedwaters that are expected to have higher biological and organic fouling tendencies. Permeate flow rate is about 40 m3/day with 99,5 % salt rejection.

4.3. Forward Osmosis

Osmosis may be used directly to achieve separation of water from a solution containing unwanted solutes. A "draw" solution of higher osmotic pressure than the feed solution is used to induce a net flow of water through a semi-permeable membrane, such that the feed solution becomes concentrated as the draw solution becomes dilute. The diluted draw solution may then be used directly (as with an ingestible solute like glucose), or sent to a secondary separation process for the removal of the draw solute. This secondary separation can be more efficient than a reverse osmosis process would be alone, depending on the draw solute used and the feed water treated. Forward osmosis is an area of ongoing research, focusing on applications in desalination, water purification, water treatment, food processing.

4.4. Capacitive deionization (CDI)

CDI shown in Fig. 9 is a technology based on the recognition that high-surface-area electrodes, when electrically charged, can quantitatively adsorb ionic components from water, thereby resulting in desalination.

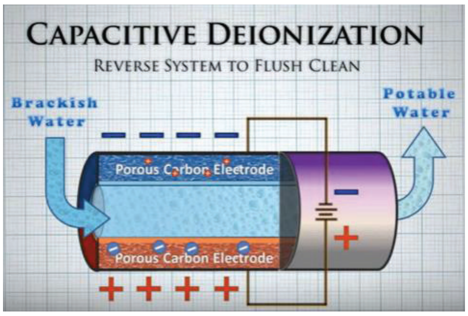

Fig. 9 Desalination process through Capacitive deionization (CDI)

4.5. Ozone Water Treatment

Ozone generators incorporate the most sophisticated electronics technology available. Ozone has been used for many years to improve the aesthetic qualities of water and for its germicidal action. It is an accepted fact that drinking water is disinfected when a residual ozone level of 0.4 mg/l has been maintained for a period of 4 minutes. Ozone has many additional benefits in the drinking water process: In pre-ozonation, ozone improves clarification, limits the formation of haloform precursors, reduces iron and manganese and promotes the destruction of micro-organisms such as algae.

Main ozonation treatment breaks down trace contaminants and enhances the biodegradability of organic substances which are then removed in a biological treatment step. Finally, combined treatment steps involving ozone and activated carbon or ozone and peroxide are currently the most powerful means available to water process engineers for the removal of contaminants and constitute a vital safeguard against contamination entering a drinking water system.

5. Conclusions

At any given time, 35 000 ships are en route on the water of the Earth. They use water of higher or less quality in huge volumes. If the ships are well equipped they can solve not only water treatment problem, but also to provide poor coastal regions with potable water. The UN considers the introduction of non-indigenous oceanic species, delivered with bilge and ballast waters to be one of the top four serious threats to the global environment. Economic consequences of sea water pollution in form of high fines could be fatal for many maritime companies. Therefore so much efforts have been taken to prevent the seas from contamination, which has dramatic consequences for biodiversity and for industries such as fishing and aquaculture.

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Web Application for Indexation of Costs in Freight Road Transport

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Abstract

Cost Index CESMAD BOHEMIA is monitoring system of costs development of Czech freight carriers. This Index is based on methodology of the Dutch company NEA and methodology of transport experts from Czech Technical University. Cost Index CESMAD BOHEMIA has a goal to give information about costs development on one kilometre for different relations in Europe and to describe general trend across the market of truck transport. The aim of this Index is to ensure that carriers and their customers are incorporated in a suitable version in their contracts and achieve the objective indexation of prices for transport. Therefore, this paper deals with construction of web application of Cost Index ČESMAD BOHEMIA, which carriers can use from beginning of this year.
KEY WORDS: *freight road transport, costs, indexation, application, monitoring system*

1. Introduction

The cost index ČESMAD BOHEMIA is a system for monitoring the development of costs of Czech truck carriers. It is based on the methodology of the Dutch company NEA and the methodology of experts from the Faculty of Transportation of the Czech Technical University in Prague, who are its processors. The index is designed to provide objective information on the development of costs per 1 km which carriers have in different European terms, as well as a general overview of the development of the entire truck transport market. It is also the ambition of the index that the carriers themselves and their customers will incorporate it in an appropriate version into their contracts to achieve an objective adjustment of prices for transport. It also includes a commented assessment of the development of costs in individual quarters and a description of the basic trends.

The index is based on a composition of costs for a 40-tonne trailer set. The user is given the opportunity to choose between different index variations for vehicle types according to their emission categories for the destinations to which they are directed. So far, the index has been prepared for six routes starting in the Czech Republic and heading to Spain, Germany, Italy, the United Kingdom and Slovakia. The last route is intended for national carriers, representing the connection between Pilsen and Olomouc. Relatively significant differences may occur for individual routes as shown in the enclosed graph. The cost increase on the route to the UK is faster in 2015 and 2016 compared to e.g. Germany, where the main reasons is the introduction of tolls in Belgium and the increase in ferry prices between Calais and Dover.

Besides routes, the user can choose between vehicles with engines EURO V and EURO VI according to the composition of his vehicle fleet. A part of the web application is also a calculation of the MIX variant, which considers the share of EURO V and EURO VI vehicles according to the current market share and it is calculated including the toll (route GLOBAL, emission category MIX, with a toll). The user can also select interquarterly (iQ - development of costs between particular quarters of the year) or basic (iB) index where costs are related to the basis (base), which is the average cost of 2014 (for the EURO V variant), alternatively, the average amount of costs of 2015 (for EURO VI and MIX variant).

The index may affect costs, including toll, or without it, with different periods being compared. The basic period is a quarter, and the main trend index for the whole domain is **the GLOBAL MIX index with a toll** that affects all international relations with weight according to the volume of trade of the Czech Republic. The weights of the individual relations included in the calculation of the GLOBAL index are continuously updated according to the latest known data on the volume of exports made by road freight transport. These are mentioned in the Yearbook of Transport of the Ministry of Transport of the Czech Republic. In this main index it is also taken into account both the decisive emission categories EURO V and EURO VI as well as the paid toll.

The costs of base on the GLOBAL route for the selected year yn_{Gy} were determined on the basis of this equation:

$$n_{Gy} = v_{ESPy} \cdot n_{ESPy} + v_{GERy} \cdot n_{GERy} + v_{ITAy} \cdot n_{ITAy} + v_{SVKy} \cdot n_{SVKy} + v_{GBRy} \cdot n_{GBRy}, \quad (1)$$

where v_{ESPy} $(v_{GERy}, v_{ITAy}, v_{SVKy}, v_{GBRy})$ are the weights of individual routes according to the current export of goods from the Czech Republic to individual countries in the given year y and n_{ESPy} $(n_{GERy},\ n_{ITAy},\ n_{SVKy},\ n_{GBRy})$ are the costs of individual routes in CZK / km for the year *y*, which were determined as the arithmetic mean of the costs calculated for the route in all four quarters. This was made possible thanks to the fact that the base was set retroactively in order to eliminate seasonal fluctuations. For completeness, let us add, that for the year 2014, the same equation as for the base applies.

The coefficients referred to in the equation express the part of the countries on the route in transport streams with export from the Czech Republic to selected EU countries by road freight transport, i.e. in direction to Spain (cost of 1 kilometre with ESP index) expresses the share of exports to France and Spain, the direction to Germany contains only the share of Germany (Germany is not included in the direction of Spain), the direction to Italy includes the share of Austria and Italy, direction to Slovakia contains only Slovakia and direction to United Kingdom contains shares of the Netherlands, Belgium and the United Kingdom. [1]

The indexes are then calculated on a quarterly basis according to the relationship, so for example the base index for the fourth quarter of 2016 will be:

$$iB = \frac{n_{G2016\_4Q}}{n_{G2014}}. \tag{2}$$

The quarterly index is a simple quotient of two consecutive quarters:

$$iQ = \frac{n_{G2016\_4Q}}{n_{G2016\_3Q}}. \tag{3}$$

2. The Web App Description

The ČESMAD BOHEMIA Index is presented to the public via the web application at www.indexcesmad.cz. On the home page (see fig. 1), the user finds the individual index options described in the previous first chapter. Here is the option to choose route, emission standard, fuel costs, and toll costs. The user also chooses the range of periods for which the index is to be set. Based on the user-specified option, the appropriate values of the given index variation in the implementation of iQ (Quarterly index) and iB (Base index) are immediately displayed. For selected index variants, it is possible to display a chart of development of index trend, which is compiled in cooperation with the website of traffic data: www.ioda.cz.

Fig. 1 The initial web app page offering ample options to calculate the index

If the user is interested in more detailed values for each index folder, they can be displayed for each period by clicking on the Detail button (see Fig. 2).

Detailní složky indexu podle druhu nákladů v období **2016/4** Zavřít detail

Detail	1.PohHmo	2.Materiál	3.PořVoz	4.Opravy	5a.Mzdy	5b.Diety	6.Mýto	7.Ostatní	8.Režie	Celkem
Podíl	27,88 %	2,97 %	17,98 %	1,75 %	12,11 %	10,69 %	16,74 %	3,98 %	5,90 %	100,00 %
iQ	103,38 %	100,00 %	100,19 %	101,19 %	100,53 %	99,98 %	99,75 %	100,00 %	101,19 %	101,07 %
iB	93,40 %	100,00 %	99,95 %	105,15 %	107,95 %	95,40 %	99,25 %	107,41 %	104,00 %	98,87 %

A share of different items in the index; Quarterly index; Base index

Fuel; Material; Vehicle acquisition; Repairs; Wages; Per diem costs; Toll; Other; Overheads; Total

Fig. 2 Index components broken down by the types of the costs

Index components broken down by the types of the costs display 9 basic index components: fuel (1), material (2), vehicle acquisition (3), repairs (4), wages (5a), per diem costs (5b), toll (6), other (7), and overheads (8). Index component values are set for iQ and iB. Additionally, it also shows a share of different items in the index in the percentage. If the user does not enter an optional component (e.g. Fuel) in the index variant selection, there is displayed and proportionally calculated only the limited selected set of index components (see Fig. 3), where the Fuel (1) and Toll (6) components are missing and the index is calculated without them.

Detailní složky indexu podle druhu nákladů v období **2016/4** Zavřít detail

Detail	2.Materiál	3.PořVoz	4.Opravy	5a.Mzdy	5b.Diety	7.Ostatní	8.Režie	Celkem
Podíl	5,36 %	32,47 %	3,16 %	21,87 %	19,30 %	7,19 %	10,66 %	100,00 %
iQ	100,00 %	100,19 %	101,19 %	100,53 %	99,98 %	100,00 %	101,19 %	100,34 %
iB	100,00 %	99,95 %	105,15 %	107,95 %	95,40 %	107,41 %	104,00 %	101,75 %

Fig. 3 Selected view of a limited set of index components

For a continuous index determination in the current period, for example, for the last quarter, some components of the index may only be preliminary since some components of the index are already known as final ones but others are only to be estimated by the time of publication of the final data. This applies, for example, to the Wages component (5a) in which the data base for its final determination are known with a certain time delay compared to the data base of the other components. If the index values are only preliminary, the user is notified by the red coloration of the given value (see Fig. 4).

GLOBAL, emisní kategorie **MIX**, index **bez nafty bez mýta (2017/1 - 2017/1)**

Období	iQ	iB	Akce
2017/1	*100,52 %	*102,28 %	Detail

Detailní složky indexu podle druhu nákladů v období **2017/1** Zavřít detail

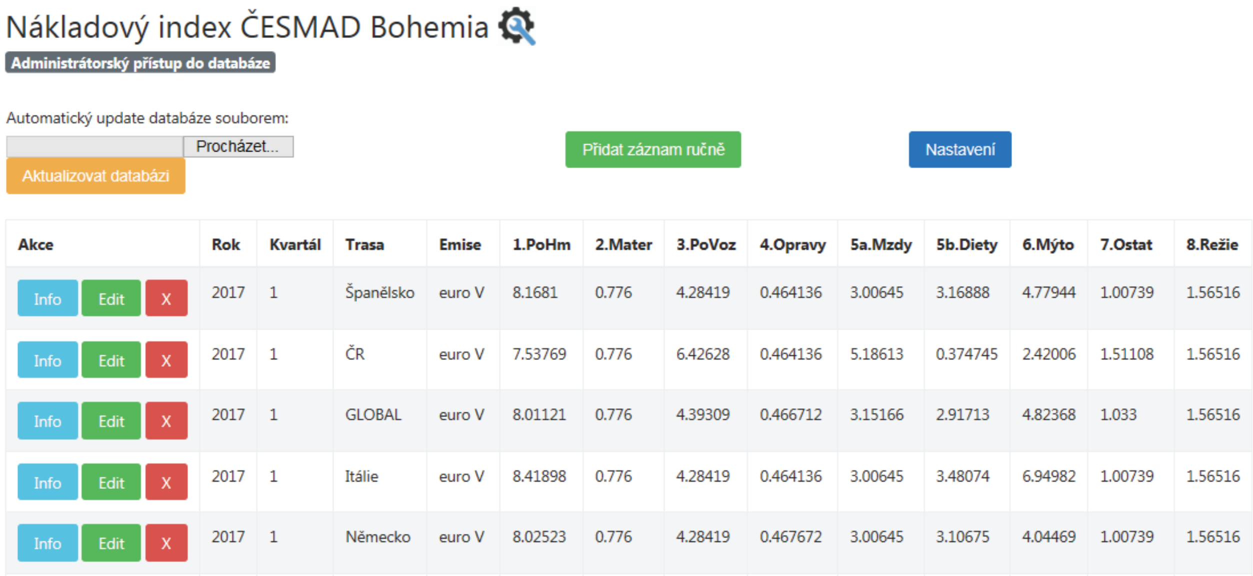
Detail	2.Materiál	3.PořVoz	4.Opravy	5a.Mzdy	5b.Diety	7.Ostatní	8.Režie	Celkem
Podíl	*5,33 %	*32,26 %	*3,20 %	*21,97 %	*19,34 %	*7,15 %	*10,75 %	100,00 %
iQ	100,00 %	99,86 %	101,90 %	*100,99 %	100,73 %	100,00 %	101,35 %	*100,52 %
iB	100,00 %	99,81 %	107,14 %	*109,02 %	96,09 %	107,41 %	105,40 %	*102,28 %

Fig. 4 The display of preliminary index values due to the absence of final data of the component „Wages“ (5a)

If the value of a component is only preliminary, it is, due to its inclusion, also preliminary the complete iQ and iB index. The percentages of all other components of the index are preliminary due to the calculation to 100%. At the moment of the availability of the final data bases, the updated data are inserted and the component is finally determined. The user is informed about all important events in the application through transparent chronological news (see fig. 5).

Fig. 5 Transparent news informs users of all important events

The application is managed on the background by the Administrator through a transparent admin interface (see Fig. 6).



Akce	Rok	Kvartál	Trasa	Emise	1.PoHm	2.Mater	3.PoVoz	4.Opravy	5a.Mzdy	5b.Diety	6.Mýto	7.Ostat	8.Režie
Info Edit X	2017	1	Španělsko	euro V	8.1681	0.776	4.28419	0.464136	3.00645	3.16888	4.77944	1.00739	1.56516
Info Edit X	2017	1	ČR	euro V	7.53769	0.776	6.42628	0.464136	5.18613	0.374745	2.42006	1.51108	1.56516
Info Edit X	2017	1	GLOBAL	euro V	8.01121	0.776	4.39309	0.466712	3.15166	2.91713	4.82368	1.033	1.56516
Info Edit X	2017	1	Itálie	euro V	8.41898	0.776	4.28419	0.464136	3.00645	3.48074	6.94982	1.00739	1.56516
Info Edit X	2017	1	Německo	euro V	8.02523	0.776	4.28419	0.467672	3.00645	3.10675	4.04469	1.00739	1.56516

Fig. 6 Interface on the background for the Administrator

The Web Application Index of Česmad Bohemia is designed for desktops as well as for tablets and smart telephones. The software is compatible with the latest PHP 7.0 and MySQL 5.6 standards.

3. Development of Road Freight Transport Costs between 2015 and 2017

Fundamental calculation items of the cost development are fuel, depreciation (leasing) and wage costs (along with diets), which make up 65-70% of all costs. [2] Fuel is significantly determined by oil prices (Fig. 7), which have ceased to decline during the year, followed by a rise in fuel prices in the first quarter of 2017, which was a dominant factor with respect to costs – for the MIX variant (where is assumed a vehicle fleet mixed from vehicles of EURO V and EURO VI emission classes) were the values between 3% and 7% according to the routes.

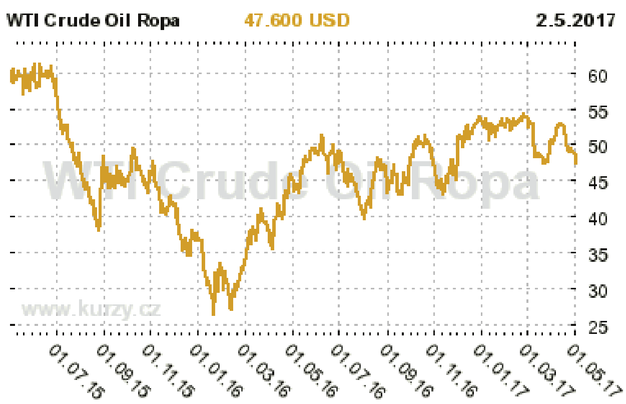


Fig. 7 Development in oil prices over the period 2015-2017 [3]

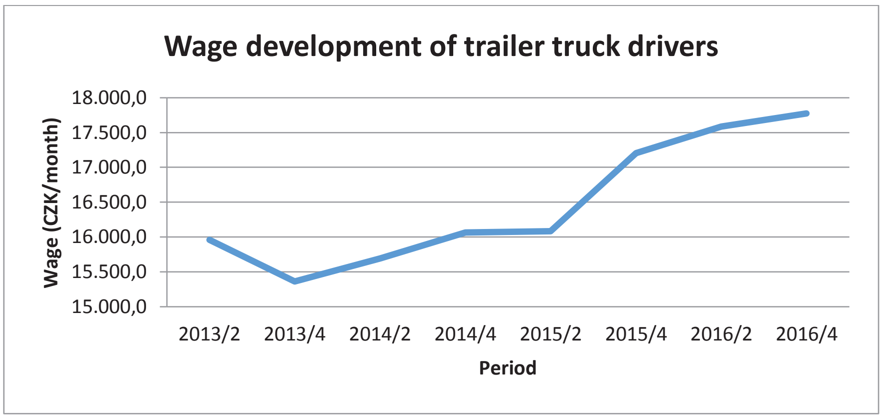


Fig. 8 Wage development of trailer truck drivers in the period 2013 – 2016 [4]

The rise of driver's wages, which stagnated (or more precisely the wages decreased) in 2008 to 2013, also plays a key role. Positive economic development and lack of drivers are the main causes of wage growth in 2014-2016, in average of 5% (Fig. 8).

Vehicles acquisition costs were affected by very low interest rates over the reporting period. However, there was a negative impact of an artificially low-maintained CZK exchange rate by the Czech National Bank. The Czech National Bank ended foreign exchange interventions on 6th April 2017, which should have an impact on lower costs of fuel, tolls, vehicle acquisition. Another factor is the composition of the vehicle fleet, the share of EURO VI emission class vehicles is still increasing (Fig. 9). This means higher costs for the vehicle acquisition and lower costs associated with fuel consumption, in some countries also lower toll costs [5] [6] .

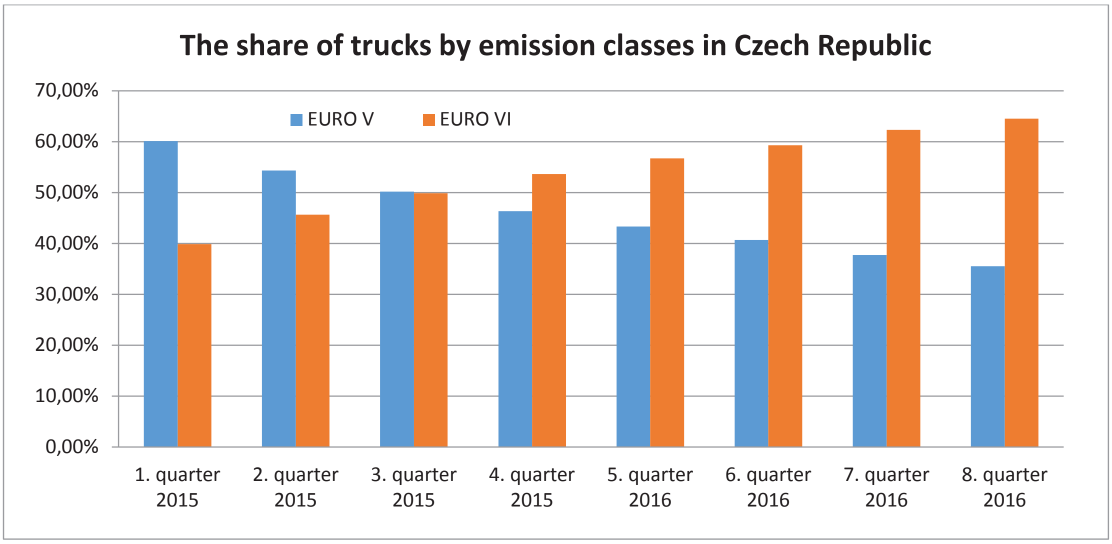


Fig. 9 Share of trailer trucks in EURO V and EURO VI emission classes [1]

Thus, in the period under review, there was a sharp drop in costs (compared to the year 2014 of around 8%), when substantially showed the sharp drop in fuel prices. This decline was stopped in 2016. In combination with the increase in wage costs, this causes a gradual return of road freight costs of transport to the level of 2014 (Fig. 10). In the near future can be expected the impact of the end of foreign exchange interventions, which should cause a reduction in items purchased outside the Czech Republic.

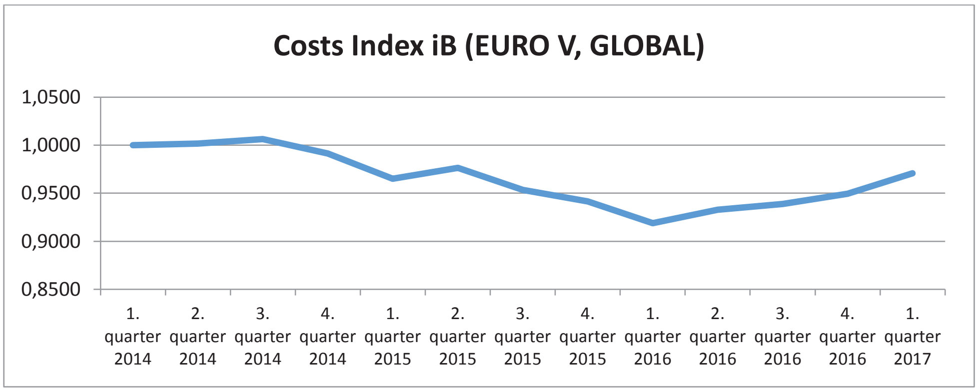


Fig. 10 The development iB costs index GLOBAL, EURO V in the period 2014 – 2017 [7]

4. Conclusion

The article deals with the creation of a cost index in road freight transport. We have already described the methodology on which it is based in other publications [8], here we deal more with how to present the issue through the web application to the professional public and, above all1, to the carriers. The article summarizes the basic principles of the web application and the user choice options. In the final section is summarised the development of costs in the period 2014 - 2016 and the essential factors in costs. It is observed that after a decrease in costs, during the year they are gradually returning to the level of 2014.

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Study of the Rolling Properties of Universal and Summer Car Tires

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Abstract

The wheel of a car should provide good grip with the road, as this affects the safety of driving. Also the wheel should roll easily. The rolling properties of the wheel determine the road resistance coefficient. The strength of the road resistance is valid at all times when the car is moving. Tires of a car, that roll easily, can significantly reduce fuel consumption and exhaust fumes. In the course of this study, the rolling properties of second-hand tires of different types are established. As a result of the research, it was noticed that the difference between the rolling properties of summer and universal tires is insignificant.
KEY WORDS: *car tire, rolling resistance, fuel economy*

1. Introduction

Car tires provide contact of a wheel with road. In addition to good grip, other requirements are imposed on tires: durability, low noise level during rolling, small energy losses during rolling, etc. Manufacturers constantly improve tires in order to obtain better performance.

The wheel of a car with a pneumatic tire tends to resist rolling. The road resistance of the tire depends on many factors: road surface, rolling speed, tire structure, tire tread pattern and properties of the rubber compound, gas pressure in the tire, load, etc. The properties of road resistance are established using the road resistance coefficient f, the dependencies of its change due to various factors. Depending on the road surface, tire structure and other factors, this coefficient can be from 0.006 to 0.06 [1]. The road resistance force of the tire directly depends on the coefficient value and can significantly affect the fuel consumption of the car.

In this article we will provide the results of experimental studies. The purpose of the experimental studies is to establish the road resistance properties of different tires. During the research, the coefficients of road resistance of different tires (universal and summer) were established. Also, tires with tread defects were studied.

Knowing the coefficient, which determines the rolling properties of tires, you can predict the fuel consumption of the car when driving in certain modes. Depending on the car, the effect of tires with different characteristics on fuel consumption is also different.

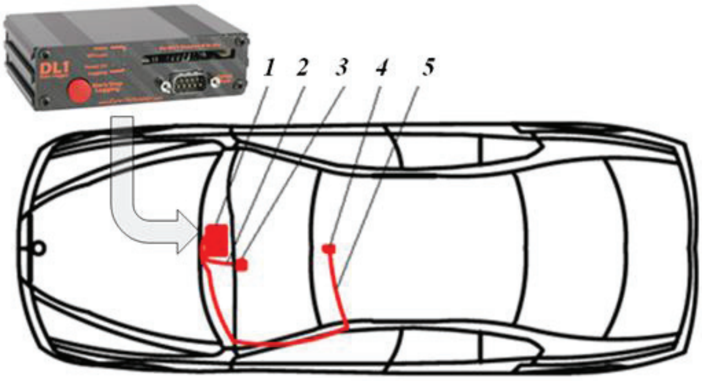
2. Research Methodology

Several methods can be used to establish the rolling properties of car tires [2, 3]: wheel rotation on the cylinder, driving through special sensors installed in the road surface; free-running rolling from an elevation of a certain height; free rolling of a vehicle at a certain speed. All these techniques require special equipment of different levels and complexity and have certain advantages and disadvantages. The coefficient of road resistance is most accurately established when the wheel rotates on a cylinder, but in this case the results do not reflect the road properties of the tire when rolling on a real road surface, in addition, special equipment is required. In order to establish the rolling properties of tires in real conditions, the most common method is when the car rolls freely on the road at a certain speed to a stop. During this test, the distance travelled and/or the deceleration acceleration can be measured. During the experiment, when measuring the deceleration acceleration of a car, it is possible to accurately estimate the dependence of the road resistance coefficient of a tire on speed, in addition, the experiments requires quite complex and universal equipment available at the Department of Transport Engineers KUT. Despite the listed advantages, this method has drawbacks - it is necessary to accurately estimate the road conditions (road inclination, turns and temperature of the coating), weather conditions (wind speed and direction and temperature) and properties of the car (inertia of the transmission and wheels, drag forces in the transmission).

The experiments were carried out with two cars - ALFA ROMEO GT 1.9 JTD (C_dA = 0.61 m^2, m = 1395 kg) and VOLVO S60 2.4D (C_dA = 0.663 m^2, m = 1535 kg) [4, 5]. Aerodynamic resistance of the car is calculated by the formula:

$$F_{aer} = \frac{C_d A \cdot \rho \cdot v^2}{2} . \quad (1)$$

The experiments were carried out using the DL1 Data Logger equipment (Fig. 1) [6]. This powerful multifunctional equipment, which is mobile, does not take up much space and is usually mounted in a car, it provides much data on the movement of the car. The device „DL1“ (1) in the car is fixed so that it would be parallel to the pavement and not tilted. Power cable (2) is connected to the car cigarette lighter outlet (3). GPS antenna wire (5) is connected to the device socket and the antenna itself (4) is placed on the roof. When you turn on the ignition and when the engine starts, DL1 receives power from the car and the device can be used.



Technical parameters of the block

Power supply voltage, V	12
Power supply for sensors, V	5
3 axes acceleration, g	2
Analog input channels	7
Frequentative inputs channels	4
Operating frequency, Hz	100

Fig. 1 Installation scheme of equipment in the car and technical parameters of “DL 1”

As a result of the experiments, in the "Race Technology v8.5" window of the DL1 Data Logger program, you can see a satellite image and it shows the route passed (Fig. 2). To obtain the desired values, the data from this program need to be transferred to Microsoft Excel, where further calculations are carried out.

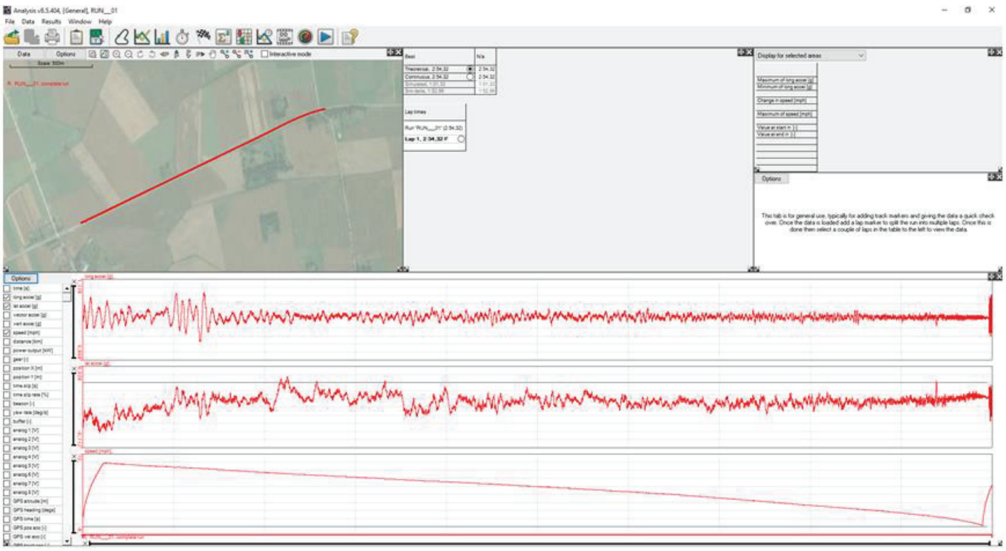


Fig. 2 Race Technology v8.5 window

During the research, the road resistance at different speeds is calculated; at different speeds the deceleration acceleration will be different. The road resistance coefficient is calculated based on the experimental results of free-rolling movement 3. The most important of the data, received from DL1 Data Logger, are the acceleration of deceleration and rolling speed; Microsoft Excel is used to establish the average speed and acceleration at the selected intervals of speed. When having these data and knowing that the deceleration of the car by free running is influenced by the resistance forces with direction, opposite to the driving direction: the aerodynamic force - F_{aer} and the road resistance of the wheels F_r, we can use Newton's Second Law, which states that the resultant of the forces acting on the body is equal to the product of the mass of the body by the acceleration being acquired. This law is represented by expression 2:

$$m \cdot a + F_{aer} + F_r = 0\,, \tag{2}$$

here m – weight of a car, kg; a – average acceleration of a car at the section of the speed under study, m/s^2; F_{aer} – aerodynamic force, N; F_r – wheels road resistance force, N.

The wheels road resistance force is established by the formula:

$$F_r = G \cdot f_a\,, \tag{3}$$

here G – car weight force, equal to the product of the car weight m by the free fall acceleration g, N; f_a – road resistance force.

The road resistance coefficient, at a certain speed value, is calculated as follows [7]:

$$f_a(v) = f_0 \cdot \left(1 + \frac{v^2}{1800}\right), \tag{4}$$

here f_0 – initial road resistance coefficient (at low speed).

The road resistance of wheels depends on the car speed squared.

Writing down the expressions 1, 3 and 5 in 2, we obtain:

$$-ma = G \cdot f_0 \cdot \left(1 + \frac{v^2}{1800}\right) + \frac{C_d A \cdot \rho \cdot v^2}{2}. \tag{5}$$

The road resistance of wheel is calculated from expression 5 at a low speed f_0:

$$f_0 = \frac{-m \cdot a - \dfrac{C_d A \cdot \rho \cdot v^2}{2}}{m \cdot g \cdot \left(1 + \dfrac{v^2}{1800}\right)}. \tag{6}$$

6 sets of tires were used for the study - 3 universal and 3 summer. Main sizes of the all tires are similar, the remainder of the tire thread is similar ~6-7 mm, air pressure in tires is 2.4 bar.

Sets of universal tires:

- Hankook Winter i-cept Evo;
- Michelin Alpin 5;
- Continental ContiWinterContact TS850.
- Sets of summer tires:
- Bridgestone Potenza Ra050 RFT (RunFlat);
- Michelin Primacy HP;
- Michelin Primacy HP (hard and graded).

There are two identical sets of tires Michelin Primacy HP, but their characteristics are very different. One set rides perfectly and without extraneous sounds, another set rides loud, during the test, there was also an increase in fuel consumption, and road irregularities were more noticeable.

A segment of the road is chosen based on how smooth the road is, the test requires a smooth and straight segment of the road. The segment of the straight road had to be at least 2 kilometers long, because the road section, on which the car rolls freely, was 1.5-1.7 kilometers. The condition of the road is satisfactory, therefore it corresponds to the signs of satisfactory asphalt. The traffic on the selected segment is not very heavy. During the research, the weather was favorable, the wind was imperceptible, even its directions could not be established, therefore, the wind effect is not taken into account for further calculations in calculating the road resistance coefficient. The temperature was about +18 C °, the test was carried out in the spring when it was already possible to drive using summer tires, so during the research the traffic rules were not violated when driving tires intended for the summer season.

3. Results of the Study and their Analysis

As a result of the experiments, road resistance coefficients of tires were established. Table 1 presents average values of road resistance f_0 of different tires at low speed (~30 km/h).

Table 1

Road resistance coefficients of various tires

Tire model	Road resistance coefficient f_0
Summer tires	
Bridgestone Potenza Ra050 RFT (RunFlat)	0.0167
Michelin Primacy HP	0.0151
Michelin Primacy HP (graded)	0.0176
Universal tires	
Hankook Winter i-cept Evo	0.0177
Michelin Alpin 5	0.0169
Continental ContiWinterContact TS850	0.0176

The results, presented in Table 1, show that the lowest road resistance coefficient is characteristic of summer tires Michelin Primacy HP ($f_0 = 0.0151$). Defective tires of this model (graded-worn tread pattern) have a 15% higher road resistance coefficient. Road resistance coefficient for tires Run flat type Bridgestone Potenza Ra050 RFT is also greater in comparison with the quality Michelin Primacy HP. For tires with a universal tread pattern suitable for the winter season, the road resistance coefficient is not much higher than that of summer tires and differs insignificantly for all three models.

Fig. 3 shows the dependences of road resistance coefficients on the rolling speed of three tires are presented.

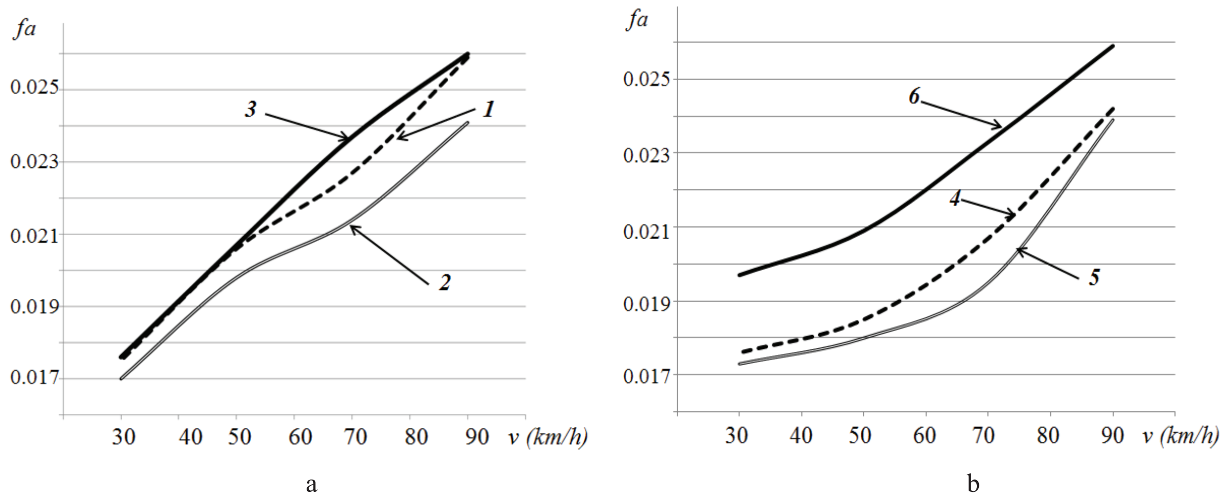


Fig. 3 Dependences of road resistance coefficients on speed for various tires. a - universal tires: *1* - Hankook Winter i-cept Evo; *2* - Michelin Alpin 5; *3* - Continental ContiWinterContact TS850; b – summer tires: *4* - Bridgestone Potenza Ra050 RFT (RunFlat); *5* - Michelin Primacy HP; *6* - Michelin Primacy HP (graded)

The comparison of the rolling properties of the universal (Fig. 3a) and summer (Fig. 3b) tires shows that the road resistance coefficient for the universal tires increases linearly along the whole distance of the three velocities. Dependences of the road resistance coefficient for summer tires are somewhat different – up to 70 km/h the increase is insignificant, when the speed increases the increase of the coefficient is more considerable. The results of these studies can be used to draw a conclusion that the road resistance properties of universal and summer tires are similar and the road resistance coefficient is slightly different. Some advantage is observed for the summer tires at movement speed of up to 70 km/h.

4. Conclusions

1. As a result of the full-scale experiments, road resistance coefficients for summer and universal second-hand tires were established. Among the three tires, Michelin Primacy HP have the lowest road resistance coefficient ($f_0 = 0.0151$), and universal tires Hankook Winter i-cept Evo ($f_0 = 0.0177$) have the highest coefficient.

2. When comparing the rolling characteristics of second-hand tires, there is a significant difference between high-quality and low-quality tires. The Michelin Primacy HP tires with a graded worn tread pattern have approximately 15% more road resistance than high-quality tires.

3. When comparing the rolling characteristics of summer and universal tires, there was no significant difference. Only the dependence of the change in the road resistance force on the speed of motion differs significantly. Summer tires have the advantage at speeds up to 70 km/h.

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Study of the Connection between Intercity Trains Using Fuzzy Linear Programming Method

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Abstract

The aim of this study is to develop a methodology for optimization of the connection between intercity passenger trains in transfer stations taking into account the uncertainty of the processes by using fuzzy linear programming method. The present research studies fuzzy problems with fuzzy numbers as the upper and lower limit of transfer time. The time it takes to make the transfer has been studied according to the delays of the trains. The delays have been investigated as a random variable and the log-normal distribution has been determined. The minimum length of the transfer has been used as a criterion of optimization. The fuzzy linear problem has been solved by membership function. The application of the methodology makes it possible to study the impact of the fluctuations in the delays on the length of the connection between intercity trains. The decision approach proposed in this study was tested for Sofia Central Railway Station on the Bulgarian rail network and an organization of sustainable railway passenger transport was proposed. As a result of using the methodology, the number of transfers between intercity fast trains at Sofia Central Station increased by 34% and the average length of the connection time was reduced by 26% as compared to the existing situation. The approach presented in this research can also be used for solving the connection between other categories of passenger trains and also in other types of transport which could contribute to increasing transport sustainability.

KEY WORDS: *fuzzy linear programming, connection time, transfer, intercity train, delay, railway transport*

1. Introduction

Optimal connection of passenger trains at junction stations is important for the total trip time of the passengers from the starting to the final point of their travel and for the overall organization of transport.

The length of transfers depends on railway infrastructure, the speed of passenger movement, how accurately the train schedule is kept, on the average delay of the passenger trains, especially for each of the railway lines that make the connection. The need for passenger transfers is the result of economic considerations because it is impossible to meet all passengers' requirements for direct transport. Transfers increase the number of possible connections, improve the operational flexibility and efficiency of the rail network. Transfers also have their inconveniences - discomfort caused when changing trains (need for orientation and pedestrian movement for changing trains, passing through tunnels, underpasses, etc.), prolongation of travel time. Improvements in the quality of transport service are achieved by synchronizing fast trains at railway stations.

Research studying the connections of trains aims to determine the transfer time of passengers when changing trains in the Netherlands [1]; the cyclic train timetable employed for German railways [2]; genetic algorithm for train timing optimization used in France [3]; determination of the so-called 'ideal running time supplements', which depends on the trains delay employed for the intercity railway network in Belgium [4]. A Mixed Integer Programming based timetable rescheduling algorithm has been proposed in [1], which minimizes the sum of the positive difference between the inconvenience of traveling by train and a planned timetable. The inconvenience of traveling by train has been defined as the weighted sum of the travel time on board, waiting time on platforms and the number of transfers. The length of the transfer time was determined by experts to be 10 min. The model presented in [4] includes two phases. In the first phase, ideal running time supplements are calculated to safeguard connections when the feeder train is late. The supplements are based on the delay distributions of the trains, passenger numbers and the weighting of different types of waiting times. In the second phase Linear Programming is used to construct an improved timetable with well-scheduled connections. A bi-objective problem has been considered in [5], which minimizes train delays and missed transfer connections by passengers. The results of passenger satisfaction survey in the City of Zagreb long distance terminal, in Croatia, have been presented in [6]. Simulation modeling of technological activity has been used in [7]. A model that considers the impact of train types on capacity and waiting time has been given in [8].

Some researchers have conducted research to establish the distribution of delays of trains. They have established negative exponential distribution [9], q-exponential functions [10], and Weibull distribution [11].

When determining the length of transfer time, it is important to take into account the uncertainty of the processes, because it cannot be predicted whether the connection will be affected because of delayed trains or other reasons.

The Fuzzy sets theory allows for the description of real situations, taking into consideration the uncertainty of the processes. The fuzzy linear programming approach (FLP) is an extension of the linear programming (LP) approach that allows for the incorporation of the uncertainty factor in the construction of a mathematical model for increasing the adequacy of optimization. Fuzzy programming is more flexible and makes it possible to find solutions which are more satisfactory for the real problem. In FLP, the uncertainty can be present in the objective function and/or in the constraints of the problem, and it can be represented by fuzzy sets. Many researchers have considered various types of the FLP problems and proposed several approaches for solving FLP problems [12-14].

It can be summarized that in transport research the fuzziness in the FLP models was investigated for costs, tonnage of the trains, time interval between a train leaving a station and the arrival of another train at the same station. The running time [15], the train re-scheduling problem [16], headway time for station and headway time for section [17] were investigated by FLP with soft constraints. The fuzziness of time interval connection has not been investigated.

The aim of this study is to develop a methodology for optimizing the connection between intercity passenger trains in transfer stations taking into account the uncertainty of the processes. The novel contribution of this paper is the adoption of the fuzzy approach for investigating the connection time in a transfer station by using the fuzzy integer linear programming method.

2. Methodology

Fuzziness can appear in different forms i.e. with fuzzy inequalities, fuzzy objective function, both fuzzy inequalities and fuzzy objective function and fuzzy parameters.

In this research the optimization of connection between intercity trains is made using the fuzzy set theory.

The optimal connection of the trains in the railway junctions is defined by the minimum length of the passengers' stay to make the connection between the trains. 'Connection' refers to the time interval between the arrival of the train from a certain direction to the moment of train departure from the same point to another direction. Passenger transfer time in stations is the minimum time that is required to change trains.

The railway network is represented as one connected junction structure. For every section between two junctions transport servicing is set, for which we can determine the minute of departure X_{ki}.The minute of arrival X_{kj} in the next junction is fixed depending on the minute of departure from the previous junction and the travel time between both railway junctions t_{ki}, i.e.:

$$X_{kj} = X_{ki} + t_{ki}, \text{ min}, \tag{1}$$

where $k = 1, \dots, K$ - number of junctions; $i = 1, \dots, n$ - number of sections between junctions.

To define the travel time we calculate only the part which exceeds the hour. For example, if the travel time is 2h 38 min, we calculate only 38 min. The main unknown quantities of the model are the minutes of departure X_{ki}. As the main unknown values are the minutes of departure, they may take values from 0 to 59 minutes. To facilitate the task, the minutes shall be transformed in hour hundredths. The main unknown values must meet the following conditions:

$$0 \leq X_{ki} < 1 \tag{2}$$

The objective function shows the minimization of the length of train connection time in the transfer station.

$$W = \sum_{k=1}^{K} \sum_{p=1}^{m} w_{kp} \rightarrow min, \tag{3}$$

where w_{kp} - length of connection time, min; p = 1,..,m - serial number of transfer between direction i and direction j.

$$w_{kp} = X_{ki} - X_{kj} + X_{kv} \geq \tilde{t}_{min,kp}; \tag{4}$$

$$w_{kp} = X_{ki} - X_{jk} + X_{kv} \leq \tilde{t}_{max,kp}, \tag{5}$$

where X_{kv} - additional integer unknown quantities, introduced to limit the main unknown values in the interval [0,1], i.e. negative values and values exceeding 1; $v = 1, .., V$ - number of the connections in the transfer station; $\tilde{t}_{min,kp}$, $\tilde{t}_{max,kp}$ - fuzzy quantities of minimum and maximum length of connection time which are modeled by fuzzy numbers of the highest and lowest acceptable levels, min.

$$X_{kv,min} \leq X_{kv} \leq X_{kv,max}; \tag{6}$$

$$X_{kv,min} = \tilde{t}_{min,kp} + t_{ki} + 1; \tag{7}$$

$$X_{kv,max} = \tilde{t}_{max,kp} + t_{ki} - 1, \tag{8}$$

The determination of the minimum length for the transfer of passengers from train to train can be defined in various ways, such as using appropriate models and presentation of transferability; expertly, using the experience of the staff; statistically, by observations of the length of the movement made with chronometers. For this purpose it is necessary to know: the passenger service technology at the station; the location of the building and the electronic interlocking boards; the timetable for the arrival and departure of trains at the station, i.e. the platform of arrival and the platform of departure for every train; the location of passenger service facilities - staircases, escalators, etc.; the average length of time needed to pass through technical facilities at the station.

The main prerequisites for determining the length of the minimum transfer time are: the passengers who will make a connection do not know on which platform the train is located; the passengers go to the electronic interlocking boards showing the arriving and departing trains; the passenger has purchased a ticket to travel from the start station of his trip or purchases a ticket at the station of transfer.

$$\tilde{t}_{min,kp} \geq t_{p,ij,k} + t_b + t_d + t_e, \text{min}; \tag{9}$$

$$\tilde{t}_{max,kp} \leq \tilde{t}_{min,kp} + t_o, \text{min}, \tag{10}$$

where $t_{p,ij,k}$ - length of the passenger movement from disembarkation on the platform from the arriving train i in station k to the arrival on the platform of the departing train j, min; t_b - length of time for buying a ticket for the train with which the connection will be made, min; $t_b = 0$ if the passenger has purchased a ticket for the transfer destination at the initial station; t_e - additional transfer time, which includes additional unrecognized factors such as, the difference in the psycho-physical qualities of each passenger in his movement, depending on their age, etc.; t_d - length of the average delay of intercity fast train, which is determined by establishing the distribution of delays for the junction, min.; t_0 - additional length that specifies the difference between the minimum and maximum length of the transfer, min. In the study it has been accepted that $t_0 = 10$ min.

The Fuzzy Linear programming method assumes that objectives and constraints in an imprecise and uncertain situation can be represented by fuzzy sets in fuzzy programming. The fuzziness of available resources is represented by the membership functions over the tolerance range. The membership functions that can be applied are linear, nonlinear, triangular, and trapezoidal. Linear membership functions are used in this research.

The membership functions can be expressed as:

$$\mu_W = \begin{cases} 1, if \;\; W \leq W_L \\ \frac{W_U - W}{W_U - W_L}, if \; W_L \leq W \leq W_U \\ 0, if \; W \geq W_U \end{cases} \tag{11}$$

where W_U, W_L – highest and lowest acceptable levels of the objective that can be obtained with individual optimization.

For constraints by type “>=” (4) the membership functions are:

$$\mu_{w_{kp1}} = \begin{cases} 1, if w_{kp} \geq tmin_{kp,U} \\ \frac{w_{kp} - tmin_{kp,L}}{tmin_{kp,U} - tmin_{kp,L}}, if tmin_{kp,L} \leq w_{kp} < tmin_{kp,U} \\ 0, if \; w_{kp} < tmin_{kp,L} \end{cases} \tag{12}$$

where $tmin_{kp,L}$, $tmin_{kp,U}$ - highest and lowest acceptable levels of the fuzzy quantities of minimal value of time connection, min.

For constraints by type “<=” (5) the membership functions are:

$$\mu_{w_{kp2}} = \begin{cases} 1, if w_{kp} \leq tmax_{kp,L} \\ \frac{tmax_{kp,U} - w_{kp}}{tmax_{kp,U} - tmax_{kp,L}}, if tmax_{kp,L} < w_{kp} \leq tmax_{kp,U} \\ 0, if \; w_{kp} > tmax_{kp,U} \end{cases} \tag{13}$$

where $tmax_{kp,L}$, $tmax_{kp,U}$ - highest and lowest acceptable levels of the fuzzy quantities of maximal value of time connection, min.

Fig. 1, a, b and c present membership functions for minimization of objectives, for constraints by type “>=” and for constraints by type “<=”.

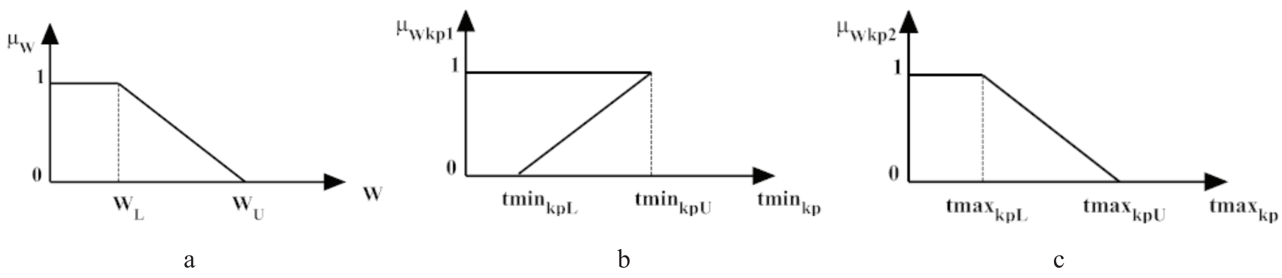

Fig. 1 Membership functions for (a) minimization of objective, (b) for constraints (4), (c) for constraints (5)

By introducing a new variable λ, the problem can be reorganized as fuzzy linear programming model:

$$max\lambda. \tag{14}$$

Subject to:

$$\lambda \le \mu_W \text{ , for objective function;} \tag{15}$$

$$\lambda \le \mu_{w_{kp1}}\text{, for each fuzzy constraint;} \tag{16}$$

$$\lambda \le \mu_{w_{kp2}} \text{ , for each fuzzy constraint} \tag{17}$$

$$0 \le \lambda \le 1, \tag{18}$$

and constraints (2), (6).

3. Results and Discussion

The proposed methodology has been applied for the railway junction of Central Railway Station - Sofia on the Bulgarian railway network. This is the largest railway station in Bulgaria. The main railway lines of the railway network of Bulgaria meet in this junction and that was why it was selected to conduct the study. A combination of railway directions was made in order to simplify the model and reduce the number of unknown values. Fig. 2 shows a scheme of the main unknown values in the model. Only train connections in one junction - Sofia Central Station - were investigated in this model, so the number of the node is not recorded in unknown values, only the serial number is recorded. The unknown values X_1/X_2 combine departure/arrival of trains in the direction of the towns of Vidin, Lom, Ruse and Varna; the unknown values X_3/X_4 combine the departure of trains to Varna and Burgas; the unknown values X_5/X_6 combine the departure of trains in the direction of Plovdiv - Burgas and Svilengrad; the unknown values X_7/X_8 combine the departure of trains in the direction of Kyustendil and Kulata.

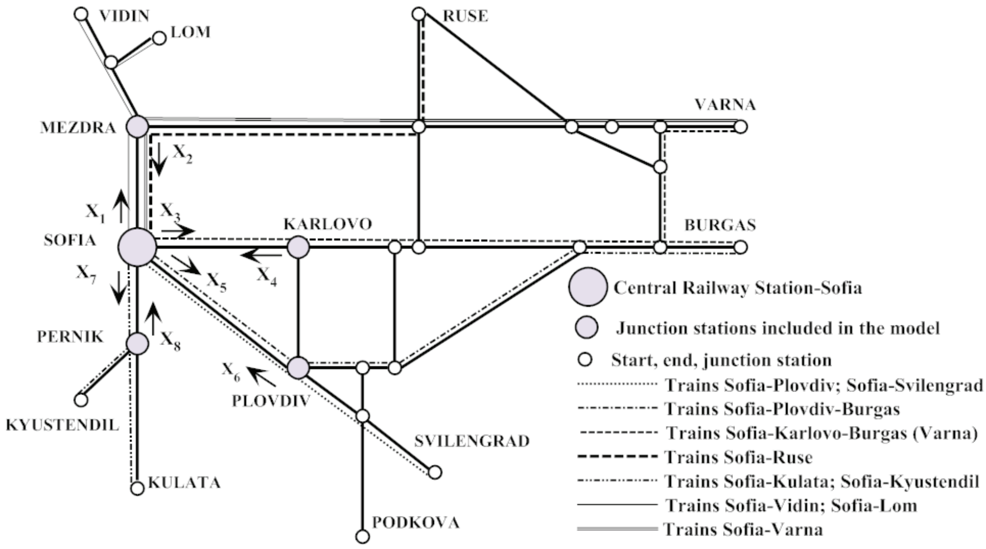

Fig. 2 Scheme of the train routes from Sofia Central Railway Station on the railway network and the main unknown values in the model

In the study it was accepted that the length of passage of the passenger from the platform of the arriving train to the platform of the departing train was $t_{p,ij,k}$ = 10 min; the average delay time of a fast train t_d = 20 min, which is based on the designated log-normal distribution with an average delay time of 15.4 min and a standard deviation of 12.61 min. The value of t_d includes half of the standard deviation since the number of cases of delay over 20 min is small. In this case, the minimum length of the connection time is 30 min; the maximum length of connection time is 40 min. To account for the uncertainty of the processes the highest and lowest acceptable levels of the fuzzy quantities of minimal value of connection time are $tmin_{kp,L}$ = 25 min, $tmin_{kp,U}$ = 30 min; the highest and lowest acceptable levels of the fuzzy quantities of maximal value of connection time are $tmax_{kp,L}$ = 40 min, $tmax_{kp,U}$ = 45 min.

Data for the daily delays of the intercity fast trains due to the disruption of train connections provided by BDZ - Passenger Services Ltd was used to conduct the study. A three-year period (2011-2013) has been analysed with a total of 495 cases with delays of up to 60 minutes. The type of histogram of the probability distribution of the random variable assumed that the distribution can be described by the following distribution: log-normal, Gamma, Weibull and exponential distribution. Fig. 3 shows the results. It has been found that the distribution of the delay of intercity fast trains is logarithmically normal, with an average delay of 15.40 min and a standard deviation of 12.61 min. The confidence interval is within the range [14.28; 16.51]. The probability value (p-value) of lognormal distribution is 0.0796 by Kolmogorov-Smirnov test with 95% significance level. For the other studied distributions p-value is less than

0.5 indicating that they are not applicable.

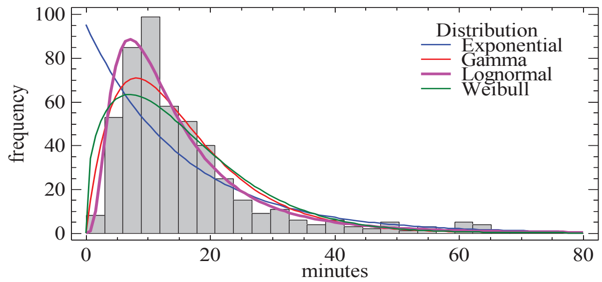

Fig. 3 Distribution function for train delay

Table 1 shows the results of the study. The fourth column of the table shows the way of obtaining the minute arrival according to formula (1). The fifth and sixth column of the table shows the results for the minutes of departure and the value of the objective function for the individual optimizations using the highest and lowest acceptable levels of the minimal and maximal value of connection time and fuzzy optimization. The study was conducted by setting an initial value of one of the unknown values - minute of departure from Sofia Central Station in the direction of Sofia - Plovdiv (X_5=0.25; this is the 15th minute), which allows for a more comfortable time of departure for the passengers from the starting station. The chosen value corresponds to the current train schedule. This direction was preferred because it has maximum passenger flows. The individual optimizations were performed on a linear optimization model with right boundaries of restrictive conditions (4) and (5): $tmin_{kp}$ = 30 min and $tmax_{kp}$ = 40 min to determine the lowest acceptable levels of the objective W_L; $tmin_{kp}$ = 25 min и $tmax_{kp}$ = 45 min to determine the highest acceptable levels of the objective W_U. The fuzzy linear optimization allows us to reduce the average length of connection time as compared to individual optimization. The obtained results for the minutes of departure of intercity fast trains (the last column in Table1) were used to elaborate a train timetable with synchronized connections between intercity trains. The elaborated model allows us to develop a cyclic train schedule. Table 2 presents the comparison of the obtained results and the 2015/2016 train timetable. We have realized a change of departure time and arrival time of intercity trains from/in Sofia Central Station, which allowed for a reduction of the average length of connection time. The number of train connections per day increases from 28 in the train schedule 2015/2016 to 38 by using the methodology.

Table 1

Results

From - To	time: h, min	Unknowns in model		Results of minutes to depart, min		
				Individual optimization		Fuzzy optimization
		minute of departure	minute of arrival	lowest acceptable levels	highest acceptable levels	
Sofia - Mezdra	1h 3 min	X_1	X_1 +3	15	59	14
Mezdra - Sofia	1 h 31 min	X_2	X_2+31	14	3	16
Sofia - Karlovo	2h 27min	X_3	X_3 +27	15	59	14
Karlovo - Sofia	2h 26min	X_4	X_4+26	19	8	21
Sofia - Plovdiv	2h 34min	X_5	X_5 +34	15	15	15
Plovdiv - Sofia	2h 44min	X_6	X_6+44	1	50	3
Sofia - Pernik	48 min	X_7	X_7+48	15	59	14
Pernik - Sofia	48min	X_8	X_8+48	57	46	59
Value of objective function				W_L = 19.94	W_U =21.99	λ = 0.441
Average length of connection time, min				30	28	27
Average length of connection time by train timetable 2015/16, min				41		

Table 2

Comparison of length and number of transfers by railway lines

From/To	Plovdiv-Sofia				Mezdra-Sofia						Pernik-Sofia						Karlovo-Sofia			
1- Length of transfer, min	Sofia-Pernik		Sofia-Mezdra		Sofia-Plovdiv		Sofia-Pernik		Sofia-Karlovo		Sofia-Plovdiv		Sofia-Mezdra		Sofia-Karlovo		Sofia-Pernik		Sofia-Mezdra	
2- Number of transfers	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Train Timetable	49	3	46	5	37	6	35	4	42	3	37	1	32	1	0	0	31	2	43	3
Methodology	27	5	27	5	28	5	27	5	27	2	28	5	27	5	27	2	26	2	25	3

4. Conclusions

The present study develops a methodology of optimizing the connection between intercity trains by taking into account the uncertainty of the processes by using the fuzzy linear programming method. As a criterion for optimization we have applied the minimum length of time for connections of trains in railway junctions.

Connection time has been determined by taking into consideration the average delay of intercity fast trains. The lognormal distribution of delay of intercity trains has been defined in the study.

The methodology has been tested for the optimization of intercity fast train connections at Sofia Central Station. As a result of using the methodology, the number of connections between the intercity fast trains at Sofia Central Station increased by 34% and the average length of the connection was reduced by 26% when compared to the existing organization. The obtained results make it possible to develop a cyclic passenger railway timetabling.

The methodology can be used to optimize the connection between trains in transfer stations once or more times a day or for elaboration of a cyclic train schedule. The methodology can be applied also for both railway junctions and railway network. It also could be used to determine the connection between other categories of passenger trains such as suburban trains or international passenger trains.

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On the Problem of Quantitative Analysis of the Concentration on the Postal and Logistics Market

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Abstract

Slovak competition policy is built on the pillars of the EU legal framework. It is designed to address issues related to the elimination agreements restricting competition and abuse of dominant market position, the control of company fusions, liberalization of monopoly economic sectors and state aid monitoring. Application of those rules are becoming increasingly concerns the postal and logistics services after the completed liberalization process. On the one hand, the postal sector is characterized by the existence of a highly competitive environment, particularly through the development of e-commerce. On the other hand, there still exists an obligation to ensure the availability of postal services that are regulated by the government. Many practical examples (from other sectors) indicate the tendency of enterprises to create conditions and scope for abuse of its market dominance. The role of regulatory authority starts here to control market concentration and to assess effective competition.

The paper deals with the diagnostics of the competitive environment in the postal and logistics sector by applying quantitative methods and procedures for analysing the market concentrations and entry barriers.

KEY WORDS: *market concentration, market share, quantitative analyses, postal and logistics market*

1. Introduction

The guarantor of economic competition in the EU is the EC, which has a number of tools at its disposal. These include primarily a ban on cartels in a single market, a ban on abusing dominant position on the market, ensuring a level playing field and equal access to public and private business entities, control of mergers, and oversight on supranational subsidies or state aid. The protection of economic competition affects business entities in two basic areas, specifically: in the field of anti-competitive behavior of business entities (so called anti-monopoly, or antitrust policy); and in the field of state intervention, which can deform competition mainly by providing state aid. [6, 11, 13, 14]

Competitive structure of each sector can take on a various characteristics, depending on the number and size of the entities operating in given field. One of the possible forms of competitive structures of the field is a concentrated industry. The concentration can take on various forms in connection to the nature of business. Usually, we talk about horizontal concentration, vertical concentration, and mixed concentration (conglomerate). Horizontal concentration occurs by merging entities operating in the same industry that produce identical or similar product and sell them in the same geographical conditions. The consequences of horizontal concentration is the increase of the size of the entities and the decrease of the number of entities in the sector. [1, 10]

2. Goals and Methodology

In the paper we will focus on the horizontal concentration, because the development and the level of horizontal concentration in the sector is an essential factor characterizing the level of competitive environment, and its exact definition is based on the system of quantitative characteristics. These are part of analytical materials in state institutions dealing with the enforcement of economic competition rules in most developed economies. Many authors as a Unčovský, Brezina (1999), Mihalčová, Hintošová (2004), Schaeffer, Kouassi (2014), dealt and are dealing with this issue [15, 17, 18].

There are a number of methods published in the literature that can be used successfully to evaluate the level and concentration in the conditions of imperfect competition. Basically all of them are based on market share. The market share is the share of the entity in given market or a sector. If n represents the number of entities in a particular sector and qi indicates *i*-th entity in given sector ($i = 1, 2,..., n$), then the market share of *i*-th entity in the field can be calculated based on the following relation:

$$s_i = \frac{q_i}{\sum_{i=1}^{n} q_i}. \quad (1)$$

Depending on whether indicators quantify the level of concentration with respect to all entities, or only with respect to the subset with a certain quality, we differentiate indicators to two groups, namely:

1. Indicators for measuring the absolute concentration.
2. Indicators for measuring the relative concentration.

The most famous quantitative approaches used to analyse the market include statistical and economic methods, game theory, and special indexes. [3, 12, 18]

The analysis of the concentration of any sector can be implemented using indexes that allow to analyse the status of competitive behaviour of entities operating in the relevant market. This analysis provides information to the regulatory bodies on the structure of the market and it allows to create recommendations for specific economic measures.

The most well-known indexes for measuring concentration in given industry include the m Concentration Ratio of the strongest entities in the sector *CRm* and the *HHI Herfindahl-Hirschman Index of Concentration*. The GI Gini Index is also frequently used, which is based on the Lorenz curve capturing actual distribution of market shares. When evaluating the status of the competitive environment of the sector, other special indexes, such as Complex Concentration Index, Rosenbluth Index, Hannaha-Kaya Index, can be used. Many analyses combine various indexes by the authors: Kwoka (1977), Golan, Judge and Perloff (1996), Bikker and Haaf (2002), Naudé (2006), Kate (2006), Glick and Campbell (2007).

2.1. Measuring the Absolute Concentration

Determining the degree of concentration is usually linked to market assessment. The absolute level of market concentration allows to describe the market structure. Indicators usually serve for indirect comparison of economic power of market participants, or to compare their competition and inequality of market share distribution.

The indicators express the level of concentration that is determining for the regulatory authority in case it is necessary to intervene and prevent changes in concentrations in the relevant markets. The calculation of the individual indicators of absolute concentration is linked to the market share of market participants. The limiting case is a monopoly, which expresses the maximum concentration, since the share of a single market entity is 100%. In case there are more entities in the market, their share depends on the distribution of total production in sectors between these entities and also on the number of these entities. If the market is made of different products that have a certain degree of substitution or aggregation, it is necessary to set the rules for the assessment of production in given market.

Concentration Ratio - CR_m

Serves to measure the concentration for *m* most powerful companies in the sector in terms of the market share of homogeneous production. The concentration ratio for *m* most powerful companies in given sector is simply expresses their market share on the total production of all companies in given sector, whereby $s_1 \geq s_2 \geq s_3 \geq .... \geq s_n$, where we calculate s_i using the relation (1).

$$CR_m = \sum_{i=1}^{m} s_i \,, \tag{2}$$

here $m \in \langle 1; n \rangle$.

This indicator can reach values in the interval $0 \leq CRm \leq 1$. Usually *CRm* is quantified for *m* = 4, 8, 10, 25, 50, 100, or *m* = 3, 6, 25, 50, 100 most powerful companies in the sector. However, in our case we will consider the first option, because Slovak Republic is one of the smaller countries, where it is not usual to consider the concentration of higher classes for 50 or 100 most powerful companies. Most common, the concentration of the 4 most powerful companies in the sector is used; Federal Trade Commission (FTC) in the USA uses it to a large extent.

When considering the concentration based on the concentration ratio for the 4 most powerful companies in the sector (CR4) according to the FTC in the USA, the sector is:

- Un-concentrated, if the 4 most powerful companies produce less than 25% of industry output,
- Moderately concentrated, if the 4 most powerful companies produce at least 25% and less than 50% of industry output,
- Concentrated, if the 4 most powerful companies produce at least 50 % of industry output.

Herfindahl-Hirschman index - HHI

It is the convex function of market shares of all companies in given sector. We define this rate is the sum of squares of market shares s_i, (according to the relation (1), i = 1,2,...,n) of all companies in given field:

$$HHI = \sum_{i=1}^{n} (s_i)^2. \tag{3}$$

The HHI index can reach a maximum value of 1. This status occurs if in the sector the offer is concentrated by 1 company with a minimum value of 1/n in case that all companies have the same market share. However with its construction, the HHI does not reflect the impact of small companies on the concentration in given sector, the share of which on the production of the sector is less than 1%. [3] The market share of the company or a merged company can be used to consider the concentration and its subsequent approval or rejection. The new classification (since 2010) of the degree of concentration in the industry, according to the calculated index value, as listed by FTC in the USA [21] is:

- Unconcentrated if the HHI value is less than 0,15
- Moderately concentrated if the HHI value is within the range of $\langle 0{,}15;\ 0{,}25 \rangle$
- Concentrated HHI value is greater than 0,25

The own classification of the degree of concentration in the sector concerned is used by the European Commission for the assessment of horizontal mergers under the Council Regulation on the control of concentrations between undertakings (2004/C 31/03) within the scope of:

- Un-concentrated industry, for an HHI value of less than 0,1,
- Moderately concentrated industry, for HHI from the interval, $\langle 0{,}1;\ 0{,}2\rangle$
- Concentrated industry, for an HHI value greater than 0,2.

2.2. Indicators to Measure the Relative Concentration

Indicators to measure the relative concentration are characterized by the shares of individual entities corresponding to the total number of entities in the market and the concentration in the sector can be determined by the unequal distribution of the values of the monitored indicators.

General concentration index - points to the dispersion of individual entities in the market, whereby it also considers the absolute value. Market participants need to be ranked in an ascending manner. The main emphasis is placed on entities with the largest market share.

Dispersion rate – this indicator is the equivalent of the absolute concentration ratio and it is also expressed using it. The dispersion rate is defined as a share of the concentration ratio value of a certain number of entities, which corresponds to the highest value of the indicator. The market share of these participants is based on the uneven distribution of the value of the monitored indicator corresponding to these entities, which have the highest indicator value.

The resulting value of the dispersion rate is in the range (0, 1), whereby the value of 0 is reached in case of evenly distributed shares in the sector among the monitored entities. If the indicator value reaches 1 or it is close to it, we talk about the dominance of some entities in the market.

Variation coefficient - expresses the extent to which the influence between market entities is distributed, so it characterizes the relative rate of variability. It represents the equivalent of the relative concentration indicator to the Herfinadhal-Hirshman Index, whereby in determining the concentration level it considers the specific number of entities in the market in the monitored sector. If the value of the variation coefficient equals 0, we can assume that the market share in the sector is absolutely evenly distributed among the entities.

3. Results and Discussion

3.1. The Core Indicators for the Measuring the Concentration in the Postal and Logistic Services Sector

Network industries represent strategically important components of the national economy. An important characteristic of these industries is a general nature of the need for their performance and universality of mutual relationships with all sectors of the national economy [4, 5]. The development of this sector especially in the field of parcel and express services is linked in Europe and other world countries also to mergers, acquisitions, or market dominance, etc., which requires the states to be prepared for ex ante or ex post regulations. The existence of four global integrators (UPS, FEDEX, DHL, TNT) and many major European or national providers and also regional providers creates substantial competition on the logistics, express services and parcel market. This also shows the data provided by the European Regulators Group for Postal Services (ERGP) or Universal Postal Union. [19, 20] According to the ERGP report (16) 46, as suggested by HHI and the number of postal service providers with a market share of more 1%, we can state that the European postal market is highly concentrated, whereby there is a discrete growing trend of the number of these operators.

In terms of market shares of universal service providers, these maintain a high market share in the segment of letter items (on average 87% in 2015) and in the non-export market (70%). Their market shares are much lower in the parcel segment, only 30%, and 20% in the case of express items in 2015. The total volume of postal services in the postal market between 2013 and 2015 fell by 4.3% and decrease of letter items by 4.6% contributes significantly to this fact, whereby package volumes increased by 6.9% (see Table 1).

Table 1

Total postal volume and revenues: annual average change (2013-2015)

Total postal volumes	Annual average change	Total postal revenues	Annual average change
Total Postal Volumes	-4,3%	Total Postal Revenues	+0,3%
Total Letters Volumes	-4,6%	Total Letters Revenues	-1,8%
Total Parcel Volumes	+6,9%	Total Parcel Revenues	+5,1%
Total Express Volume	+27,8%	Total Express Revenues	+8,6

In the ERGP countries, the universal service providers generally maintains a high market share for letter volume, which was in 2015, on average 87% (in 2013 was 88%). In general, the universal service providers' market share remains stable between 2013 and 2015. But in Netherlands and Czech Republic the universal service provider volume share for letters decreased in this period, while in Lithuania and Croatia increased, respectively, 11,0% and 11,3%. The universal service providers have much lower markets shares regarding the parcels, which, on average is around 30,3%

(in 2013 was 31,4%). In general, the universal service providers lost market share for the parcel segment, but there are some exceptions (Luxemburg, Portugal, Hungary and Poland). The average universal postal providers' market share for express items in 2015 is 20,4%, a slight decrease compared with 2013. It is worth mentioning that in the case of Poland, the universal service provider market volume share increased from 3% in 2013 to 16% in 2015.

Total volume across ERGP countries has fallen (see Table 2), on average, by 4,3% each year since 2013. Driven by continued electronic substitution of traditional letter volumes, between the period of 2013 and 2015, volume declined by around 4,7 billion items.

The total volumes decline has been highest in the Western cluster of countries (see the ERGP Report (16) 38). Nevertheless, the highest decrease in terms of rate was in the Southern cluster: on average, volumes fell by 5,3% each year between 2013 and 2015 across this group of countries. Across each cluster, volumes have declined. Express volume, on the other hand, has been rising with an annual average change of 13,1%. The increase of parcel volumes, which often include additional services such as increased speed and guarantee of delivery time, has contributed to this growth.

Table 2

Total Postal Volumes and annual Average Change 2013 – 2015

	Total Postal Volume - Annual average change	Total Postal Revenue - Annual average change
All countries	-4,3%	+0,3%
Western	-4,1%	+0,2%
Southern	-5,3%	+0,4%
Eastern	-3,6%	+1,3%
Non-EU	-3,2%	+6,3%

Between 2008 and 2015, there has been a decline of 13,0% in the number of people employed by the universal service providers across this period. For other postal services providers, there has been a 29,8% increase in the number of people employed. As a result, for these countries, total postal employment decrease 1,2% between 2008 and 2015. Into the period of 2013 to 2015, across ERGP countries the universal service providers and also the other postal service providers, the total employment variation decrease on average -6,9%. For the majority of the countries there was a decrease in the employment, with the exception of Luxemburg (1,3%), Bulgaria (2,5%), Latvia (2,6%) and Slovakia (6,0%).

3.2. Measuring the Concentration in the Parcel and Express Services Sector in Slovakia

The postal services sector belongs in the section H - Transportation and storage according to the SK NACE industry classification. Under this section we will monitor Division 53 - Postal services and courier services. This industry is characterized by a moderately concentration as shown in Fig. 1 and Fig. 2. A typical feature is that part of the services are currently subject to regulation (universal service), however a large part of the industry is characterized by considerable upheaval, which mainly relates to the development of information and communication technologies. These penetrate the industry directly through newly created additional and support services for classic delivery services. Another major aspect of the development of these services is e-commerce, where the postal and logistical services sector ensures distribution channels for goods originating in the virtual environment, both in the domestic and foreign market.

The number of postal services providers has been stable over the last couple of years. In 2010 there were 23 postal companies registered, whereby in 2015 there were 22. However, if we consider the parcel and express services sector (CEP), the number of providers is somewhat lower (see Table 3).

Table 3

Number of parcel and express services providers

	2010	2011	2012	2013	2014	2015
Number of CEP providers	13	13	15	15	15	17

To identify HHI and the concentration ratio we use data on market shares of major CEP providers in the postal market between 2010 and 2015. Applied indicators are the input source for asserting the competitive market environment and also a control tool to monitor market changes, as well as decision making on future regulation. HHI as well as the concentration ratio offer in this case an effective and relatively simple calculation method, and therefore it is used very often in profession and scientific circles. From the presented HHI development it is clear that the marked manifests moderately concentration.

We calculate the concentration ratio for $m=4$ of the most powerful companies in the sector using relation (2). The concentration ratio of the most powerful company in the CEP sector for Company 1 in 2010 was $CR1 = 0,25$; so the share on total CEP sector was 25%. The concentration ratio of the two most powerful companies in the CEP sector (Company 1 + Company 2) in 2010 was $CR2 = 0,43$; so the share was 43%. The concentration ratio of the three most powerful providers in the sector was $CR3 = 0,58$; so the share was 58 % and that of the four most powerful providers in the sector was $CR4 = 0{,}72$; so the share was 72%. Figure 1 shows the concentration ratio for the most powerful companies in the industry (for $m = 1, 2, 3, 4$) for the next years.

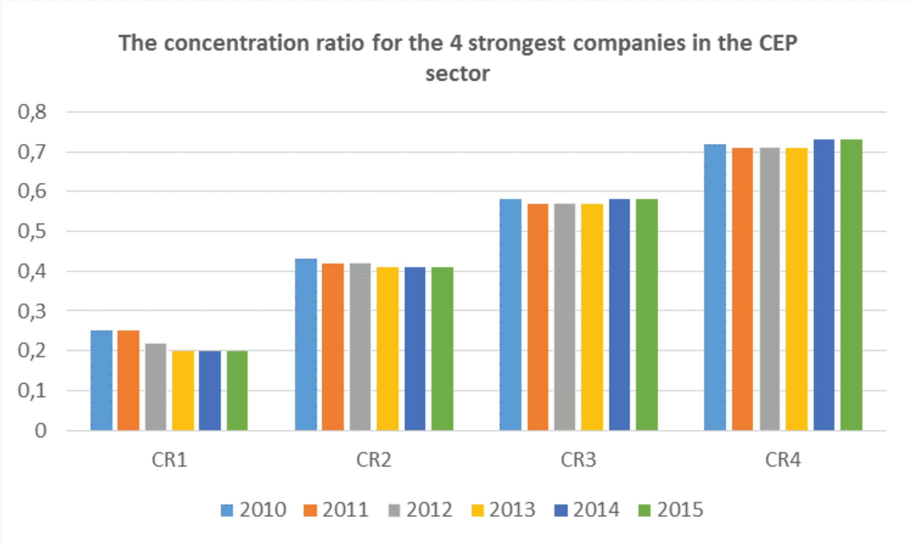

Fig. 1 Concentration ratio for the 4 strongest companies in the CEP sector

Based on the concentration ratio for the four most powerful companies in the sector, according to the generally accepted FTC USA classification, given sector is concentrated, because the CR4 value is higher than 0,5 (see Fig. 1). In the CEP industry the CR4 value in all monitored periods is higher than 0,7; i. e. 70%, so it exceeds the stated threshold by more than 20 percentage points.

The most commonly used concentration ratio is HHI, which is calculated based on the relation (3). For the CEP industry the value of this index in 2010 was 0,1471; in 2011 it was 0,1495. In each years, the number of CEP providers was different in the market (see Table 3). In 2010 there were 13 companies, in 2015 there were 17 providers. Fig. 2 shows the HHI index values for 2010-2015.

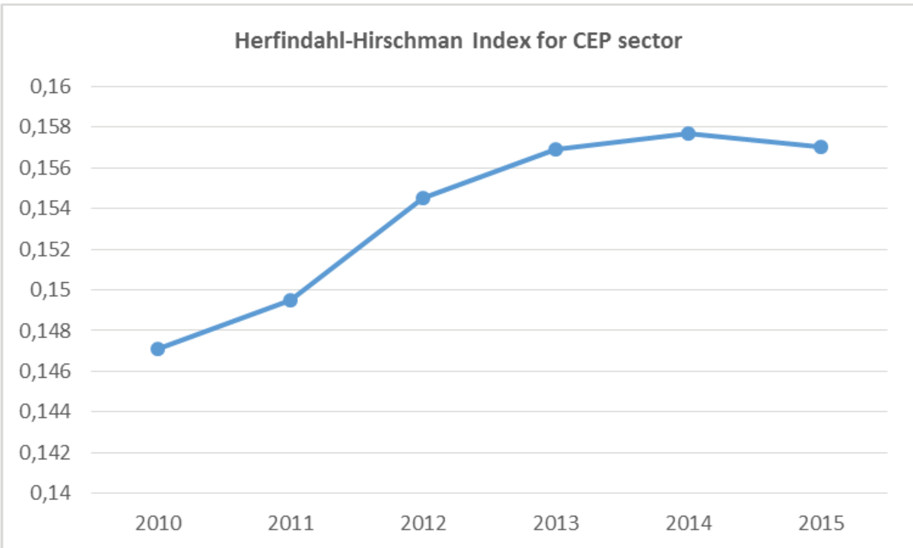

Fig. 2 HHI for CEP sector in Slovakia

The structure of the muscle with no moving parts allows achieving quite short response time – the favourable parameter for the application in active suspension. That is why as an initial stage of the presented research the investigation of the operational parameters of the muscle itself is very important.

4. Conclusions

The selection and application of a suitable analytical indicator depends on the goals of the analysis of the market environment in relation to the type and structure of the industry. A necessary aspect of using quantitative methods of assessing concentration in given market is the existence of relevant information source. Data and market monitoring gain importance especially in industries, which are subject to regulation or oversight due to the application of various measures for the needs of maintaining effective economic competition or consumer protection. In the environment of postal service existing legislative regulation defines the assessment of the situation especially in markets in the segment of so-called interchangeable service in the extent of the universal postal service. However, due to the development market it is appropriate to define also other relevant markets outside of the universal service segment. Currently, based on applicable legislation governing the regulation of postal services as well as the protection of economic competition there may be a conflict in decision-making power or in issuing decisions by individual state administration bodies. Therefore it is necessary to ensure a coordinated execution of substantive powers of the Antimonopoly Office of the SR and the Regulatory Authority for Electronic Communications and Postal Services of the SR in order to prevent the occurrence of positive or negative conflicts of competence, but especially in issuing mutually conflicting decisions.

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Torsional Vibration of Unconventional Crankshaft in Four-cylinder Passenger Car Engine

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Abstract

Modern internal-combustion engines have to meet demands on the overall engine efficiency which consists of particular efficiencies. The one of them is mechanical efficiency and its high value is exacted from internal-combustion engines. The reduction of friction losses of crankshaft main bearings can significantly contribute to the enhancement of this efficiency. This is the reason of development of an innovative design of a crankshaft. The potential and capabilities of computational modelling during the development of this innovative crank train is described in the paper. The dynamic computational model of the whole crank train is assembled and solved by using a Multi-Body System software, where modally reduced flexible bodies along with hydrodynamic bearings are incorporated. The paper presents the simulation results concentrated on the torsional vibration and its analysis, including concept design of a torsional damper, because a reduction of friction losses is associated with the improvement of torsional vibration in this case. On the grounds of low-costs, a rubber torsional damper is taken into account.
KEY WORDS: *torsional vibration, crank train, crankshaft, Multi-Body System*

1. Introduction

Torsional vibration is common to internal-combustion engine crank train owing to its working principle. The crank train generates alternating torque due to alternating combustion pressure in conjunction with the alternating effect of reciprocating parts inertia. This torque brings the elastic crankshaft in vibration about the axis of rotation. The torsional vibration can cause cracking and crankshaft failure; and therefore, this crankshaft loading is very dangerous [1].

This type of loading is investigated in the case of unconventional crank train of a 1.6-litre naturally aspirated spark-ignition in-line four-cylinder engine with reduced friction losses. The reducing of crank train friction losses is achieved by a reduced number of crankshaft main bearings from 5 to 3 [1].

The new 3-main-bearing crankshaft is based on a 5-main-bearing version of the standard engine. The missing main bearings are replaced by sheet-metal webs due to mass, inertia moments and engine block load reduction, see Fig. 1. A connection between the web and the crankshaft is created by laser welding for low thermal load of the weld. Current version of the 3-main-bearing crankshaft results from a previous design, computational, and technology studies [2].

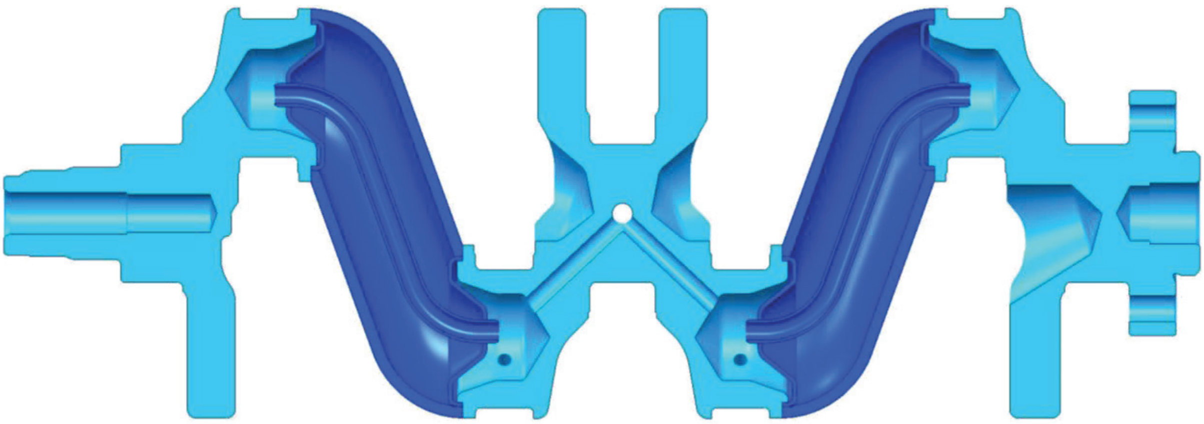

Fig. 1 Longitudinal section of the 3-main-bearing crankshaft

These studies show that potential for savings of power losses of crankshaft main bearing reaches around 33% in comparison with the standard 5-main-bearing crankshaft [2].

The new concept of crankshaft design however brings not only friction losses reduction, but also increase in crank train vibration level. In order to investigate these changes in crank train vibration, particularly in comparison with the standard configuration, the state-of-the-art computational methods are used and further described.

2. Computational Model of the Crank Train Dynamics

A complex computational model of an engine (in other words a virtual engine) is solved in the time domain. This enables different physical problems including various non-linearities to be incorporated. The virtual engine is assembled as well as numerically solved in MBS (Multi-Body System) ADAMS which is a general code and enables integration of user-defined models to be made directly using ADAMS commands or user-written FORTRAN or C++ subroutines [3].

In general, the virtual engine includes all significant components necessary for dynamics analyses. The included module is a crank train, a valve train, a timing drive and a rubber damper. Following analyses just deal with the crank train as a main module of the virtual engine [4].

The crank train module consists of solid model bodies, linearly elastic model bodies and constraints between them. Solid model bodies – defined by location of centre of gravity, mass, and inertia tensor – are: piston assembly, connecting rod assembly, dynamometer rotor.

The linearly elastic model bodies are modally reduced finite element models suitable for dynamic simulation. These are: crankshaft, crankshaft pulley, flywheel, engine block, cylinder head, crank train sump, gear case.

A dumb-bell shaft connecting a flywheel with a dynamometer rotor is represented by a body with defined torsional stiffness and damping. These characteristics are adjusted on account of torsional vibration measurement.

The interaction between the crankshaft and the engine block is ensured via a non-linear hydrodynamic journal bearing model [5]. Since a detail vibration transmission between the power train and the car body (so called *external vibration*) is not the object of this investigation, engine mounts are simulated by simplified viscoelastic model.

Virtual engine is excited by means of cylinder pressure, defined by high-pressure measurement of the standard engine, and via inertial forces from moving parts. Simulations start from 1000 rpm and are carried out to 6200 rpm.

3. Results of the Crank Train Torsional Vibration

The crankshaft pulley angular displacement is chosen for description and comparison of the crank train torsional vibration due to its complexity, the crank train speed oscillation and crankshaft torsional static and alternating deformation are therefore included into this quantity [6].

Harmonic analysis of a pulley angular displacement of the standard crankshaft is shown in Fig. 2.

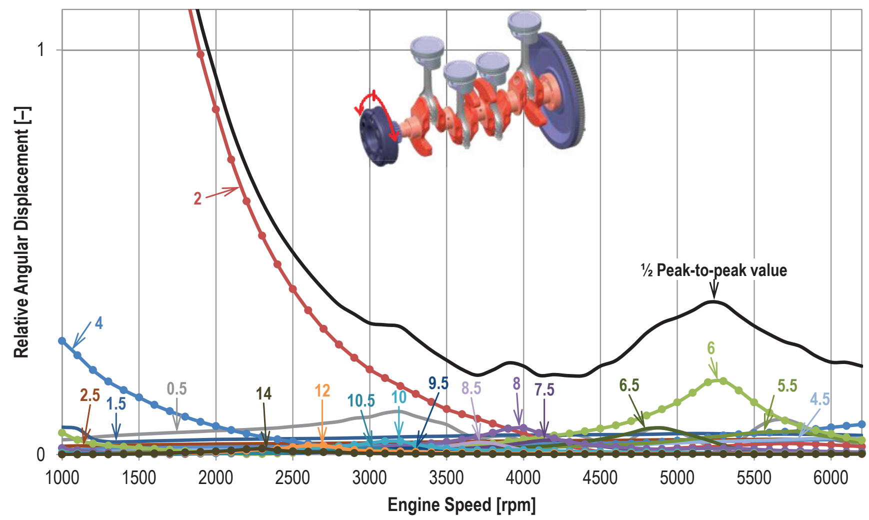

Fig. 2 Harmonic analysis of a pulley angular displacement of the 5-main-bearing crankshaft

It is obvious that there is a relatively strong impact of the 6th harmonic component of the torsional vibration that is reaching resonance under the high speed. At 3900 rpm the resonance of the 8th harmonic component is evident. The 10th harmonic component shows some resonance too, but its impact on the total shaft oscillation is considerably smaller. The mentioned harmonic components bring crankshaft on alternating torsional deformation which influences the crankshaft fatigue life. While lower harmonic components, reflecting resonances at lower engine speed (the 2nd one or the 4th one), show whole crank train speed oscillation and therefore these components are significant for gear train design or the whole drive train design [7, 8].

The major orders take the highest part in vibrations due to their identical phase angle at all cylinder units of the engine [9]. For an in-line four-cylinder four-stroke engine these orders are integer multiples of 2. The synthesis is equal to the half-size of peak-to-peak value from the periodic torsional oscillation. The occurrence of half-harmonic components (6.5th, 7.5th etc.) is caused by the fact that whole working cycle of a four-stroke internal-combustion engine takes two crankshaft revolutions (720°) while the fundamental frequency for engine dynamics is crankshaft rotational frequency (360°).

In the Fig. 3, the results of the new crank train harmonic analysis are presented. The 3-main-bearing crankshaft is torsional softer than the standard one. Lower torsional stiffness is evident, for example, at the resonance from the 8th harmonic component which occurs at 3600 rpm (minus 300 rpm in comparison with the standard one). This is caused mainly by enlarged counterweighs of the new crankshaft significantly reducing load of the middle main bearing however also decreasing torsional natural frequency of the crank train. Further reason is lower torsional stiffness of the sheet-metal webs compared to the original forged main pin and adjacent crank webs.

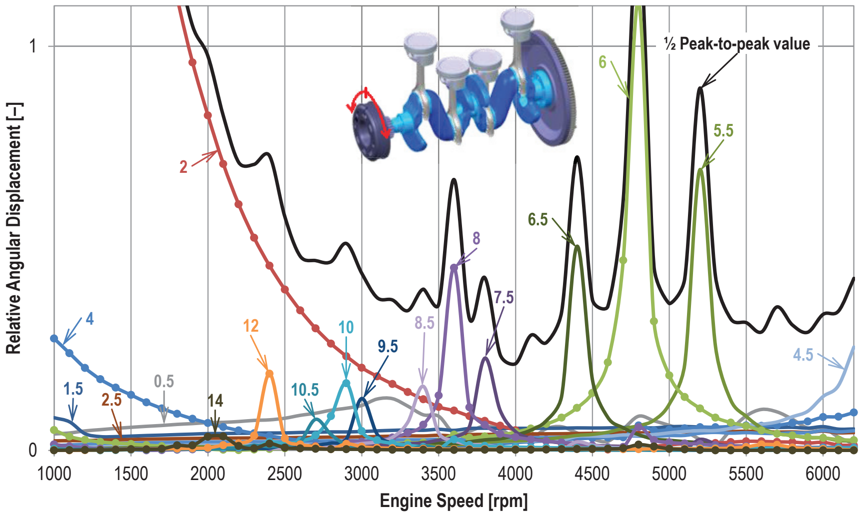

Fig. 3 Harmonic analysis of a pulley angular displacement of the 3-main-bearing crankshaft

Nevertheless, the small number of the crankshaft pivot points at the engine block brings specific changes in crank train dynamics behaviour. The resonance amplitudes not only of the major harmonic orders but also their closest harmonic orders are increased.

The inherent damping of the crankshaft material is determined by the experimental modal analysis for the need of simulation. However, as the simulation results show, "the sharpness" of resonance curves is caused, in particular, by the lower external damping of crank train torsional vibration since the dominant sources of damping of the crank train without an external damper are the crankshaft main bearings.

Torsional vibration of the new crankshaft, shown in Fig. 3, cannot be admitted owing to likely crankshaft failure. Hence the next step for its reduction must be done.

4. Influence and Concept Design of a Torsional Vibration Damper

Engines of class as presented used to be equipped by a tuned rubber torsional vibration damper featured by good effect and low-costs [10]. The damper consists of a rubber band interposed between an inertia ring and a crankshaft pulley, see Fig. 4, and its function, in sum, rests in retuning of the torsional system and putting more damping into it.

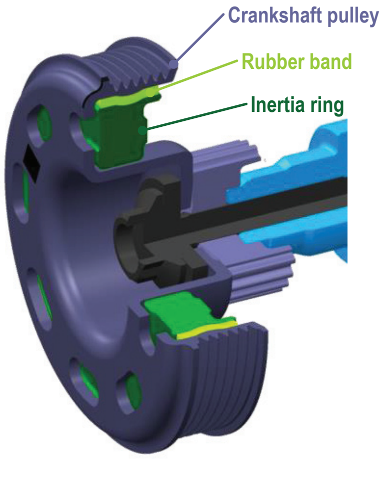

Fig. 4 Tuned rubber torsional damper

According to Fig. 5, that describes torsional system including the reduced crank train and parallel model of torsional damper and with the use of relative parameters, can be derived:

$$\xi = \sqrt{\frac{4\gamma^2\eta^2 + \left(\eta^2 - w^2\right)^2}{4\gamma^2\eta^2\left(1-\eta^2-\mu\eta^2\right)^2 + \left[\mu w^2\eta^2 - \left(\eta^2-1\right)\left(\eta^2-w^2\right)\right]^2}}\ , \qquad (1)$$

where ξ is relative amplitude γ is relative damping η relative frequency w is the damper relative tuning and μ is relative size.

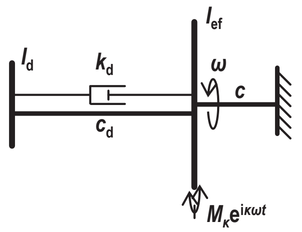

Fig. 5 A scheme of reduced crank train with a torsional damper

This formula allows to investigate the influence of damper relative parameters on the resonance curves of harmonic components of the crank train torsional vibration and is very useful for parametric studies.

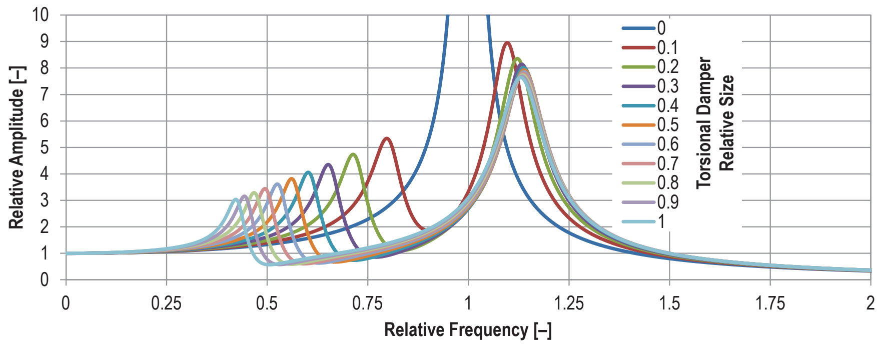

Fig. 6 Comparison of the torsional damper effect on resonance curve

Resonance curves, presented in Fig. 6, show the influence of damper relative size on relative amplitude for given relative tuning and the same damping ratio. The range of damper parameters is, in practice, limited by the build-up area, and material properties of a rubber band.

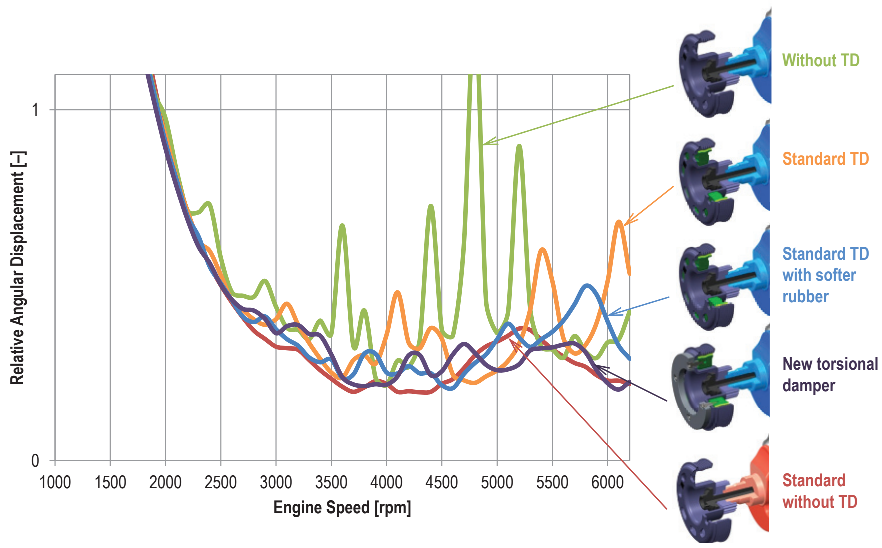

Fig. 7 Comparison of the torsional damper effect on a crankshaft pulley angular displacement (½ peak-to-peak value)

In this stage of the project, the effect of the torsional vibration damper is verified by the virtual engine as well. Since real rubbers show hysteretic damping properties rather than viscous, Wiechert rheological model of a rubber band is used [11, 12].

The influence of the torsional vibration damper upon a crankshaft pulley torsional vibration, represented by the half-size of peak-to-peak value, is shown in Fig. 7 where the notes used mean:

- Without TD: the new crank train without the torsional damper;
- Standard TD: the new crank train with torsional damper intended for the standard crank train;
- Standard TD with softer rubber: the new crank train with torsional damper intended for the standard crank train but with lower torsional stiffness of the rubber band (lower Shore hardness);
- New torsional damper: the new crank train equipped with torsional damper with optimized parameters;
- Standard without TD: the standard crank train without a torsional damper.

Since the standard crank train can operate reliably without the use of a torsional damper (verified by an experiment), it is evident that the new crank train equipped by the optimized torsional damper should operate as well.

5. Conclusion

The low level of friction losses is required of modern internal-combustion engines, as it is a good influence on engine overall efficiency and fuel efficiency exactly. However, lowering of friction losses is often attached to the rise in crank train vibration. The described unconventional crank train represents an extreme case of friction losses (positive effect) and crank train vibration (negative effect). Nevertheless, modern computational methods can bring solutions of the mentioned challenges and can shift manufacturing of expensive prototypes to later phase of the development process.

The simulation results show that suitable designed tuned rubber torsional damper could be the solution of excessive torsional vibration of the unconventional crank train. However detail FE analysis of the rubber band in conjunction with experiments is necessary to review temperature endurance of the rubber band and its temperature-dependent viscoelastic properties.

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