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Jan Perner Transport Faculty

6th International Scientific Conference – Conference Proceedings

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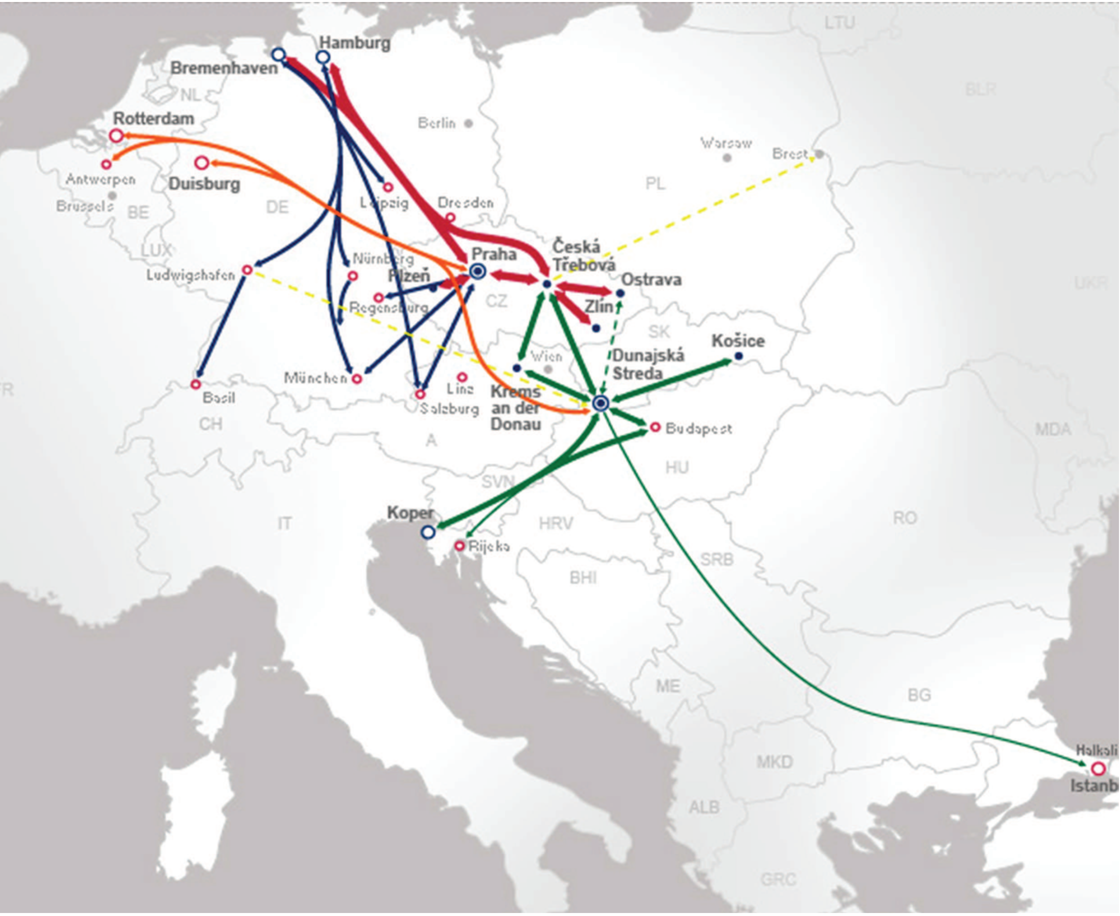

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GLOBAL LOGISTICS FOR CENTRAL EUROPE AND BEYOND

CONTENT

GREENHOUSE GAS EMISSIONS IN THE CONTEXT OF SUSTAINABLE TRANSPORT IN THE CZECH REPUBLIC

Barbora Antonová[1], Jaroslava Hyršlová[2], Tomáš Kučera[3], Klára Lustigová[4], Ivo Drahotský[5]

Abstract: Transport has significant and long-lasting economic, social and environmental impacts, and so it is an important factor of sustainability. Transport sustainability is an essential driving force towards achieving sustainable development. Transport and transport infrastructure development enable economic and social development, but are often detrimental to sustainable development due to congestion, accidents, smell, noise, air pollution, health effects etc. Among the major environmental impacts of transport are greenhouse gas emissions that contribute to climate change. Climate change is an aspect all over the world, and its complexity is increasing. The aim of this paper is to analyze the long-term development of greenhouse gas emissions from transport in the Czech Republic. The development is examined in terms of the EU transport policy goals in this field.

Key words: sustainable transport, transport environmental impact indicators, greenhouse gas emissions.

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1 Introduction

The promotion of wellbeing, improved quality of life, equity, economic development and environmental protection for present and future generations are fundamental principles of the current concept of sustainable development [20]. The concept of sustainable development is based on three pillars: environmental, economic and social. The broad concept of sustainable development and sustainability has become widely popular in research, political, and community agendas, especially since the Brundtland Report [21] identified the declining environmental condition and associated human factors as a global problem. With emphasis placed upon resolving the global environmental crises, the equal centrality of environment, economic, and social dimensions in the conceptual understandings of sustainability has been lost. If sustainability seeks to balance three interlinked objectives, to protect the environment while promoting economic vitality and social equity, then more research is needed to understand the environmental dimensions of sustainability. Of this sustainability triad (environment, economic, and social dimensions), this paper focuses exclusively on the environmental dimension. In doing so, it is not assumed the environmental takes precedence over the significance and urgency of the social or economic concerns. But if all the dimensions are to be balanced, it is important to also examine the implications of those sustainability dimensions which receive less attention.

2 Sustainable transport and transport environmental impact indicators

Transport is one of the branches that significantly influence the sustainable development of society. That is because transport has major economic, environmental and social impacts [16]. Sustainable transport means finding the right balance between (current and future) economic, environmental and social qualities [8, 19]. Transport is an important factor for the growth of social welfare because it provides accessibility to various human activities. Mobility and transport play a key role in all three pillars of sustainable development. They contribute to economic growth, improve accessibility and support economic integration. Therefore, they have significant long-term economic and social impacts. Transport also affects the environment, thus it has environmental aspects and impacts. The transport of people and goods must happen in an environmentally friendly way, be safe and accessible to all, thereby contributing to the improvement of social equity, health and resilience of regions [20].

A well devised system of indicators can be used for the establishing, monitoring and evaluation of sustainability objectives in transport [6, 10, 18]. Sustainable transport indicators are statistical measurements that indicate the sustainability of economic, environmental and social development [9]. The set of indicators must not be very large but it should contain all the key indicators for the economic, environmental and social aspects of transport. The set of indicators must be an integral part of evaluation mechanisms. Indicators should be internally consistent and coherent with respect to measurement assumptions, understandable to the general public, transparent in the sense that they are easily understood and interpreted, useful for decision-making processes and available to all stakeholders [11]. The indicators are not only useful for assessing the sustainability of various transportation systems and city and regional transport systems, but they could also help with the coordination of activities at regional and local levels and with evaluating the effectiveness of state policies with respect to sustainable development.

To encompass environmental aspects and impacts, sustainable transport should be defined in the following way: “It limits emissions and waste within the planet´s ability to absorb them, uses renewable resources at or below their rates of generation, and uses non-renewable resources at or below the rates of development of renewable substitutes, while minimizing the impact on the use of land and the generation of noise"[3]. Research agendas [5, 11] dealing with the concerns for the long-term environmental impact of transport have included air pollution from vehicular emissions, global climate change and overconsumption of energy resources. Potter [15] distinguishes local (smell, air quality, and noise), regional (land use and waste disposal), continental (acid rain) and global environmental impacts (climate change, ozone depletion).

Environmental impacts of transport may be measured by various indicators. In their research Santos and Ribeiro [16] found out that CO2 emissions (per capita), air and noise pollution exposure and health impacts are the most frequently used sustainable transportation indicators for measuring the environmental impact of transport. Haghshenas and Vaziri [7] include also emissions of local air pollutants (CO, VOC, NOx, etc.) per capita, transportation energy use per capita, and land consumption for transportation infrastructure (private, public) per capita among the indicators of the environmental impact of transport. Shiau and Liu [17] carried out a research about indicators to evaluate transport sustainability strategies by local governments. They recommended to use following indicators for measuring environmental impacts: emission intensity of greenhouse gases (GHG), emission intensity of air pollutants, proximity of transport infrastructure to designated environmentally sensitive areas, and recycling of end-of-life vehicles; indicator alternative and renewable energy consumption may be included in this group of indicators. Transport policy of the Czech Republic [12] has been using following environmental indicators for the assessment of individual objectives and measures:

- emissions of nitrogen oxides, CO2 emissions from transport,
- share of gasoline, diesel and kerosene on total energy consumption,
- share of the fleet in road transport using energy not derived from crude oil,
- share of population exposed to excess noise from transport.

The starting point for European Union countries in the field of sustainable transport is the White Paper, which is based on the European Commission´s vision of transport in 2050, entitled Transport 2050. The previous White Paper's focus is on reducing greenhouse gas emissions [1]. White Paper valid until 2010 speaks of reducing greenhouse gas emissions so far generally, in the form of a gradual reduction of emissions from road transport as the most significant polluters. The current White Paper set an objective to reduce emissions by 2050 by 80 – 95% below 1990 levels [2]. To achieve this it is necessary to reduce greenhouse gas emissions in the transport sector by 2050 by at least 60% compared to 1990; intermediate step to achieving this goal is to reduce greenhouse gas emissions by 2030 by 20% below 2008 levels [2].

3 Objective and methodology

The paper focuses exclusively on the environmental aspects of sustainable transport and especially, on the long-term development of greenhouse gas emissions from transport in the Czech Republic. This indicator is one of the most frequently used indicators for measuring and assessing environmentally sustainable transport. The aim of this paper is to analyze the long-term development of greenhouse gas emissions from transport in the Czech Republic.

The EUROSTAT data on fluctuations in greenhouse gas emissions from transport in 1990-2012 [4] was used for the analysis. Additional data was gathered from transport yearbooks published annually by the Czech Ministry of Transport [13]. The development prediction of the indicator was made in order to assess whether the greenhouse gas emissions have been developing in the line with the objectives set in the White Paper [2] for 2030.

For prediction of greenhouse gas emissions, ARIMA model was used; this model, unlike classical regression models, enables to model trends and seasonal influences and is based on the autocorrelation [14]. For time series modelling, R software (the R Project for Statistical Computing) was used. Considering the emission data are annual and there appears to be no seasonal pattern, a non-seasonal ARIMA model was selected. The resulting ARIMA model processed by the R software has the following form:

$$y_t = 13{,}176.027 + 1.549 y_{t-1} - 0.5897 y_{t-2} + e_t \; .$$

This model is stationary and et are white noise process errors (Q-Q plot, histogram, Shapiro–Wilk test and Ljung–Box test were used).

Prediction intervals can be viewed as a reflection of precision of predicted values. Prediction interval gives an interval within which we expect predicted value to lie with a specified probability - in forecasting, it is common to calculate 80% intervals and 95% intervals [14]. Broader interval means less accurate values of prediction.

4 Results and discussion

Data in Figure 1 describe annual emissions of greenhouse gases produced by the transport sector in the Czech Republic. Data for the period 1990-2012 are taken from the EUROSTAT database [4]. Greenhouse gas emissions are expressed in thousands of metric tonnes in CO2 equivalents (TMT of CO2eq).

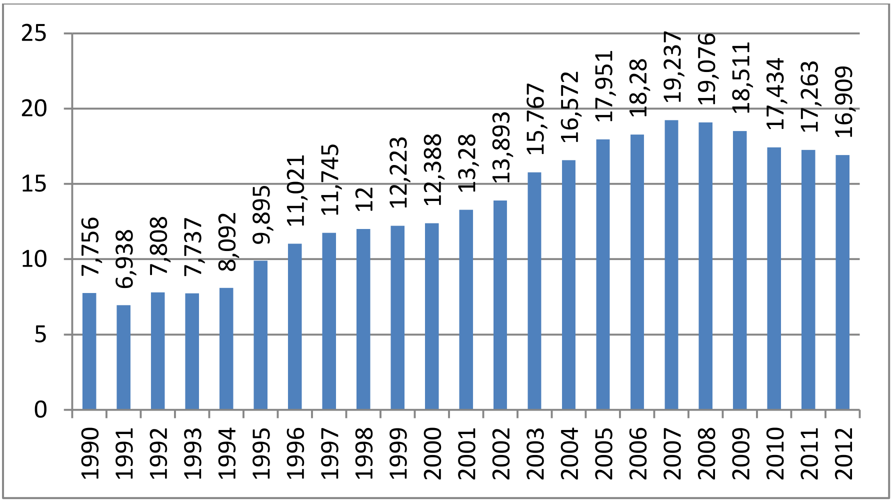

Fig. 1: Development of greenhouse gas emissions from transport in the Czech Republic (TMT of CO_2eq) [4]

Greenhouse gas emissions from transport in the years 1990-2007 were rising steadily (except the years 1991 and 1993). The highest increase in emissions was in 1995 and 2003; in 1995, emissions increased by 1,803 TMT, compared with 1994; in 2003, it rose by about 1,874 TMT, compared with 2002. In 2007, transport produced the highest amount of emissions in the observed period – 19,237 TMT of CO2eq, which was almost 2.5 times more than in 1990. Since 2008, there has been a gradual decrease in the amount of greenhouse gas emissions. In 2012, 16,909 TMT of emissions were produced by transport, decreasing by 2,328 TMT compared with 2007; greenhouse gas emissions in 2012 reached the level of emissions in 2004.

Changes in the amount of emissions produced are influenced by a number of factors. Tables 1-3 show the development of transport performance and the number of road vehicles between 2007 (the year in which the amount of emissions caused by transport was the highest) and 2012 (the latest data available).

90% of total CO2 emissions are caused by road transport; especially by individual car transport [13]. Tables 1 and 2 indicate that a decrease in emission occurred in 2008, despite higher transport performance in comparison to the previous year (2007). The performance of road freight transport increased by 2,736 mill. tonne-km, urban public transport improved by 1,528 mill. passenger-km and passenger car transport increased by 840 mill. passenger-km. There was an increase in the number of road vehicles during the observed period - see the Table 3; the highest increase in the number of road vehicles occurred in 2008 and 2012. The analysis shows that the volume of greenhouse gas emissions depends not only on transport performance, but also on the use of different transport modes and on the condition of vehicles and the quality of transport infrastructure.

Tab. 1: Total goods transport performance (mill. tonne-km)

Mode	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Rail transport	16,304	15,437	12,791	13,770	14,316	14,266
Road transport	48,141	50,877	44,955	51,832	54,830	51,228
Air transport	41	37	29	22	22	17
Inland waterway transport	898	863	641	679	695	669
Total	**65,384**	**67,214**	**58,416**	**66,303**	**69,863**	**66,180**

Source: [13]

Tab. 2: Total passenger transport performance (mill. passenger-km)

Mode	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Rail transport	6,898	6,803	6,503	6,591	6,714	7,265
Bus transport	9,519	9,215	9,494	10,336	9,267	9,015
Air transport	10,477	10,749	11,331	10,902	11,586	10,612
Inland waterway transport	19	17	10	13	15	17
Urban public transport	14,352	15,880	15,555	15,617	15,281	15,814
Passenger car transport	71,540	72,380	72,290	63,570	65,490	64,260
Total	**112,805**	**115,044**	**115,183**	**107,029**	**108,353**	**106,983**

Source: [13]

Tab. 3: Number of the road vehicles (thousands)

	2007	**2008**	**2009**	**2010**	**2011**	**2012**
Individual car transport	5,140	5,316	5,338	5,421	5,526	5,683
Road freight transport	818	900	913	931	953	991
Road public passenger transport	20	20	20	20	20	20
Special vehicles	47	44	39	37	35	34
Total	**6,025**	**6,280**	**6,310**	**6,409**	**6,534**	**6,728**

Source: [13]

Figure 2 shows the development of greenhouse gas emissions from transport in the period 1990-2030. Data for the period 1990-2012 are taken from Figure 1; this means real greenhouse gas emissions produced by transport (emissions are expressed in TMT of CO2eq). The development of emissions in the period 2013-2030 is based on the ARIMA model results; this means a prediction of production of greenhouse gas emissions (see Table 4). Specific values of the prediction of greenhouse gas emissions, calculated using the ARIMA model, are determined by the upper (Hi) and lower (Lo) limits of the confidence interval; calculations were done for confidence levels of 80% and 95%.

Tab. 4: Predicted values of greenhouse gas emissions from transport in the Czech Republic (TMT of CO2eq)

Year	Forecast	Lo 80	Hi 80	Lo 95	Hi 95
2013	16,550	15,643	17,457	15,163	17,937
2014	16,20	14,530	17,876	13,645	18,761
2015	15,877	13,532	18,221	12,291	19,462
2016	15,576	12,670	18,482	11,131	20,020
2017	15,302	11,939	18,664	10,159	20,444
2018	15,055	11,327	18,782	9,354	20,755
2019	14,834	10,818	18,850	8,692	20,976
2020	14,637	10,394	18,879	8,148	21,125
2021	14,462	10,042	18,882	7,703	21,221
2022	14,307	9,750	18,864	7,337	21,277
2023	14,170	9,506	18,835	7,037	21,304
2024	14,050	9,303	18,797	6,790	21,310
2025	13,944	9,133	18,755	6,586	21,301
2026	13,850	8,990	18,710	6,417	21,283
2027	13,768	8,869	18,666	6,276	21,259
2028	13,696	8,768	18,624	6,159	21,232
2029	13,632	8,682	18,583	6,061	21,203
2030	13,576	8,608	18,545	5,978	21,174

Source: prepared by authors, using [4]

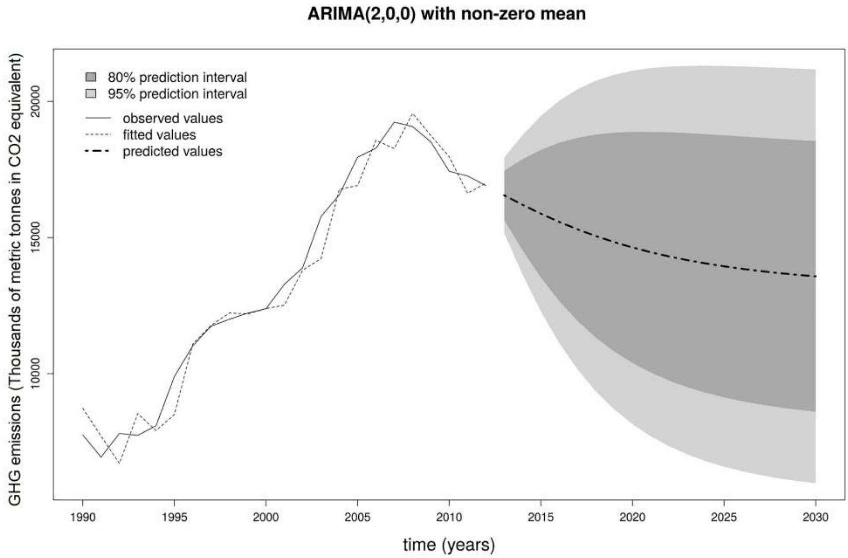

Fig. 2: Visualization of the original data, fitted values, forecasts and prediction intervals (prepared by authors, using [4])

From Figure 2 and Table 4 it is clear that the longer is the period for which the prediction is made, the wider is the range of options for the development of greenhouse gas emissions. The narrowest range is for the prediction of development until 2020.

Using EUROSTAT data and ARIMA model, prediction of greenhouse gas emissions from transport in the Czech Republic for the period 2013 – 2030 was prepared; calculations were done for confidence levels of 80% and 95%. The predicted values for 2030 were used to assess the development of greenhouse gas emissions in the context of the objectives that were set in the document Transport 2050. Partial target set by the White Paper for 2030 in the area of reducing greenhouse gas emissions from transport is a reduction by 20% below 2008 levels. Greenhouse gas emissions produced by transport in the Czech Republic in 2008 amounted to 19,076 TMT of CO2eq. Should the set target be achieved, emissions in 2030 should not exceed the level of 15,261 TMT of CO2eq. ARIMA model outputs show that the Czech Republic might be able to achieve the set target for greenhouse gas emissions (the mean value of the indicator reaches a level of 13,576 TMT of CO2eq).

5 Conclusion

Greenhouse gas emissions currently represent a very significant problem. Transport, as producer of greenhouse gas emissions, contributes to air pollution and climate change; from the point of view of transport sustainability greenhouse gas emissions represent a major environmental aspect.

Greenhouse gas emissions are also addressed in the document Transport 2050. The basic objective for 2050 set out by the transport strategy is to reduce greenhouse gas emissions from transport by at least 60%, compared to the level of 1990. Of all CO2 emissions from transport sources in the European Union, 80% are from road vehicles (with most of the rest being from air transport). Just over half of road transport´s CO2 emissions come from private cars, 23% from goods vehicles and under 2% from buses and coaches [15]. To achieve the objective of reducing greenhouse gas emissions, technical improvements to vehicles will probably not be sufficient; these may be ineffective and very difficult to achieve politically and socially. Also efforts to strengthen public transport may not bring the expected effects; this measure may be difficult to fulfil politically and socially as well. Combined strategies will have to be sought; strategies related to technical improvements, alternative fuels, and strengthening public transport on the one hand, and to the change in behaviour of individuals and management practices within the business community on the other hand. Transport policies at the local, national and international levels must be harmonized; as a part of policies' frameworks technical improvements must be optimally linked to modal shift and to the behaviour of people and management. Sustainability may be achieved only by using these combined strategies.

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HISTORY OF USING GPR FOR DIAGNOSTICS OF TRANSPORT STRUCTURES

Salih Serkan Artagan[1], **Vladislav Borecký**[2]

Abstract: Ground penetrating radar (GPR) is a special type of radar, which uses reflections of electromagnetic (EM) waves transmitted into the ground or structures to survey soil, rock and building materials. This article describes the origins and history of the use of GPR with an emphasis on the applications for the purposes of transport engineering. The development of this technology, since discovery of its principles and laws until today, is briefly described in this article. Currently, GPR is used for non-destructive diagnostics of transport structures rather rarely, however, thanks to the development of hardware and software, the options of its usage are still growing and it increasingly replaces the time consuming and destructive conventional methods.

Key words: ground penetrating radar, transport infrastructure, diagnostics, history.

1 Introduction

Ground penetrating radar (also *georadar*, *ground probing radar*, or *subsurface radar*) is a device that, besides large number of other applications, is used for relatively quick and non-destructive diagnostics of transport structures. It is a special kind of radar designed for soil, rock and building materials survey. GPR uses EM waves transmitted into these materials in the form of radar pulses and display reflected signal. [1]

GPR is increasingly being used in transport engineering for example for geotechnical investigation of foundation conditions, bridge decks diagnostics (e.g. determination of rebar location and size), assessing the condition of the railway substructure, diagnostics of road construction layers (e.g. layer thicknesses, crack detection, moisture content, delamination), etc. Currently there are many

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manufactures of these devices, which offer dozens of types designed for specific applications. However principles and laws, which GPR is based on, are generally the same as in 1926, when radar waves were first used for detecting objects beneath the surface.

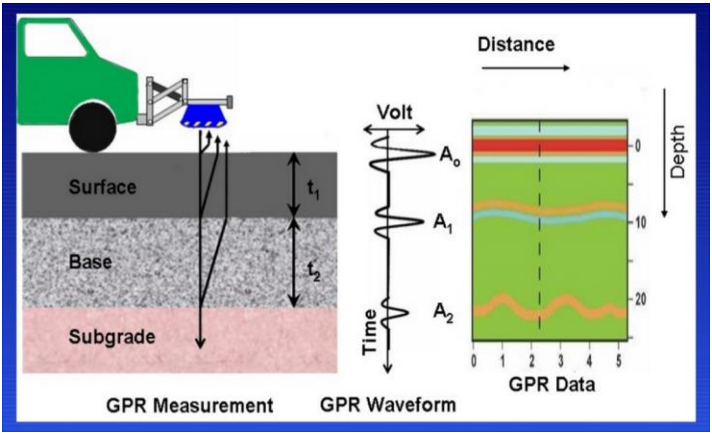

Fig. 1: GPR principle [2]

2 Discovery and the beginning of radar technology

RADAR acronym was created in the thirties of the twentieth century for RAdio Detection And Ranging. The existence of EM waves, which GPR uses, was firstly described by James Clerk Maxwell (1831 -1879) in 1861. History of exploration of detection methods, by using these waves, dates back up to late nineteenth century, when Heinrich Hertz (1857-1894) conducted first experiments. Hertz tested Maxwell's theories from his work „Treatise on Electricity and Magnetism" published in 1873. In 1887 Heinrich Hertz successfully developed a simple transmitter and receiver. He discovered that EM waves could be transmitted via different type of materials, and be reflected by others such as conductors and dielectrics. [3], [4]

In 1897, while testing the device to detect lightning strikes, Alexander Popov observed interferences precisely at that time when some boat had passed nearby. Although he realized that this could be possibly used to detect objects, he did not research it further. [5] These findings were used in 1900 in Germany, when

Christian Hülsmeyer registered the patent on anti-collision device for ships (but only with range of 1 mile).

In 1910 Gotthelf Löwy and Heinrich Leimbach placed dipole antennas into vertical boreholes and compared the signal strength of each antenna. This enabled to create crude image of subgrade. In 1917 Nikola Tesla stated initial principles concerning the frequency and signal strength for the first primitive radar units [1]. In September 1922 researchers Albert Taylor and Leo Young from U.S. Navy observed the same phenomenon like Popov before them. They assumed that it would be possible to construct a transmitter and receiver of radio waves for vessels navigation in low visibility conditions. [5]

During The World War II radar devices were systematically used as a tool for military defense systems improvement that provided early detection of enemy aircrafts and vessels. During this period pulse radars were established to enable determination of the target distance by calculation of signal delay during its travel at the known speed of light c (299 792 458 m/s in a vacuum) to the target and back [3]. During The Vietnam War (1955-1975) U. S. Army developed radar system called "Combat Radar" to search for mines, tunnels and bunkers. Through further research this radar system led to the development of different radar device used for identification and profiling of subsurface geological phenomena. [4]

3 Beginning of GPR

To detect objects placed underground, radar waves were firstly used in 1926 (Hülsenbeck). The importance of environment's relative permittivity was also presented at that time. This was the first application when EM waves were intentionally radiated trough solids [4]. GPR as itself was firstly used three years later in Austria (Stern) in order to determine the thickness of the glacier. For next two decades this technology was developed rather isolated and not much attention was paid to it. This situation changed just in the fifties when The United States Air Force (USAF) aircraft tried to land onto ice in Greenland. Due to the penetration of radar waves into ice mass, the altitude of an aircraft was determined incorrectly which caused the aircraft crash. Subsequent investigation revealed the ability of radar waves to penetrate into ice mass and other materials and also that GPR can be used for determining ground water level and geological mapping. [6], [3]

4 Modern GPR

First „modern“ GPR was developed in sixties in laboratories of MIT Lexington [7]. In 1967 GPR was used on the Moon in the Apollo 17 mission (within Surface Electrical Properties Experiment project) [6].

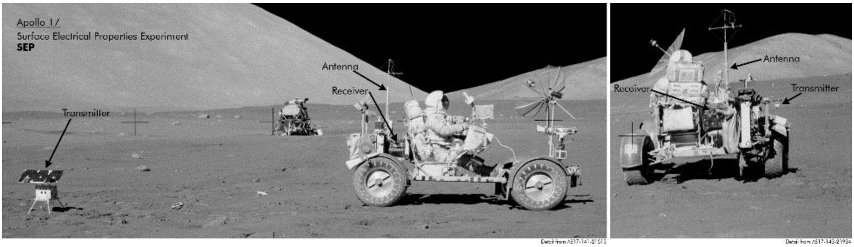

Fig. 2: GPR equipment on the Moon [8]

In 1972 GSSI company (Rex Morey and Art Drake) began selling the first commercial GPR system ever, which marked the beginning of rapid development (within next 20 years more than 300 patents were registered). This research was in its infancy supported mainly by *The Geological Survey of Canada* a *The US Army Cold Regions Research and Engineering Laboratory* (CRREL) [6]. In seventies GPR was used for example for surveying in coal and salt mines or in glaciology.

History of using GPR in road diagnostics dates back exactly to this era (mid-seventies), when the possibility of using GPR for tunnel and bridge deck applications were tested in *The Federal Highway Administration* (FHWA) in USA. This system was later used for detecting cavities under rigid pavements. Since the seventies GPR has been used in many applications including the utilities detection, determining the thickness of the ice and profiling the bottom of lakes and rivers. [4]. Furthermore GPR was used for example in archeology, mining industry or for identifying sites suitable for nuclear waste storing. [1].

5 Digital age

In the eighties GPR road surveys began to be conducted also in Canada and Scandinavia. The first tests in Scandinavia were carried out in Sweden and Denmark, however GPR became to be a common tool in this region after 1986 when this technology was tested in Finland. These surveys were conducted with mainly air-coupled antenna with high central frequency of 1 GHz at first and later with ground-coupled antennas. In 1985 the first GPR system was particularly designed to be mounted on the road vehicle for FHWA [9]. The first test of GPR in UK was carried out in 1984. In France the biggest emphasis was placed on road properties testing while in Netherlands focus was addressed on measuring the layer thicknesses. At late eighties and early nineties the most of GPR road applications in North America were focused on determining construction layer thicknesses, detection of cavities under the pavement and mapping material degradation on bridge structures. [10]

In the mid-nineties there was massive expansion of this technology and also the development of many hardware and software providers (Mala, Roadscanners, IDS, Penetradar, Sensors and Softwares, UTSI Electronics). In the late nineties GPR was used in road construction area for layer thicknesses determination, detection of cavities, delamination, isolating layers and rebar, and also geological profiles mapping [10]. At this time attention of academic community began to be attracted to GPR technology in connection with the development of computer technology, transition of signal processing from analog to digital and new possibilities of 2D and 3D numerical modelling. [11],[12] .

6 Conclusion

Since GPR was firstly used almost 100 years ago, it has evolved from being a unique experimental device to a relatively widespread tool for earth survey or structure diagnostics. This article describes this development which can provide guidance to estimate its future potential.

In its early days GPR suffered from many shortcomings especially insufficient computational capacity or inappropriate imaging methods. These deficiencies were however overcome during last twenty years and nowadays the current computer technology enables the development of algorithms and procedures for data processing, which results that GPR technology can be used in an increasing number of sectors. There has been also progress in the knowledge of electrical properties of the geological and building materials and their behavior in EM field. However the complexity and uncertainty in estimating the behavior of these multi-component materials are not still always adequately described.

In transport construction GPR is still used rather rarely, however it is gradually getting into the awareness of professionals as a tool, which will be able to replace the current time consuming and costly destructive diagnostics methods in the future. Hardware and software development along with new algorithms for data processing, which will use available computing capacity, will lead to even faster development of this technology for the needs of various industries in near future. Therefore GPR will be probably used as a routine, non-destructive and time saving tool in the next few years.

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INTEGRATING SUSTAINABILITY INITIATIVE INTO THE 3PLP SELECTION PROCESS: AN OVERVIEW AND FUTURE RESEARCH AGENDA

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Abstract: Sustainability management has begun to play an extremely important role in the efficient management of the supply chain. The group of critical success factors (quality, costs, timely delivery etc.) which ensure the competitive advantage of the supply chain has increased with its emergence. All supply chain partners must therefore make an effort to provide services and products which create the minimum negative impact on the environment. A brief literature review revealed that some partners - namely manufacturers, wholesalers, and suppliers, have already put significant emphasis on sustainability, while the progress of logistics service providers (LSP) lags behind considerably. Due to the significant impact of sustainability on competitive advantage, moving the logistics sector forward to sustainable development is necessary. Buyers of logistics services in this case play a key role. Their contribution to "greening" logistics services can be achieved in one of several ways. We decided to start at the very beginning, in one of the initial and most important phases of logistics outsourcing, specifically LSP selection. Accordingly, this study first aims to provide a brief review of literature related to environmental sustainability among supply chain partners with a main focus on LSP, as well as of the importance and impact of sustainability in the selection process of LSP. Secondly, based on a literature review, a detailed framework for future research has been designed including a detailed description

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of methodology. A three-phase approach has been proposed. Each research phase will be treated in a single article using a carefully chosen methodology.

Key words: supply chain management, environmental sustainability, logistics outsourcing, logistics service provider, LSP, logistics service buyer, overview, future research

1 Introduction

The struggle for existence in a highly competitive global environment is fraught with difficulty. Providing quality products or services correctly and in an appropriate manner and following new or advanced indicators of competitiveness is the only way to ensure the efficiency and effectiveness of one's business [26]. Despite this, true competitive advantage does not depend solely on a single company, but on the entire supply chain [2]. We are now facing competition between the supply chains of various companies, rather than competition between individual companies [11], which requires the integration and synchronization of all partners in the supply chain network, including logistics service providers.

Providing the correct, quality product in an appropriate manner has become much easier since companies began to focus on their core-business while leaving secondary activities to be outsourced. Meeting the increased requirements which ensure competitiveness is, however, a far more difficult task. Low cost, high quality and reliable delivery - which in the past were sufficient factors for providing competitive advantage [33] are no longer enough. Although they are still among the key indicators, new ones have begun to appear on the horizon. One of these new indicators is sustainable supply chain management, which has recently been the focus of a great deal of attention due to the deterioration of the environment [27], as well as a need for the reduction of waste and costs [22]. The environmental aspect is not the only facet of sustainability; those social and economic aspects which contribute to sustainability are included as well [24].

Ensuring a sustainable supply chain means that every member involved strives to achieve the targets related to sustainable development. The role of LSP is substantial in this case, perhaps even vitally important. This is for two reasons: first, logistics providers began to play a crucial role in the supply chain and secondly, transport is one of the biggest polluters of the environment. Despite the importance of LSP, the impact of other logistics functions should not be ignored [6]. Considering the critical role played by logistics functions, this article aims to investigate the efforts made by LSP, as well as buyers of logistics services in order to achieve environmentally sustainable goals reached thus far. Our study is limited in scope to the environmental aspect since we do believe that it is the most significant facet and the one which most contributes to sustainability. Based on a brief analysis of the current situation in this area, suggestions for future research are proposed, including a detailed description of the methodologies used for implementation.

The paper is structured as follows: the next section presents a brief review of results which form the basis for the third section where we make suggestions for future work. Section four describes the research methodology, followed by the conclusion in the last section.

2 A brief overview of the contribution made to this issue

Sustainable supply chain management has been the focus of increased attention by researchers since 1990 when the first articles dedicated to this topic appeared [24]. Although it includes three aspects (environmental, social and economic), most of the articles discuss only the environmental aspect together with economic issues. Articles focused on the social aspect received less attention [8, 24]. This reveals that there is a lack of integration of all dimensions (environmental, social, and economic) of sustainable development [32].

Manufacturers (those representing the central part of the supply chain) are most frequently examined in the above mentioned articles, followed by wholesalers, suppliers, customers and retailers [7, 14]. Last place belongs to LSP [8]. Within all the studies taken into consideration, more attention was paid to functions such as purchasing and supply, production and product design and distribution [30]. Articles are mainly focused on automotive, electrical, retail, pharmaceutical, agricultural and some other industrial sectors [1, 9, 10, 23, 25, 28, 32] and rarely on the transport and logistics industry. Most of those articles regarding the logistics industry are focused on modal changes, carbon footprint reduction, green information technologies and the green design of the logistics network [3, 4, 12, 13, 14, 17, 20, 21, 31]. It can be summarized that increased attention has been given to the manufacturing industry, while the scope of the logistics industry has largely been ignored.

Some recently published research in the area of green initiatives of LSP have been found, which indicates some progress in this area [7, 14, 15, 18, 25]. However, this is only one aspect of sustainable logistics which unfortunately cannot be realized without buyers' initiatives, which represent the second aspect of ensuring sustainable logistics. The study done by C. Mack (2012) [14] indicated that a buyer of logistics services in fact often discusses sustainability issues with LSP, which are later not included in the selection process. The same research also summarized that buyers often put pressure on LSP to be more environmentally responsible and require sustainable practices such as (1) the reduction of their carbon footprint, a reduction in fuel consumption, the implementation of various certificates, and recycling programs. However, only three of the thirty-six LSP included in this study indicated that sustainability issues were a major factor when extending existing contracts. Hassini et al (2012) [7] underlined the fact that buyers of logistics services require environmental performance of 3PLs in questionnaires, which play a minimum or no role at all in the final selection or contract. Their survey showed that there is a large discrepancy between the wishes of customers and their practical application. The result of a study done by Halldorson et al (2010) [6] further revealed that buyers still place too much focus on traditional criteria, rather than on an environmental criteria. It can be concluded that there is a wide margin for manoeuvre left for buyers as well as LSP in this area.

3 Implications and directions for future research

After the brief literature review, it is clear that most of the articles regarding environmental sustainability in the supply chain draw attention first to the manufacturing companies, followed by wholesaler and supplier. Environmental sustainability in the logistics industry was given less attention, and even then only in the last few years. This implies that the green logistics market is currently in an evolving phase [16] and is making slow (one might believe too slow) progress [5].

Taking into consideration the increased positive impact of environmental protection on the efficiency of the supply chain and regarding the fact that only mutual interaction among the supply chain partners can result in success, speeding up the implementation of green logistics is imperative. Manufacturing companies, as a central and essential part of the supply chain and the greatest buyer of logistics services, have the greatest impact and therefore the maximum influence on the environmental sustainability of LSP. In doing so, however, the role of other partners partaking of logistics services (supplier, wholesalers, etc.) should not be ignored since together each player forms a part of the supply chain.

Previous research, however, indicated that the LSP has started to work towards ensuring sustainable logistics services for various reasons, including due to pressure exerted on the part of customers [8]. Still, there are many ambiguities and inconsistencies between the requirements of the buyers of logistics services and the offers available from LSP [5]. Hence, there is a need to clarify these ambiguities and begin regulating the field right from the initial phase of the selection of an LSP. We would like to present several suggestions for future investigation, listed below. The key area or target population that will benefit from each proposal are mentioned as well. The proposals of each group will be treated in a single article, using a carefully chosen methodology presented in Chapter 4.

The first set of research questions will be: *Are criteria related to environmental sustainability involved in the process of selecting a LSP? Which of them are most commonly used? Are they well-defined? Do they cover the entire area of environmental sustainability? Is there any relevant difference between the frequency of the use of environmental sustainability criteria between continents? Is there any difference between the evaluation criteria by continents?* The research will be presented in the first of three future articles, by using methodologies described in Subchapter 4.1. It will integrate already published knowledge and will provide an opportunity for theory development as well. Research findings will be useful for researchers as well as decision makers and managers in buying companies.

Another area for future research concerns the selection methodologies, namely: *What type of methods best suit the selection of LPS? What individual methods are most commonly used and why? What are their strengths and weaknesses? Is any difference evident in the methods used in the case of sustainable LPS selection? Is the choice of methods conditioned by the industry wherein LSP provides logistics activities?* The second paper will give answers to the above-stated questions by using the methodologies described in Subchapter 4.1. A study of this kind could be of great help to researchers in finding the most suitable method or methods, eliminating advantages of previous methods, developing software solutions for the selected method etc. Moreover, the article will also be of great advantage to end-users. Currently there is confusion as to which method is best, as there are a whole range of choices available. Decision makers do not know which to choose, how to implement their choice etc., and in some cases, are not even fully aware of the existing methods available to them.

The last step in our paper would be to demonstrate the selection process of sustainable third party logistics service provider (3PLP) in a real case study of a selected Slovenian company. Key elements of the research will be: (1) two empirical surveys that will reveal which 3PLP is sustainable and (2) generated knowledge from the first two articles. The study will answer the following questions: *Is the method suitable? What problems have arisen in the implementation of the method? What are the disadvantages of this method? How could they be overcome? Is there any software to facilitate the derivation of the selection process?* This research, presented in the third paper will open up the possibility of a great many new ideas for future research, specifically, to verify the credibility of the method used, to carry out the selection of 3PLP by using various methods in order to compare the results and propose improvements to those methods, etc. The study will, at the same time, confirm the usefulness of certain methods which will encourage decision makers to implement them. This could be of great use with regards to outsourcing.

4 Research methodology

In order to answer the above-mentioned questions, a research plan was designed. Due to the considerable scope of the study, a three-phase approach was used (see Fig. 1).

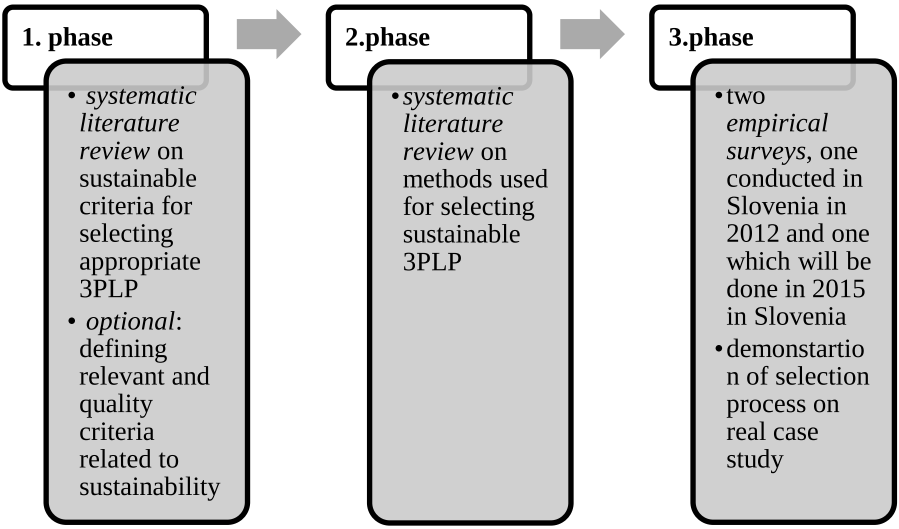

Fig. 1: the research design of this study

The research in each phase will depend on the results from the previous phase, upgrading upon the knowledge found and will be presented in a separate paper. Three different articles will therefore be produced within an interval of no more than three years. The first article is expected to be finished in the second half of 2015, the second article in the first half of 2016. A survey conducted in the third article is the most time consuming, hence it will most likely not be ready before 2017.

The aim of the first paper is to identify the most frequently used general selection criteria related to sustainability, followed by the evaluation of their suitability, quality and sufficiency. If the criteria in the published literature related to sustainability are well-defined, a detailed presentation of each precise criteria as well as critical analysis will be given. If the survey reveals a lack of criteria in the field of sustainable development, then criteria need to be determined. The second paper will be focused on a detailed review of all used multi-criteria decision making (MCDM) methods, their frequency, trend of use through the selected time zone, region/country as well as industrial sector of used method, advantages and disadvantages of various methods, etc. In addition, the study will also show whether any of the methods was more frequently used when selecting a sustainable 3PLP. Any other difference will be detected as well. Both of the previously mentioned systematic reviews will be conducted in order to integrate, refine and systematize knowledge available for researchers to make further investigations and assist decision makers or managers in making the right decisions. One part of the practical application of the received knowledge will be shown in the third article which will demonstrate the selection of an appropriate sustainable 3PLP in a real case study.

4.1 A detailed description of the methodology of the first and second phase

A systematic literature review regarding the criteria and most commonly used methods for the selection of the appropriate 3PLP will be conducted in the first and second phase. Efficiency, quality and an unbiased search are the key reasons for using such a review in this study [9, 19, 29]. Furthermore, this sort of method will enable the integration of current knowledge and will be helpful and useful for researchers as well as for company managers. This is, however, also one of key objectives of the current article. A multi-stage method, proposed by Walker et al. (2008) [29], will be used to carry out a review:

- 1. Stage – Planning the review.
- 2. Stage – Implementation of a review.
- 3. Stage – Reporting the results.

During the first stage, the need for a review will be determined and the research target defined. The second stage will cover the determination of the search inclusion and exclusion criteria, a selection of published studies, evaluation of their quality, data extraction and analysis. Result analysis and future recommendations useful for further analysis will be given in the last stage.

The first stage and some activities of the second stage have already begun. Up to this point the most appropriate keywords, time frame, inclusion and exclusion criteria have been selected. It has also been decided that the literature review will not be carried out only on scientific journals but also other sources as well, namely books, book chapters, conference proceedings, master's theses and doctoral dissertations. In addition, the most prestigious journals in the field have already been selected. Further activities for the second stage will be done in the near future. Detailed results of the research will be disclosed and critically examined in the first two articles.

If the review reveals that the criteria related to sustainable development actually do not exist or are rarely mentioned, then they will be (re)defined. Defining appropriate, quality and quantitatively sufficient criteria will require the cooperation of experts from various fields, namely science, logistics industry (3PLP), the manufacturing industry as well as government. Gathering ideas and suggestions about the appropriate criteria will be conducted using interviews as they provide much greater data credibility than surveys. The final selection criteria will be carried out using several expert meetings organized with the aim of promoting discussion. The process will be quite time consuming, but we do believe that this is the only and best method.

4.2 A detailed description of the methodology of the third phase

The third phase, which will be based on the results of two detailed literature reviews conducted in the first two stages and two empirical surveys, is the culmination of our research. The process of a systematic literature review has already been described in detail in the previous chapter, therefore this subchapter will be focused on empirical surveys. Both the empirical surveys will be limited to the Slovenian logistics market, which is small, covering only about thirty large and medium-sized 3PLP, and focused on ensuring sustainable development in two different ways; firstly, the implementation and use of sustainable standards and secondly, the use of software solution, namely a Transport Management System (TMS), Warehouse Management System (WMS) etc. The fact that only two indicators of sustainability (standards and software solutions) will be included in the study could potentially be a weak point. However, they are two of the most important and most frequently mentioned indicators in the published literature and it may be the case that this will not affect the quality of the results.

The first survey was conducted in 2012. Data were obtained from a questionnaire sent by e-mail to the senior logistics managers of twenty large and medium-sized 3PLP operating in Slovenia. Sixteen questionnaires were filled out and four managers declined to participate in the survey. The second survey will be done in 2015 in the same manner as the first survey.

5 Conclusion

This article explored the state of environmental protection of LSPs, with the aim of proposing improvements and consequently ensuring a higher profitability of the supply chain. During an investigation of the literature, we have noted that the logistics industry (in comparison with other industries) received less attention. In essence, it lags behind and has seen slower progress. Moreover, the investigation revealed some ambiguities and defects which to a significant extent hinder the environmental performance of LSPs. It was found that LSP devote attention to environmental protection, since buyers of logistics services want and require this, however, those requirements are not taken into account either in the selection process or in the contract. This constitutes a major obstacle to the formation of a sustainable supply chain since the buyers of logistics services significantly influence environmental sustainability. Hence, some implications and directions for further studies are proposed.

This study provides a great deal of useful knowledge in the field of sustainable logistics, reveals some gaps which hinder the sustainability of logistics services and consequently the entire supply chain, and provides a framework for future research in order to fill discovered deficiencies and speed up the implementation of green logistics. Despite the fact that only one aspect of promoting sustainability has been processed (logistics outsourcing), it includes two key players, namely the buyer and LSP. Taking this into consideration, we do not consider this to be the weak point of our research.

We do believe that our final result and the knowledge gained therein will be of great help to researchers, as well as to industry decision makers. Integrated knowledge from the published literature, the newly created knowledge and other obtained results will be solid foundations for further research as well as for practical decision-making.

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CHANGES IN PEDESTRIAN AND CYCLIST TRANSPORT ON PARDUBICE´S MASARYK SQUARE CAUSED BY URBANISTIC DEVELOPMENT OF CITY CENTRE

Pavlína Brožová[1], Josef Bulíček[2], Ivo Hruban[3]

Abstract: The article deals with the dilemma of traffic on Masaryk Square in Pardubice, which transport importance increases with urbanistic changes in the city centre. The main focus is on pedestrians on the pedestrian crossings, cyclists and urban public transport. The first part is focused on history of the place; the second one is focused on transport. The change of urban public transport operation in Míru Street and its influence on the operation of Masaryk Square interchanging node are evaluated. In the field of pedestrian traffic the distribution of flows between three parallel pedestrian crossings is pointed out. In the case of cyclists transport possible conflicts at pedestrian crossings were surveyed.

Key words: Cyclists**,** Pedestrian, Pedestrian crossing, Pardubice, Urban Public Transport,

1 Introduction

The transport situation in each city is changing in the time. Those changes can be caused by cities´ development or by urbanistic intervention. This contribution is focused on Pardubice and their Masaryk Square.

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Pardubice is one of the 14 Czech country seats with over 90 000 inhabitants. The city was established in the 13th century and become city in 1340. [1]

The historical centre is located next to the Pardubice castle. This centre is mainly pedestrian zone. The development of the city was relatively slow, new commuterville and new factories were built especially in 20th Century. The increasing number of commuters causes the necessity of qualitative transport junction. New railway station and the bus terminal were built in the distance 500 m between each other because railway and bus system were comprehended as two different systems at that time. The location of the bus terminal and railway station from the half of the 20th century is about 2 kilometres south-western far from the historical centre. This area was planned as development area; unfortunately those plans have not been finished yet.

The modern centre in this context has grown up on the crossing of the road II/324 from Podmokly via Hradec Kralové, Pardubice to Chrudim and streets Palackého (to railway station) and Míru (to historical city centre). This crossing is called Masaryk Square – see the map on the Figure 1.

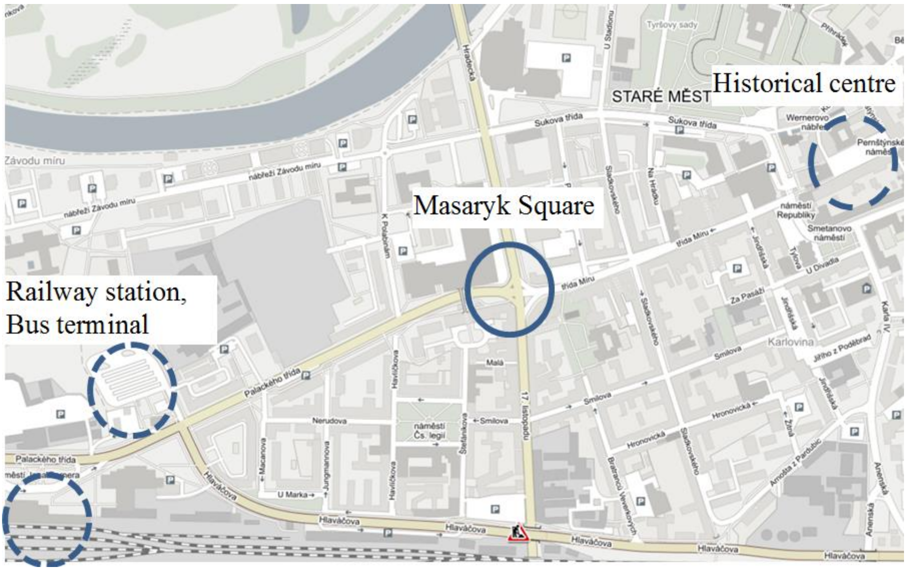

Figure 1 Map of Masaryk Square

Source: Authors on the map base of mapy.cz

2 Masaryk Square

The Masaryk Square had a lot of physique in past. This place changed most of all other places in Pardubice in few years ago. The former free spaces were built-up. The former state is shown in Figure 2.

Figure 2 Former State of Masaryk Square

Source: http://www.ateliermok.eu/detailreference.php?reference=pardubice_masarykovo

The green areas are away nowadays. The park in the middle of the Figure 2 was changed to administration-shopping building Magnum. Building with 9 floors was opened in 2009. [2]

The car park and the park situated on the left side of the Figure 2 were replaced with shopping centre with multiplex cinema. The shopping centre was opened in 2008 on the area of 13, 503 m^2. [3]

A new street interconnecting Sukova Street and Závodu míru Street has been constructed (the place is located in upper part of Figure 2 on the left below the orange building). The number of arms at signalized junction in front of ice hockey stadium has been improved from 3 to 4. This street is essential for accessing to large garage of shopping centre.

Those two buildings change the importance of Masaryk Square, since 2008 it is not only the junction of urban public transport lines, but also important point for Pardubice inhabitants´ daily life.

3 Transport on Masaryk Square

This main goal of this paper is to describe traffic situation. Time frame for evaluation of traffic situation is represented by 12 hours (from 7 a.m. till 7 p.m.) of a common working and school day, when the intensities of whole traffic flows are important.

The transport prospecting realized in 2010 by the company Ředitelsví silnic a dálnic ČR found out that via Masaryk Square pass 12011 cars per day (buses and trolleybuses included) [4]. Buses and trolleybuses are representing ca. 10 % of total traffic flow.

3.1 Urban Public Transport

Masaryk Square is an important interchanging node of urban public transport (UPT) system. This interchanging node is also one of things, which has been changed in relation to changes in the city centre (reconstruction and traffic calming of the Míru Street).

The central junction for the UPT has been established there. The current numbers of the lines on Masaryk Square are 9 trolleybus lines and 12 bus lines. For the full reader´s information the total number of day regular lines in Pardubice is 11 trolleybus lines and 17 bus lines [5]. We can see that most of the lines pass the Masaryk Square.

Not only the UPT lines have stops on Masaryk Square, but also regional buses (12 lines) as well as long-distance buses (6 lines) have stops there. Those lines are going especially in northern direction from Pardubice. Important fact is that the most of connections going towards Pardubice (or continuing in southern direction) has the stop only for alighting of passengers there. On the other hand the demand of passengers after those connections – usually terminating at Pardubice bus terminal located not far from here can be anticipated as minimal.

Interchanging node is consisted of 3 UPT stops and of 2 stops for regional and long-distance buses. The concreate stops configuration is shown in the Figure 3 (stops are marked with arrows). The stops for regional and long-distance buses (one on each side of street) are marked by yellow arrows. Two stops for UPT are located on the eastern side – one of them is for buses going to northern parts of Pardubice, the second one for buses going to eastern parts of the city. In reverse direction all UPT bus connections are using only one stop located on western side of Masaryk Square.

Figure 3 Stops at Masaryk Square

Source: Authors

There are operated 1151 UPT buses [5] and 100 buses of regional and long-distance lines [6] during selected time period.

It is able to be said that the operation is relatively rush (1.74 buses per minute in average) in comparison with the extent of infrastructure at disposal. Buses have a separate bus lanes in the street, but other road operation is reduced only to one lane in each direction. On the other hand also the comfort of interchanging passengers is able to be limited due to necessity to cross the street if the arrival and departure stops are located on different sides of street. This crossing is possible especially at pedestrian crossing located in the middle of interchanging node with no assistance of signals (traffic lights). Using of a signalized crossing in front of the Magnum-building represents 270 m long journey and necessary time is about 3 minutes (according to test realized by authors). It is depended on waiting times of 2 signalized crossings and on the situation of passenger (different time e.g. by carrying of luggage, walking with children etc.). These interchanging conditions are not suitable for the interchanging node of given meaning and for that reason the pedestrian crossing without signals in the middle of the interchanging node (Figure 4) is essential (and frequently utilized by pedestrians).

Figure 4 Pedestrian Crossing between the Stops

Source: Authors

Similar situation is also occurred by customers or visitors of the shopping centre, but they can use also the entrance located directly by junction of Míru, Palackého, 17. listopadu Streets and Masaryk Square (leading to signalized pedestrian crossing).

The most of trolleybus lines in direction from/to the eastern part of Pardubice were routed through Míru Street in the former state. The list of those 7 lines and their operational features are shown in Table 1. This (former) UPT concept was based on three main stops essential for interchanging – Masaryk Square, Míru Street, Republiky Square. The problem of this concept was that a walking transfer between some of those stops was necessary during interchanging between some lines (e.g. between the line 3 important for northern part of city and the lines 1 and 5 important for southern part). The distance between those stops for this interchange was about 250 – 300 m (according to the position of stop at Masaryk Square.).

Tab. 1 Lines on Míru Street 2008

Line number	Direction	Interval (min)	
		peak	saddle
1	Jesničánky, točna – Slovany, točna	12	15 – 30
2	Polabiny, točna – Pardubičky, točna	15	15 – 30
4*	Polabiny, toč. – Třída Míru – Polabiny, toč.	30	30
5	Dukla, točna – Dubina, sever	10	15 – 30
13	Polabiny, Sluneční – Dubina, sever	10	15 – 30
21	Polabiny, Sluneční – Slovany, točna	60	60
27	Polabiny, točna – Dukla, točna	60	60

*circuit line

Source: Authors with [7]

Míru Street has passed an important reconstruction connected also with reduction of UPT operation extent. This street is still equipped with infrastructure for trolleybuses, but the operation was calmed.

Only trolleybus lines 4, 21, 27 are operating in the Míru Street now (after calming). It represents in total 6 connections (trolleybuses) per hour only. [5]

Other lines (with a relatively rush operation) were rerouted via Masaryk Square and Sukova Street to the Republiky Square where both streets are interconnected. It represents 434 buses together per selected time frame. Problem is that a new route is about 450 m longer. Total extension of routes means 195.3 km per this time period. On the other hand the travel times (according to comparison of lines 1 and 27 [5]) are the same. It is due to the fact, that the speed can be higher at Sukova Street than in calmed Míru Street.

These changes caused that interchanging node on Masaryk Square become an important interchanging node as it is mentioned above. Capacity utilization of the node is a question, because there are about 434 bus connections more than before (during given time frame). It means that newly added bus connections are creating 37.7 % part of nowadays utilization of this node. Pervious state is evaluated by state of art extended of operation and time schedule valid in the year 2015 [6] in this paper.

Distribution of bus connections during time for all three UPT stops is represented by the Figure 5.

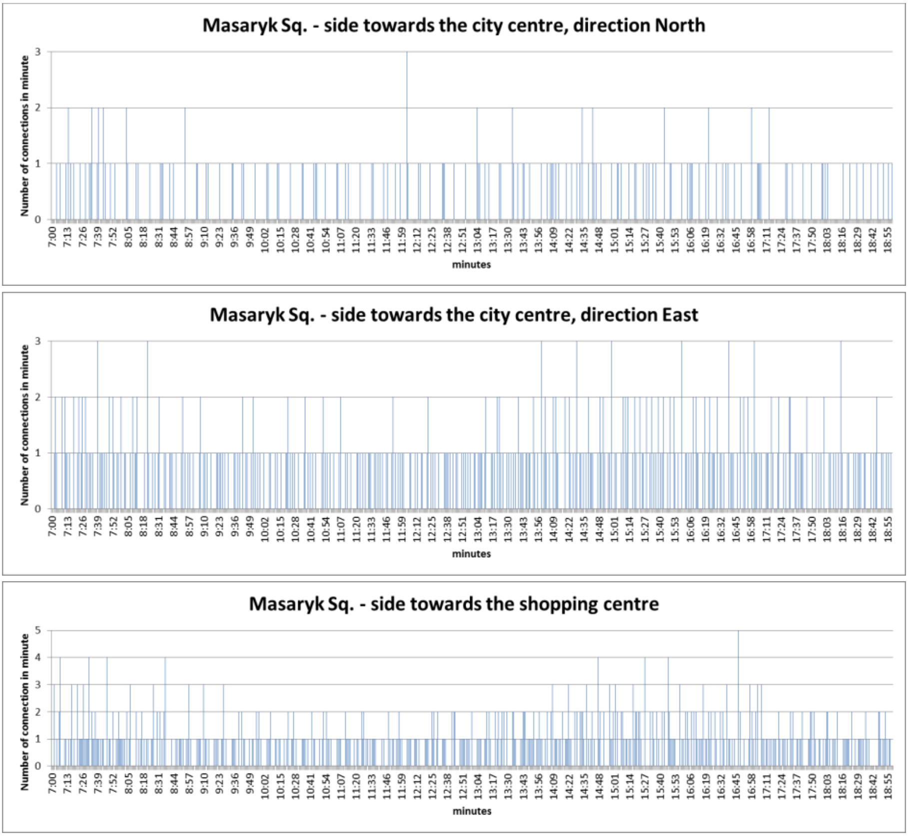

Figure 5 Distribution of UPT Connections in Time

Source: Authors with [6]

It is able to be seen (based on the Figure 5) that some time conflicts of some bus connections are occurred. The most serious conflict is that 5 buses are requiring one UPT stop on the western side in front of shopping centre at 4:47 p.m. (16:47) in one minute. Quantification of conflict presumptions is provided by the Table 2.

Important note is that they are regular conflicts (according to time schedule) only; conflicts based on irregular (stochastic) delays are not evaluated in this paper.

Tab. 2 UPT Stop Conflicts, Masaryk Square

Number of bus connections in one minute	Number of minutes (state-of-art)			Number of minutes (former state)		
	West side all directions	East side direction East	East side direction North	West side all directions	East side direction East	East side direction North
5	1	0	0	0	0	0
4	7	0	0	0	0	0
3	21	9	1	6	1	1
2	100	62	14	54	14	14
1	276	259	138	228	163	138
0	315	390	567	432	542	567
Total number of connections	**572**	**410**	**169**	**354**	**194**	**169**
Occupation degree	**0.56**	**0.46**	**0.21**	**0.40**	**0.25**	**0.21**

Source: Authors with [6]

There is able to be seen in the Table 2 that rerouting of lines from Míru Street caused about 31 conflicts at stops. Conflicts of 2 vehicles are not reflected, because stops are usually designed for two vehicles. On the other hand newly occurred conflicts are more serious (4 vehicles in 7 cases, 5 vehicles in 1 case). Western side of Masaryk Square is more problematic due to only one UPT stop at disposal. Occupation degree is calculated as the ratio between numbers of occupied minutes and the total length of time frame (720 min).

3.2 Regional and Long-distance Buses

There is better situation in the case of regional and long-distance buses. There is only one conflict of 2 buses at 4:46 p.m. (16:46) on the western side in front of shopping centre and three conflicts of 2 buses at 9:18 a.m., 12:40 p.m. and 1:40 p.m. (13:40) on the eastern side towards city centre. The conflicts of two buses are taken also in to account because these stops are shorter. Small number of conflicts is caused only by the fact that there are 100 connections of this kind (compare to 1151 UPT connections) and 2 stops are at disposal (for regional and long-distance buses). Distribution of regional and long-distance connections (together) is illustrated by the Figure 6.

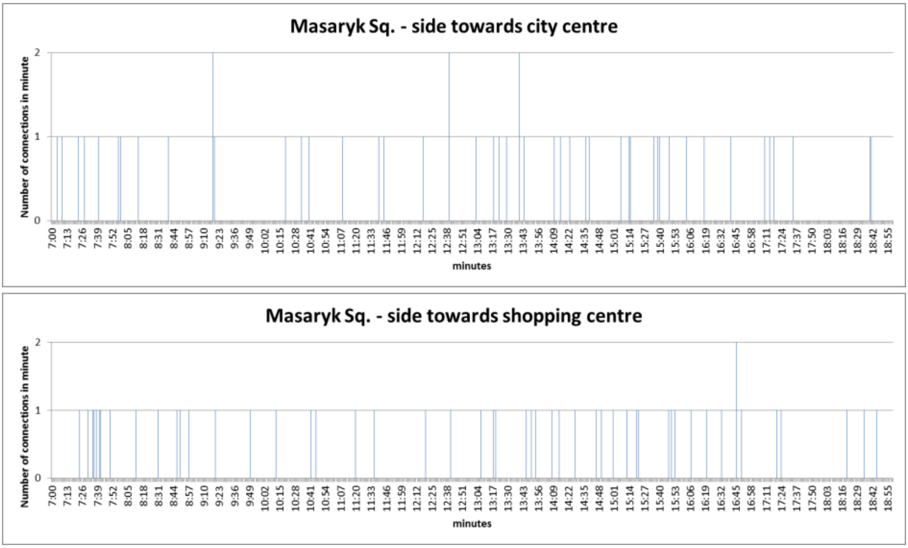

Figure 6 Distribution of regional and long-distance Connections in Time

Source: Authors with [6]

Occupation degree is 0.07 for the stop situated on the western side (51 bus connections) and 0.06 for the stop on eastern side (49 bus connections). This segment of transport is not depended on the situation in Míru Street

3.3 Pedestrian traffic

Conditions for pedestrian transport also changed. The Masaryk Square is bordered with two crossroads with signalized pedestrian crossings. The total distance between those crossings is 275 m. The road crossing outsides those pedestrian crossings was prohibited and barred with fences in the former state before urbanistic changes.

There were some changes of this regime resulting in state of art situation represented by new pedestrian crossing in the middle of this road section. This is realized hand in hand with the changes in urban meaning in surrounding.

Important fact of this development is that interchanging node was equipped only with the crossing place in the first state. This solution was bringing collisions and dangerous situations between cars and pedestrians. For that reason this crossing place was changed to pedestrian crossing without signals.

There are three pedestrian crossings now and they are shown in Figure 7.

Figure 7 Pedestrian Crossings at Masaryk Square

Source: Authors

Those crossings are named for easier orientation in the order to the Figure 7 (starting from the left).

3.3.1 Palace Pedestrian Crossing

The first one is on the crossroads of II/324, Palackého Street and Míru Street, located between Magnum building and Shopping centre Atrium Palace. It is equipped with request pedestrian signals (traffic lights). The pedestrian crossing is divided into three parts which one of them is without signals. This part is situated on the arm between Míru Street and Masaryk Square with relatively low intensity of traffic.

This pedestrian crossing is used by pedestrians going in direction between city centre and railway station or especially to Atrium Palace or to Magnum building.

3.3.2 Stop Pedestrian Crossing

This pedestrian crossing is situated between the stops of UPT and almost before one of the entrances to the shopping centre. It is used by pedestrians going to the shopping centre or changing between UPT´s lines. The meaning of this pedestrian crossing was mentioned in the chapter 3.1.

3.3.3 Stadium Pedestrian Crossing

Last pedestrian crossing is located farthest from the main places of interest. It is used especially by pedestrians going from/to the ice hockey stadium or offices next to the crossroads or to the Wonka Bridge.

This article tries to find distribution of pedestrians between those pedestrian crossings; the results of the survey are mentioned in chapter 4.

3.4 Bicycle transport

Bicycle transport is represented by cycleway on the western side of the Masaryk square and it is quite good noticeable on the Figure 3. The former direct routing (visible on the Figure 2) has been changed and now the cycleway is guided around the Atrium Palace.

The number of cyclists using the special cycle crossing is 373 in direction to Atrium Palace and 359 to the city in 12 hours. Rest of them uses pedestrian crossings.

Some of cyclists are going on the eastern side of Masaryk Square on pavement together with pedestrians. This is possible because this way is marked as collective path for pedestrians and cyclists together. In spite of the fact that there is a rush pedestrian traffic due to the wideness of pavement possible conflicts are not serious.

4 Survey of Pedestrian Crossings at Masaryk Square

As it was mentioned in the chapter 3.3, there exist three pedestrian crossings at Masaryk Square. The survey of utilisation was realised on 25th June 2015 between 7 a.m. and 7 p.m. o´clock. The survey was realised as a part of practical education of students of Department of Transport Technology and Control. The research was focused on number of pedestrians and cyclists and their behaviour. All the pedestrian crossings are shown in the Figure 7.

The results of this research are shown in the Figures 8 and 9. Each crossing is used with another group of pedestrians, for that reason it is possible to see different utilisation during the time. The comparison in utilisation of all pedestrian crossings (P.C.) is shown in the Figure 8.

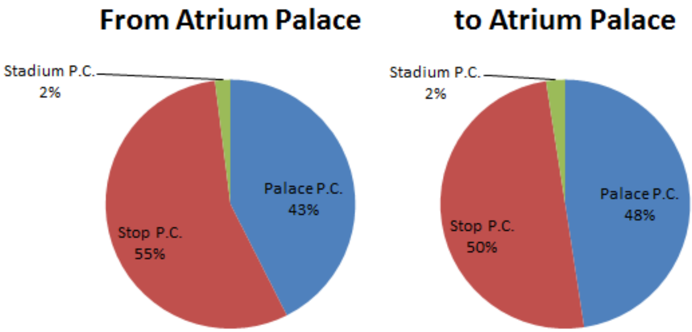

Figure 8 Ratio of Utilization

Source: Authors

The Atrium Palace is one of the places where it is possible to get a lunch in the city centre. The increasing numbers of pedestrians on both pedestrian crossings acknowledge this proposition. The last crossing at stadium is least utilised.

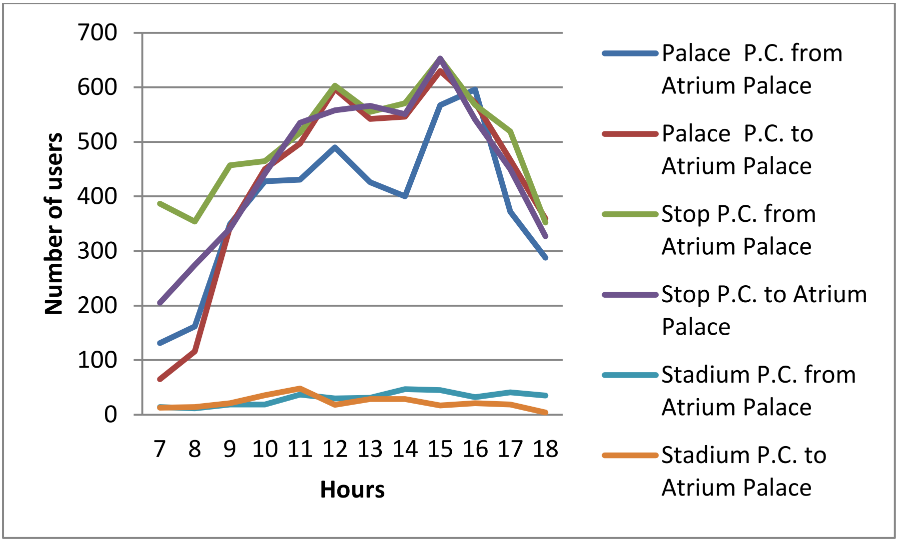

Figure 9 Twelve Hours Utilization of Pedestrian Crossings

Source: Authors

The graphs in the Figure 9 are representing total traffic intensity of pedestrians and cyclists together. These intensities are expressed in resolution of one hour. It means that the numbers are indicating numbers of users in each hour.

4.1 Palace Pedestrian Crossing

We can see that people use this crossing mainly during the opening hours of Atrium Palace, for that reason increases the number of users from ca. 150 during 7 and 8 a.m. to 340 at 9 a.m. o´clock. It is clearly visible in the Figure 9.

This crossing is the second most utilized. The maximum number of users uses this crossing at 3 p.m. o´clock in the direction to Atrium Palace (630 users), and at 4 p.m. o´clock in reverse direction (596 users).

It is possible to see another peak on the graph in Figure 9. This is at 12 p.m. o´clock during lunchtime, when a lot of people go to Atrium Palace for a lunch.

4.2 Stop Pedestrian Crossing

This pedestrian crossing is the most utilized on Masaryk Square with 10 852 users per 12 hours. The stronger direction is from Atrium Palace with 5674 users. Users´ flow on this pedestrian crossing is similar as in the pedestrian crossing before. Only mornings´ hours (7, 8 a.m.) are stronger. This fact acknowledges that pedestrians use this pedestrian crossing during the interchanging in the Masaryk Square UPT interchanging node.

Maximal number of users was measured at 3 p.m. in both directions (652 and 653 users). It is also the pedestrian crossing with minimum of conflicts. The number of conflicts is smaller than 1 %. It means that pedestrians, cyclists and drivers are careful. Also during the afternoon peak hour help to this state traffic jams in both directions when the cars are stuck in the rows.

4.3 Stadium Pedestrian Crossing

Only 481 users use this pedestrian crossing (212 in direction from Atrium Palace and 269 to Atrium Palace). But thanks to short time for walking, it is the place with the highest number of conflicts. Conflicts are in 13.6 % of cases in direction from and 10.0 % in direction to Atrium Palace. It means that each fifth user from Atrium Palace makes the conflict. In the reverse direction each eightieth user makes conflict. The green is lighting for 7 seconds and the length of the crossing is 20 m. It means that the pedestrians have to pass this pedestrian crossing with the speed 10.2 $km \cdot h^{-1}$ in the frame of “one green” (regular pedestrian speed is 4-5 $km \cdot h^{-1}$). The pedestrian crossing is divided in to two parts with independent signalisation. Naturally the green signal is valid only to the moment of entering the crossing. It is not comfortable for pedestrians because it can cause also mistaken feeling of this situation by drivers (some of them can evaluate this situation that the pedestrians are going too slowly or they can have such similar meanings about traffic situation). Real problem is that 7 seconds is not suitable for entering of the second part of this pedestrian crossing and the pedestrians are obligated to stand in the middle of this rush street. This is the core of discomfort as well as reason for conflicts (entering of second part of pedestrian crossing by red signal).

One of the results of European Conference of the Ministers of Transport [8] is regard to safety actions and improvements for the benefit of the elderly and people with reduced mobility. As the proportion of the elderly is constantly increasing in our industrialised societies, the aim is more than ever to take into account this category of the population. This is in contrast with the effort to minimize all technological times (e.g. the length of green signal, interchanging times etc.) and also for that reason it is necessary to plan the urban environment in rational way.

4.4 Cyclists on Pedestrian Crossings

All those pedestrian crossings are utilized by cyclists. The total number of cyclists crossing Masaryk Square on pedestrian crossings during the given period is 1103. The results are mentioned in same order like the pedestrian crossings were introduced in previous chapters. The counts of cyclists on pedestrian crossings are 6, 3, and 19 % of all users at given pedestrian crossing in direction from Atrium Palace and 7, 5 and 11 % in reverse direction. The Stop pedestrian crossing is less utilized because of bad conditions for crossing – high density of traffic and pedestrians.

Unfortunately quite a lot of cyclists ride a bike directly on the pedestrian crossings, which is in the Czech Republic prohibited. Cyclists break the rules in 28.1, 31.0 and 51.5 % of cases in direction from Atrium Palace and in 29.3, 37.5 and 42.3 % of cases in reverse direction.

It is noticeable that degreasing utilisation of pedestrian crossings increases possibilities for breaking the rules on cyclist's side and for riding on pedestrian crossings.

5 Conclusion

Masaryk Square is an important place for all transport modes. The paper was focused on interaction of all those transport modes. There are found out some basic presumptions for future study of this interaction in detail. It will be necessary due to the fact that each participant of transport has its own requirements and such equilibrated state among those requirements must be found. Maybe such breaking the rules causes any operational problem and on the other hand such things realised in the frame of rules are problematic. Our effort is to study the situation with all negatives and positives for creation of sustainable state. Our effort does not point out only the negatives.

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FATIGUE LIFETIME OF STEEL RAILWAY BRIDGES

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Abstract: The complex lifetime estimation of steel railway bridges depends on several main factors, such as determination of material characteristics (Wöhler curve), history of structure loading, representative stress spectrum determination, and probabilistic calculations. In the paper are non-traffic influences on lifetime and importance of fatigue critical details discussed.

The assessment of the lifetime presented in this article takes into account two important non-traffic loads – irregular temperature load and dead weight. The comprehensive probabilistic evaluation is described on the real bridge structure (steel railway bridge over the Labe River – Czech Republic). The Monte Carlo method is applied.

Determination of fatigue curves of critical details is possible through codes, empirical equations or experimentally. An example of experimental approach of fatigue curve determination of given structural detail (connection of longitudinal and cross beams – member deck of steel bridge) will be shown.

Keywords: railway bridges, Monte Carlo method

1 Introduction

An assessment of the fatigue lifetime of steel bridges is always an integral part of determining their overall reliability. Basically, this assessment (presumption) can be carried out in two different ways, based on the given conditions:

- fatigue damage cumulative theory [1],
- fracture mechanics theory [2].

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From the point of view of existing steel bridges with a generally expected good condition and no growing damage cracks, the fatigue damage cumulative theory is more suitable. This theory allows predicting the fatigue lifetime of the structure until a crack appears.

For this reason, the theory is also applied in European standards [3]. However, the suitability of standard procedures collides with certain fundamental problems:

- history of structure loading,
- determination of material characteristics (fatigue curves) with complicated structural details,
- determination of the representative stress spectrum.

Another important handicap of the standard approach is the strict choice of the hypothesis to assess the fatigue lifetime (Palmgren-Miner), which is not always suitable for the final assessment.

For these reasons, a procedure to assess the lifetime was proposed within the grant project of the Czech Science Foundation (GACR) at the Jan Perner Transport Faculty (DFJP) to decrease the handicaps to a certain extent. The procedure was verified on a real structure meeting the following conditions:

- possibility to verify the fatigue lifetime,
- temperature influence not taken into account yet,
- knowledge of the load history,
- knowledge of the age of the structure,
- typical structure (there are more structures of the same type),
- accessibility of the structure,
- possibility to perform experimental measurements.

These conditions were met by the structure of the steel railway bridge over the Labe River, km 2.184, Rosice nad Labem – Hradec Králové track (Fig. 1). At the time of resolving the grant project, this structure was in the administration of Czech Railways (CD a.s) SDC SMT Pardubice. All steps connected with experimental measurements were consulted with the administrators of the bridge.

2 Principle of fatigue curve determination

When fatigue lifetime evaluation is determined through cumulative damage theory important material characteristics, given by Wöhler fatigue curve, are taken into account. In simple cases of structural details and simple types of loads could be these material characteristics given by codes [3]. Using codes for fatigue curves determination of complicated structural details is questionable by reason of simplifications, which has to be accepted (use of interpolations, approximations).

Other way of fatigue curve determination leads to use of empirical equations [4,5]. This approach allows determination on the base of general material characteristics (ultimate strength, yield strength), on the type of structure (welded, bolted, riveted), on the geometry shape (geometry breaks, notches).

The last and the best approach of fatigue curve determination of complicated structures is through experimental fatigue tests of their critical structural details. However, also in this case are final results only assessments. The reason consist in simplifications of tested specimens, which has to be applied (more or less) during their fabrication, fixation to testing stand or by mode of loads. Experimental determination is expensive and time-consuming. In spite of that, experimental determination of fatigue curve is the best way to achieve qualitatively best results (exactness).

3 Bridge description

Fig. 1: Railway bridge, Rosice nad Labem – Hradec Králové (Czech Republic)

Location:	km 2.184, Rosice nad Labem – Hradec Králové track, Czech Republic
Obstacle:	riverbed of the Labe River, inundation area
Type:	continuous beam with bottom member deck
Spans:	29.97 + 39.41 + 39.99 + 30.01 m
Axial distance of main girders:	6.5 m
In operation since:	1966
Number of tracks:	1
Track speed:	80 km/h

3.1 Structural detail specification

Importance of fatigue structural detail shall be always taken into account. In the case of our steel bridge was critical structural detail given by type of the bridge structure – full plated main girders with member deck (Fig. 1). A fatigue crack can occur in the member deck at the place of connection between longitudinal and cross beams (Fig.2).

Fig. 2: Critical fatigue construction detail of the bridge

4 Procedure of the assessment of the overall fatigue lifetime

An assessment With respect to the calculation (determination) of the fatigue lifetime, the main purpose of the research project was to verify the suitability of the proposed procedure of the lifetime determination and to check the influence of irregular heating or dead weight of the structure on the lifetime.

The applied procedure of the fatigue lifetime assessment was as follows:

- compilation of a computing model of the bridge structure FEM,
- calculation of the dead weight stress value in the critical spot of the structure,
- calculation of the irregular heating stress value in the critical spot of the structure,
- determination of a recalculation coefficient to recalculate the stress in the measured spot (measurement in situ) to the spot of the expected crack,
- acquisition and subsequent evaluation of hydrometeorological data,
- determination of coefficients for recalculation of the air temperature to the structure temperature over the period of a year (month),
- experimental measurement of the irregular heating of the structure,
- determination of the hourly dependence between the air temperature and the temperature of the supporting parts of the structure,
- experimental measurement of the stress of the structural detail,
- assessment of the experimental measurement of the stress of the structural detail (compilation of daily records of the stress in the critical spot – without the influences of temperature and dead weight, and with the influences of temperature and dead weight, assessment of the two-parametric Rain-Flow matrices),
- compilation of physical models (structural intersections),
- compilation of the FEM computing model of the structural intersection,
- determination of the recalculation coefficient to recalculate the stress in the measured spot to the spot of the expected crack (measurement in laboratory),
- experimental determination of the fatigue curve,
- determination of the recalculation coefficient of the load history,
- probabilistic calculation of partial damage,
- determination of the lifetime for the given probability of damage.

All load influences (determined experimentally or calculated) were recalculated to the spot where a crack was expected to occur.

4.1 Computing model of the bridge structure

The determination of the structure lifetime is based on the development of stresses from dynamic load in the critical spot. During experimental measurement using strain-gauge sensors, relatively short-term loads are measured (due to the financial demands of long-time measurements, connected with much higher requirements for technical equipment, higher demands for operators etc.). The most important short-term load of bridge structures is the operation load (e.g. railway transport).

Long-term and permanent static loads can easily be determined by computer models. However, with this method of determining the load, the quality of the model is crucial, so much attention must be paid to simplifications that usually cannot be avoided with computing models.

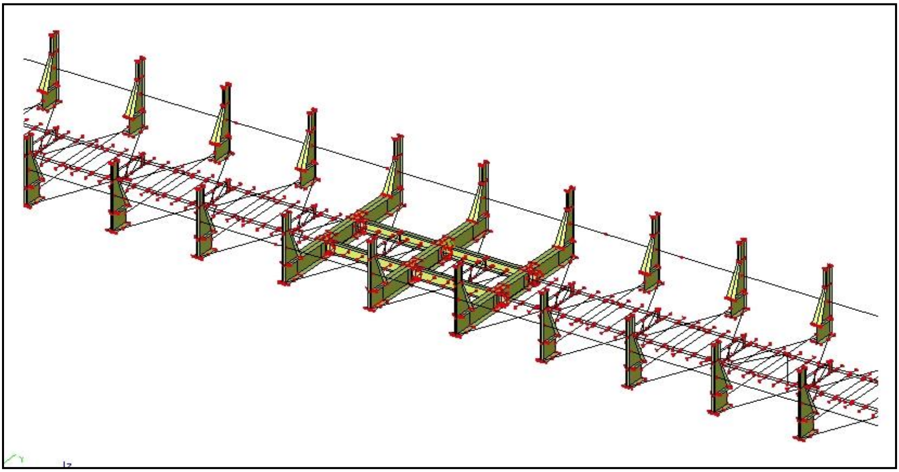

Fig. 3: Combination of beam – 1D and plate elements – 2D (ESA PT)

Gradual "tuning" of the computing model was also inevitable in our research project. The final computing model of the bridge structure was compiled in the ESA PT system [6] as a combination of 1D and 2D elements (Fig. 3).

4.2 Hydro-meteorological dates

To assess the lifetime, hydro-meteorological data from the Czech Hydro-Meteorological Institute and statistical data from Czech Railways were used. The temperature corrective coefficients for various months were calculated.

Using the corrective coefficients, the one-time day measurement of the structure temperature could be recalculated for the entire year. It was determined statistically that momentary climate conditions (cloudy, clear) have a negligible influence on the ratio of the air and structure temperatures.

Tab. 1: Corrective coefficients

month	**temperature corrective coefficients (median)**	**month**	**temperature corrective coefficients (median)**
January	2,00	July	4,33
February	2,00	August	5,67
March	2,00	September	3,00
April	2,67	October	2,67
May	4,33	November	2,00
June	5,33	December	2,00

4.3 Experimental measurement of the structural detail stress

The object of the measurement was a specific structural detail – a longitudinal beam in the connection on a cross beam. Nine strain-gauge sensors were used. The values were measured continuously. The measurement sampling frequency was 75 Hz. The total number of trains passing during measurement was 177 (Fig. 4).

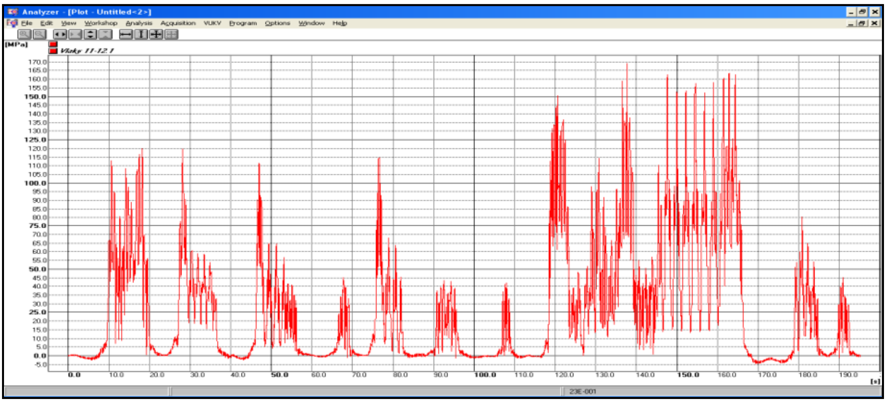

Fig. 4: Hourly stress record, time 11:00 – 12:00 (critical spot of the structure)

The records were processed using the two-parametric Rain-Flow method [7].

4.4 Load history

To determine the fatigue lifetime properly, the load history and size must be taken into account. Thanks to statistics from Czech Railways, it was possible to determine approximately the bridge load history, using the development of the traffic load [8]. The graphical representation of the operating load history is shown in Fig. 5.

Fig. 5: Load history

5 Physical model – determination of the fatigue curve

To determine the material characteristics, the Wöhler curves in case of fatigue strain, physical samples were prepared with a shape corresponding to the monitored structural intersection. By reason of spatial arrangement and force limits of dynamic stand (Fig. 6) were tested specimens fabricated in scale 1:2.

Final shape of specimens was designed as two armed cantilever given by one cross beam and two half-armed longitudinal beams (Fig. 7).

The manner of loading is described on the schema (Fig.8). Longitudinal beam in this case worked as cantilever, which was unstable under load (cross drifting, twisting). On this account was accepted solution called “fork” with special fixation of beam, which allows vertical displacement and fixed others (Fig. 9).

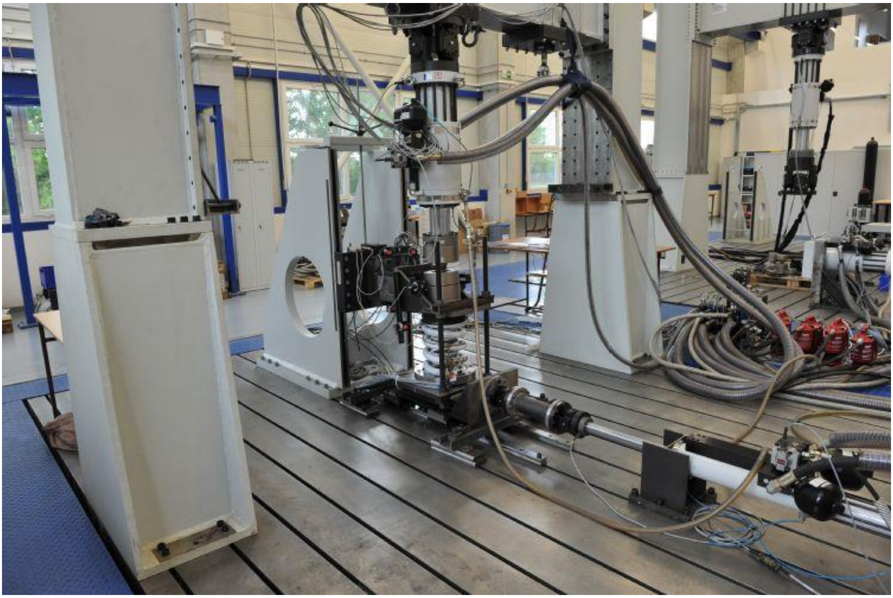

Fig. 6: Dynamic stand

Fig. 7: Axonometric view on specimen installed into stand

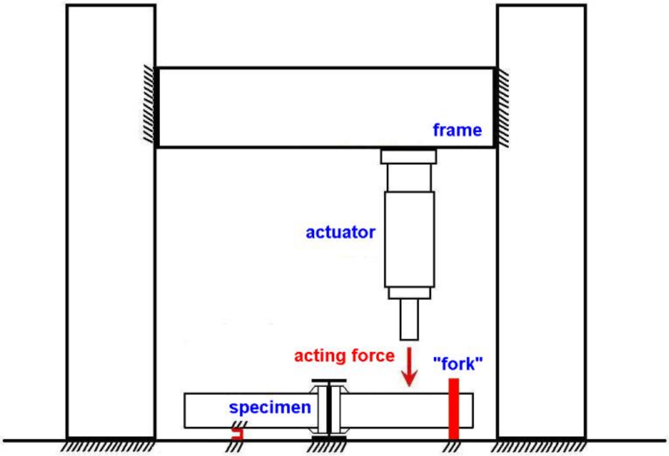

Fig. 8: Load set

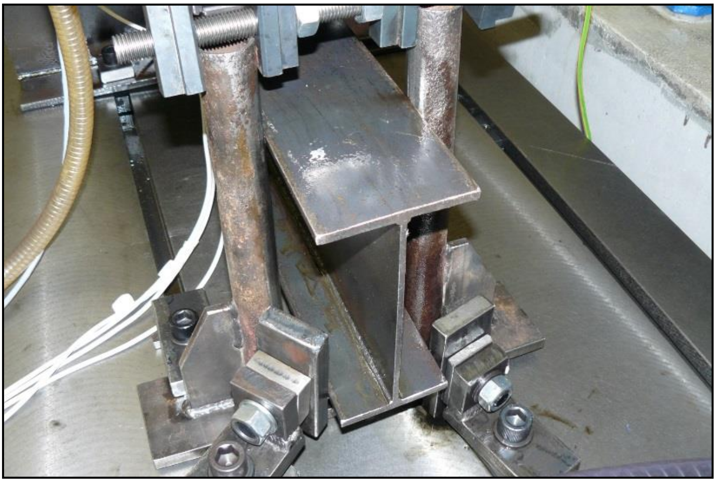

Fig. 9: “Fork”

5.1 FEM model of load set

The purpose of the FEM modeling was to determine stress flow at the physical model and on the base of FEM results to modify physical model in shape with similar behavior as real structural detail afterwards. All FEM models were solved as linear. By gradual progress were three FEM models compiled (Fig. 10).

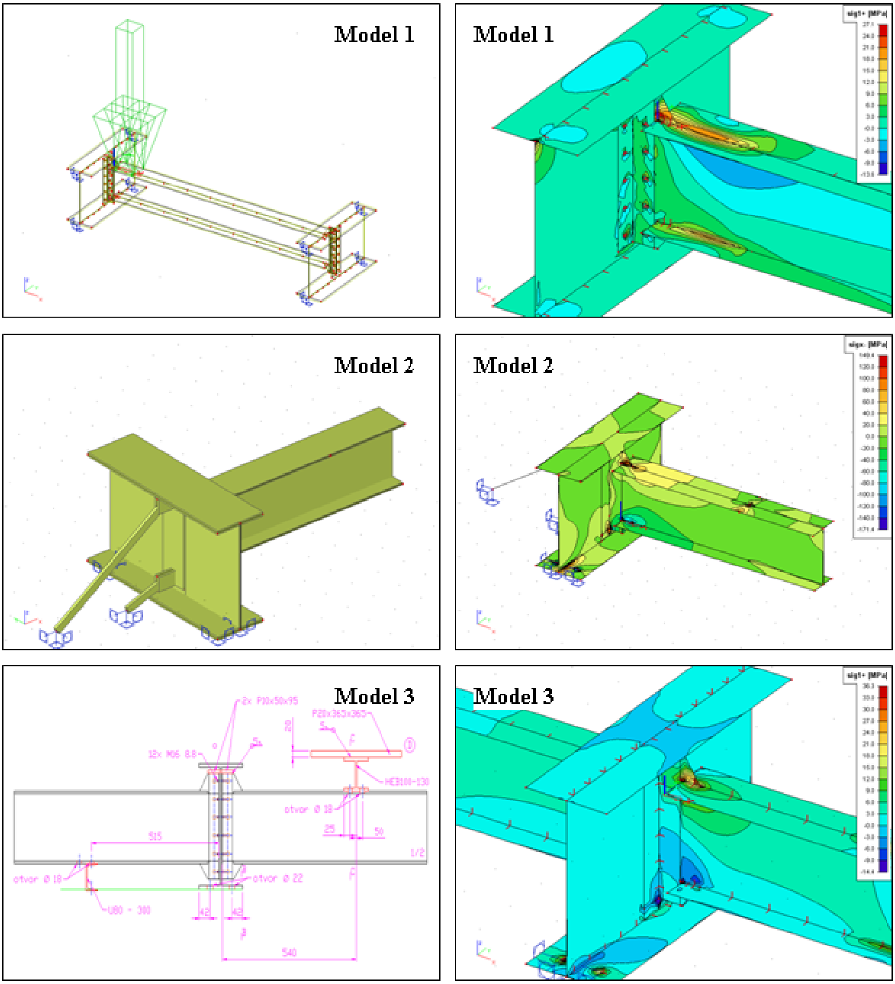

Fig. 10: FEM models

Stresses at the critical place and at the place of reference strain gauge were determined due to FEM model (Fig. 11).

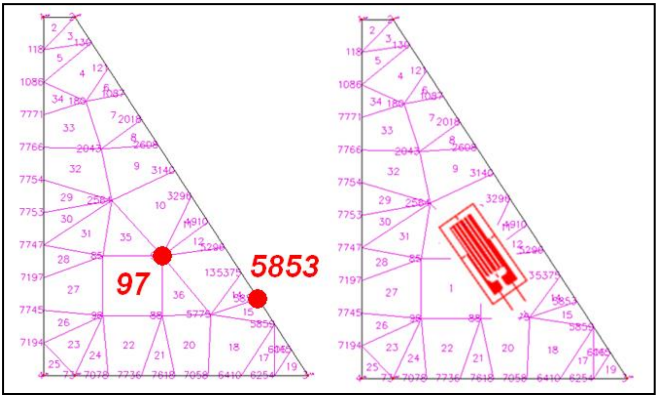

Fig. 11: Identification of stresses at the reference place, location of strain gauge

5.2 Fatigue curve determination

Experimental determination of fatigue curve for given structural detail (tested specimens) was provided by use of laboratory for dynamic and static tests, located in experimental base of Jan Perner Transport Faculty. This laboratory was established in 2006 (moved to Educational and Research Centre in Transport on 2013).

Tested specimens were equipped by strain gauges (Fig. 12). Function of gauges was to determine stress flow at gauges positions and to verify suitability of specimens in connection with real behavior of structural detail on the real bridge.

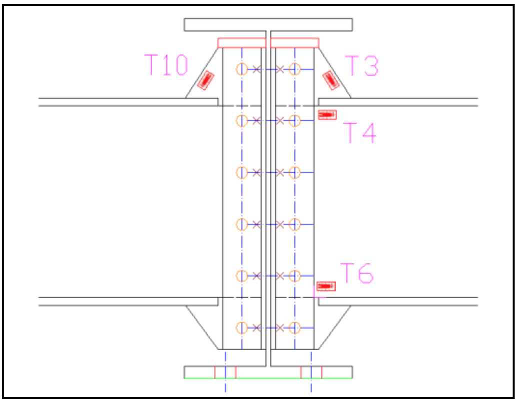

Fig. 12: Strain gauge positions

5.3 Test results

A total number of five testing samples (physical models) was prepared and one sample was eliminated during dynamic testing (Fig. 13).

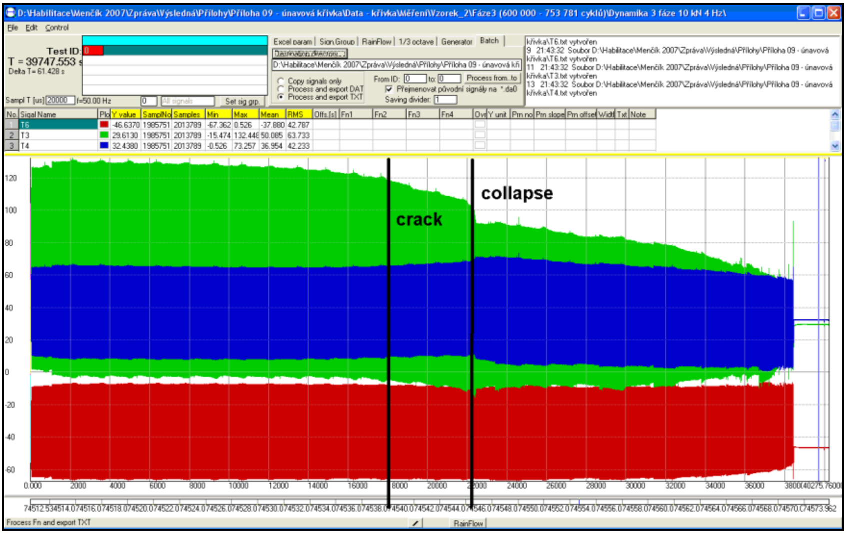

Fig. 13: Partial stress data record

Resultant values of loads, stresses in critical detail and experimentally determined numbers of cycles were:

Tab. 2: Test results

Specimen	Load [kN]	Stress in critical place [MPa]	Cycles till a crack
1	10	222	630 000
2	15	312	75 000
3	8	183	2 115 000
4	9	204	1 150 000
5	11	237	420 000

5.4 Final fatigue curve determination

A Fatigue curve determined experimentally:

$$\log N = \log a - m \times \log \Delta\sigma_R \qquad (1)$$

On the base of results mentioned above (Tab. 2) was fatigue constructed as regression curve (Fig. 14, 15).

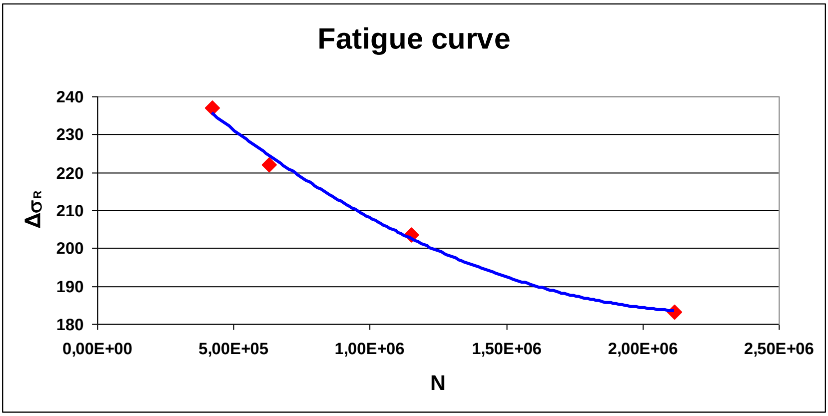

Fig. 14: Fatigue curve

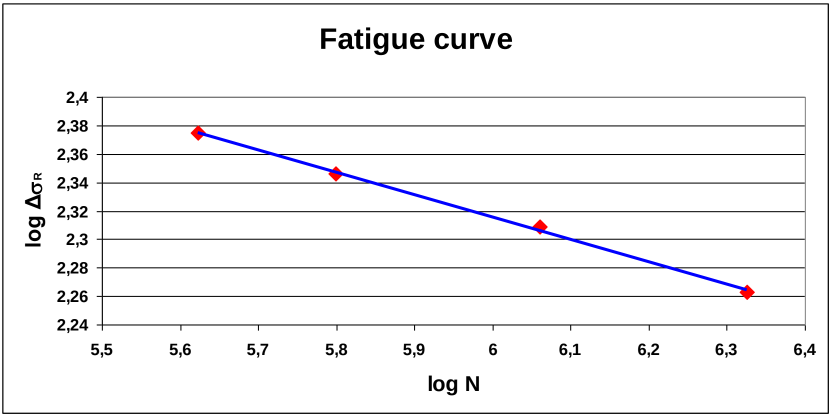

Fig. 15: Fatigue curve – logarithmic expression

Results fatigue curve characteristics (by use of regressive curve):

log a = 20,666 m = 6,337

6 Probabilistic calculation of the lifetime

The probabilistic assessment of the lifetime is based on the requirement of the probabilistic combination of the load (including the temperature and dead weight influences) and the load history. The calculation was performed using the SBRA system of MStar software [9]. The Cortan-Dolan method was chosen for the calculation [10].

The calculation (Fig. 16) led to the resulting distribution of the lifetime probability and the distribution function.

The lifetime determination in the case of one-parametric approach (without the mean value of stress range inclusion) and in case of the two-parametric approach (excluded dead weight and temperature influences) was calculated similarly.

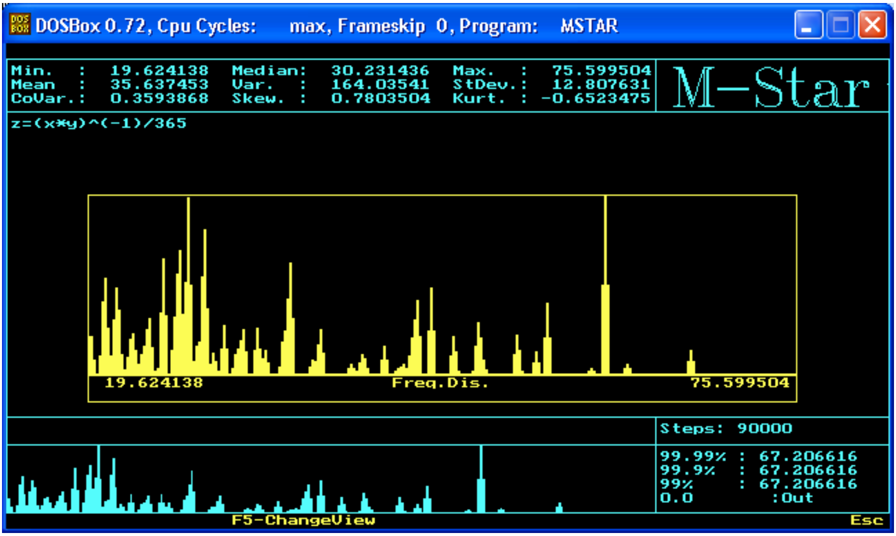

Fig. 16: Probabilistic lifetime calculation (temperature and dead weight influences) – MStar

7 Conclusion

The lifetime estimations were performed on the basis of the knowledge of partial damage under various load modes (with the temperature influence, without the temperature influence) and the knowledge of the operating load history of steel bridges. Mainly the knowledge of partial damage given by fatigue curve of structural detail is difficult to determine from computer, experimental and financial point of view. With regard to geometry dimensions of bridge structure is mostly necessary take into account simplifications, which may not influence quality of results.

Important aspect of fatigue curve determination is referential place of structural detail in which is possible presume fatigue crack growing. The fatigue curve shall be determined for this specific place. In many cases is not possible to measure stresses exactly in mentioned place. The way of exact determination could be to measure close to given detail and by use of FEM model to recalculate stress values into critical place afterwards.

These conditions were met in given example of experimental fatigue curve determination. As a result we obtained fatigue characteristics, which were different to standards.

All variables such as fatigue curve, load history, referential load must be combine. The combinations of all possibilities in given case were performed probabilistically using the Monte Carlo method.

The final assessment of the lifetime estimation for 50% probability of a crack were:

- one-parametric determination of the lifetime (without mean value influence) = 231,5 years,
- two-parametric determination of the lifetime (without the temperature and dead weight influences) = 57,0 years,
- two-parametric determination of the lifetime (with the temperature and dead weight influences) = 30,0 years.

The real fatigue lifetime of the bridge in the critical spot (approximately 32 years) corresponded best with the two-parametric determination with the inclusion of the dead weight and temperature influences.

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VIDEO-BASED VEHICLE CLASSIFICATION AND COUNTING FOR ROAD TRAFFIC MEASUREMENTS

Zbigniew Czapla[1]

Abstract: Vehicle classification and counting is carried out on the basis of a video stream from the camera placed under a road. The input image sequence consists of consecutive images obtained from the video stream. An initial detection field and a final detection field are defined. Each image from the input image sequence is converted into the binary form of the two-layer image model. The sum of the base points within the detection fields is calculated. The state of the detection fields is determined on the basis of sums of the base points. Vehicle are classified and counted by analysis of a state of the detection fields. The shape coefficient is determined for vehicle classification. Experimental results are provided.

Key words: road traffic measurement, vehicle classification, vehicle counting.

1 Introduction

Video-based determination of traffic parameters is utilized in contemporary road traffic systems [1], [5], [8]. Traffic systems applying video cameras are often attractive compared to other systems however systems using image data are usually complex an multistage. Video-based traffic systems use various methods in process stages as: segmentation, recovery of vehicle parameters, vehicle identification, vehicle tracking [6], background updating, shadow elimination, Kalman filtering, feature extracting [7], foreground estimation, foreground segmentation, object verification, vehicle tracking [10], description of virtual detection lines, edge detection, morphological operations, feature extraction [11].

Computer image analysis is carried out for determination of traffic parameters on the basis of video data. Before image analysis often image processing is performed. To important image processing techniques belongs edge detection. Very popular techniques of edge detection are gradients methods based on discrete convolution. In gradient methods of edge detection various masks are utilized e.g.

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Roberts, Sobel, Prewitt masks [4], [12]. There are also known other methods of edge detection e.g. [9], [13], [14].

The proposed video-based method of vehicle classification and counting is performed with the use of image conversion into the binary form of the two-layer image model [2]. Conversion into the two-layer image model is in character predictive with the use of a variant of delta encoding. Vehicle classification and counting is carried out by determination of change of the state of detection fields. The state of the detection field depends on the sum of the base points within the detection field. Vehicle classification is performed on the basis of the value of the shape coefficient [3]. The shape coefficient is calculated by measurement of the time needed to passing through the detection fields. The proposed method of vehicle classification and counting is intend for automatic measurement of road traffic parameters.

2 Algorithm of vehicle counting and classification

Vehicle counting and classification is carried out with the use of a video stream obtained from the camera situated under a road. An input image sequence consists of consecutive frames taken from the input video stream. Images of the input image sequence are processed separately one by one. Vehicle counting an classification is performed in the following stages:

- definition of an input image sequence,
- definition of detection fields,
- conversion into the two-level image model,
- determination of states of the detection fields,
- vehicle classification,
- vehicle counting.

The properties of processed images of the input image sequence depend on the applied camera and can change with along a time of the day and weather conditions.

3 Definition of the input image sequence

The input image sequence contains images obtained from the input video stream of f frames per second. Each image of the input image sequence is a greyscale image of 8 bits intensity resolution and of size N x M (columns by rows) pixels. Image position in the input image sequence is marked by the ordinal number in the sequence denoted by *i*. Examples of images from the input image sequence shows Fig. 1.

(a) (b) (c)

Fig. 1. Images from the input image sequence: a) i = 10, b) i = 34, c) i = 49

Neighbouring images in the input image sequence are $1/f$ seconds apart, therefore the value $1/f$ second determines time resolution of imeges in the input image sequence.

4 Definition of detection fields

There are two detection fields defined for one road lane. The detection field are called the initial detection field and the final detection field. The position of the detection fields along a road shows Fig. 2 (in the figure a car driving through the detection fields is located between them).

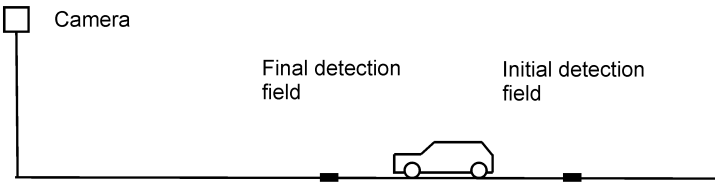


Fig. 2. A position of the detection fields along the road

Each detection field is a rectangle defined by coordinates of corners: left upper (n_L, m_U), right upper (n_R, m_U), left bottom (n_L, m_B) and right bottom (n_R, m_B). The detection fields are ($n_R - n_L + 1$) in with and cover across a road lane. The length of the detection fields ($m_L - m_U +1$) is set small which facilitates two-state interpretation of their features. Examples of images from the input image sequence with the marked detection fields shows Fig. 3.

(a) (b) (c)

Fig. 3. Images from the input image sequence with the marked detection fields: a) i = 10, b) i = 34, c) i = 49

The pair of the detection fields consists of the initial detection field and the final detection field are defined for each considered road lane.

5 Conversion into the two-layer image model

Road traffic images can be divided into regions of pixels which values are similar to one another. Region can be described by a set of values consisting of one reference base value and a sequences of difference values. Each difference value is determined as a difference between the current pixel value and the current base value. The different values form the different value layer and the base values form the base value layer. These two layers compose the two-layer image model. Layout of the base values of the two-layer image model is in accordance with the location of objects comprised in an image [2].

5.1 Determination of layers

Values of the different layer and the base laver are determined for greyscale images of intensity resolution 8 bits per pixel and of size N x M (columns by rows) pixels. The processed image is described by image matrix **X** containing pixel values

$$\mathbf{X} = \left[x_{m,n}\right] \quad 0 \le m \le M-1, \quad 0 \le n \le N-1 . \tag{1}$$

During image conversion into the two-layer image model conversion matrices **D** and **B** are utilized. Conversion matrices are required for difference values (matrix **D**) and base values (matrix **B**).

$$\mathbf{D} = \left[d_{m,n}\right] \quad 0 \le m \le M-1, \quad 0 \le n \le N-1,$$
$$\mathbf{B} = \left[b_{m,n}\right] \quad 0 \le m \le M-1, \quad 0 \le n \le N-1. \tag{2}$$

Conversion into the two-layer image model is carried out according to the scanning order. Image matrix **X** is divided into blocks of the size 2 x 2 pixels. The blocks are scanned successively by rows. Pixels inside the blocks are scanned by columns. Scanning begins from the element at coordinates (*m*, *n*) equal to (0, 0). The scanning order shows Fig. 4.

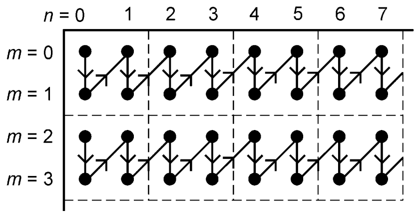


Fig. 4. The scanning order

Conversion into the two-layer image model begins with determination of initial base values $b_{0,0}$ and the initial difference value $d_{0,0}$.

$$b_{0,0} = x_{0,0},$$
$$d_{0,0} = c. \tag{3}$$

The initial base value is the first read pixel described by coordinates (0, 0). The initial difference value is the marker denoted by *c* which indicates a position of the new base value.

Elements of matrix **X** are read successively according to the scanning order. For each read element the difference value is calculated equal to difference between the current pixel value and the current base value (coordinates *m*, *n*, *k*, *l* indicates respectively current position in conversion matrices)

$$\Delta x_{m,n} = x_{m,n} - b_{k,l}. \tag{4}$$

There are two possible cases. In the first case the current difference value is included in the assumed range

$$\Delta x_{\min} \le \Delta x_{m,n} \le \Delta x_{\max} \tag{5}$$

and then the difference value is written into conversion matrix **D** according to current coordinates

$$d_{m,n} = \Delta\, x_{m,n} \,. \tag{6}$$

In the second case the difference value is not included in the assumed range.

$$\Delta\, x_{m,n} < \Delta\, x_{\min} \vee \; \Delta\, x_{m,n} > \Delta\, x_{\max} \tag{7}$$

In this case marker *c* is written into conversion matrix **D** and the new current base value, equal to the current pixel value, is set and written into conversion matrix **B** according to current coordinates.

$$\begin{aligned} d_{m,n} &= c\,, \\ b_{k,l} &= x_{m,n}\,. \end{aligned} \tag{8}$$

Conversion is finished after processing of the last element of matrix **X**. The difference values in conversion matrix **D** provide the difference layer. The base values in conversion matrix **B** provide the base layer. Both layers constitute the two-level image model.

5.2 A binary form and smoothing operations

A binary form of the two-layer image model is determined on the basis of the content of conversion matrix **D**. Binary values are placed into matrix **E**

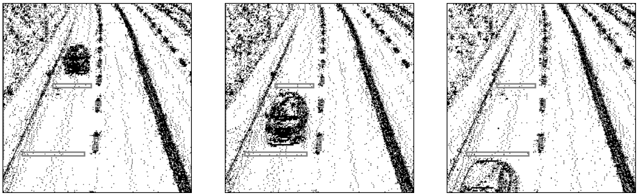
$$\mathbf{E} = \left[e_{m,n}\right] \quad 0 \le m \le M-1, \quad 0 \le n \le N-1 \tag{9}$$

according to the equation

$$e_{m,n} = \begin{cases} 1, & \text{for} \quad d_{m,n} = c, \\ 0, & \text{for} \quad d_{m,n} \ne c. \end{cases} \tag{10}$$

Each element in matrix **E,** which is equal to 1, is called the base point. Examples of images after conversion into the binary form with the marked detection fields shows Fig. 5. Layout of the base points of the two-layer image model corresponds with edges of objects comprised in a converted image.

The quality of images in the binary form of the two-layer image model can be improved by applying smoothing operations. Smoothing operation are performed for all elements of matrix **E** except border elements ($1 \le m \le M-2$, $1 \le n \le N-2$).



(a) (b) (c)

Fig. 5. Images after conversion into the binary form with the marked detection fields: a) i = 10, b) i = 34, c) i = 49

The following smoothing operation are carried out: removing the isolated base points in the orthogonal neighbourhood

$$e_{m,n} = 0 \quad \text{for} \quad e_{m,n-1} \vee e_{m,n+1} \vee e_{m-1,n} \vee e_{m+1,n} = 0\,, \tag{11}$$

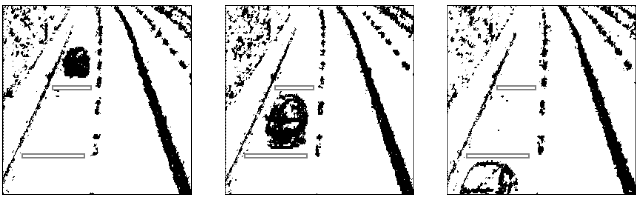
removing the isolated base points in the diagonal neighbourhood

$$e_{m,n} = 0 \quad \text{for} \quad e_{m-1,n-1} \vee e_{m-1,n+1} \vee e_{m+1,n-1} \vee e_{m+1,n+1} = 0\,, \tag{12}$$

and supplement of the base points by applying horizontal and veridical filters

$$e_{m,n} = 1 \quad \text{for} \quad (e_{m,n-1} \wedge e_{m,n+1} = 1) \vee (e_{m-1,n} \wedge e_{m+1,n} = 1)\,. \tag{13}$$

Examples of images after conversion into the binary form and smoothing operations with the marked detection fields shows Fig. 6.



(a) (b) (c)

Fig. 6. Images after conversion into the binary form and smoothing operations with the marked detection fields: a) i = 10, b) i = 34, c) i = 49

Smoothing operations usually improve the quality of images in the binary form of the two-level image model however they can be omitted. Layout of the base points better corresponds to object edges in images after applying smoothing operations than in images before applying smoothing operations.

6 Determination of states of the detection fields

A states of the detection fields describe pointers of occupancy. The state of the initial detection field describes the pointer P_{ini} and the state of the final detection field describes the pointer P_{fin}. The value of pointers is equal to 0 for the state "detection field free" and equal to 1 for the state "detection field occupied".

The sums of the base points within the initial detection field (S_{ini}) and the final detection field (S_{fin}) are calculated respectively for the current image i of the input image sequence as follows:

$$\begin{aligned} S_{\mathrm{ini}\,i} &= \sum_{m=m_{\mathrm{ini}U}}^{m_{\mathrm{ini}B}} \sum_{n=n_{\mathrm{ini}L}}^{n_{\mathrm{ini}R}} e_{m,n} : e_{m,n} = 1\,, \\ S_{\mathrm{fin}\,i} &= \sum_{m=m_{\mathrm{fin}\,U}}^{m_{\mathrm{fin}\,B}} \sum_{n=n_{\mathrm{fin}\,L}}^{n_{\mathrm{fin}\,R}} e_{m,n} : e_{m,n} = 1\,. \end{aligned} \tag{14}$$

Characteristic values of the initial detection field (L_{ini}) and the final detection field (L_{fin}) are calculated for each current image i of the input image sequence. The characteristic values are calculated as average sums of the base points sums within the detection fields for the current image i and K previous images (for images satisfying $i > K$). The characteristic values of the detection fields are given

$$\begin{aligned} L_{\mathrm{ini}\,i} &= \frac{1}{K+1} \sum_{j=i-K}^{i} S_{\mathrm{ini}\,j}\,, \\ L_{\mathrm{fin}\,i} &= \frac{1}{K+1} \sum_{j=i-K}^{i} S_{\mathrm{fin}\,j}\,. \end{aligned} \tag{15}$$

The states of the detection fields changes from "detection field free" to "detection field occupied" if the following conditions are satisfied for the initial detection field and the final detection field respectively:

$$\begin{aligned} L_{\mathrm{ini}\,i} &> L_{\mathrm{iniO}} \wedge P_{\mathrm{ini}} = 0\,, \\ L_{\mathrm{fin}\,i} &> L_{\mathrm{finO}} \wedge P_{\mathrm{fin}} = 0\,. \end{aligned} \tag{16}$$

where L_{iniO} and L_{finO} are minimum values of the threshold for the occupied initial detection field and the occupied final detection field respectively. Similarly the states of the detection fields changes from “detection field occupied” to “detection field free” if the following conditions are satisfied

$$L_{\text{ini}\,i} < L_{\text{iniF}} \;\wedge\; P_{\text{ini}} = 1\,,$$
$$L_{\text{fin}\,i} < L_{\text{finF}} \;\wedge\; P_{\text{fin}} = 1\,. \qquad (17)$$

where L_{iniF} and L_{finF} are maximum value of the threshold for the free detection fields initial and final respectively.

7 Vehicle classification and counting

Vehicle classification is carried out on the basis of calculation of shape cooefficient whose a value depends on vehicle size and the geometry of measuring position [3]. After vehicle classification the sum of vehicles in an appropriate class is increased by 1.

7.1 Determination of a vehicle speed

A vehicle moving through the detection fields changes their state. To begin with the state of the initial detection field changes from “detection field free” to “detection field occupied”. After the time dependent on a vehicle speed and a distance between the detection fields the state of the final detection field also changes from “detection field free” to “detection field occupied”. The vehicle leaving the detection field changes their state from “detection field occupied” to “detection field free”. Fig. 7 shows vehicle passing through the detection fields.

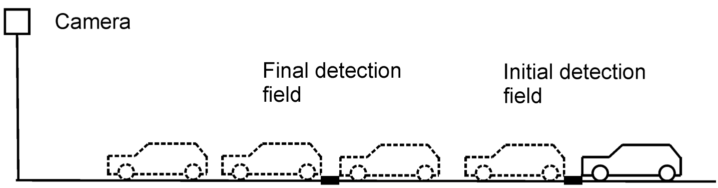


Fig. 7. Vehicle passing through the detection fields

The state “detection field free” of the initial detection field changes to “detection field occupied” in the image with the sequence number $i_{\text{ini(on)}}$. Return of the initial detection field to the state “detection field free” appears in the image with the sequence number $i_{\text{ini(off)}}$. Similarly the state “detection field free” of the final detection field changes to “detection field occupied” in the image with the sequence number $i_{\mathrm{fin(on)}}$ and return to the state “detection field free” in the image with the sequence number $i_{\mathrm{fin(off)}}$. A change of the state of detection fields illustrates Fig 8.

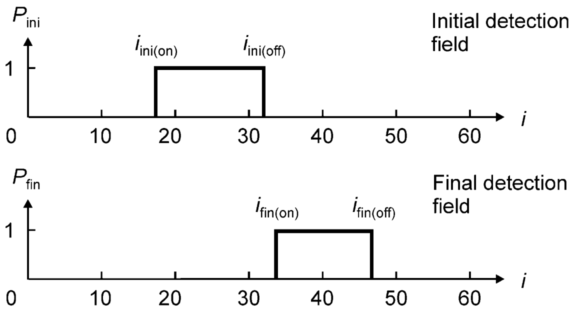


Fig. 8. A change of the state of the detection fields

If the frame rate of the input image sequence is denoted by *f* and the distance between the beginning of the initial detection field and the beginning of the final detection field is denoted by *d*, then the vehicle speed is described by the equation

$$v = d \cdot \frac{f}{i_{\mathrm{fin(on)}} - i_{\mathrm{ini(on)}}} \,. \tag{18}$$

The vehicle speed is expressed in meters per second when the frame rate is given in frames per second and the distance between the beginnings of the detection fields is given in meters.

7.2 Determination of a shape cooficient

The time in which a vehicle is passing through the final detection field depends on a vehicle speed and a vehicle length. The length of a vehicle can by given:

$$l = v \cdot \frac{i_{\mathrm{fin(off)}} - i_{\mathrm{fin(on)}}}{f} \,. \tag{19}$$

Taking into account equation (18) the vehicle length can be expressed

$$l = d \cdot \frac{i_{\mathrm{fin(off)}} - i_{\mathrm{fin(on)}}}{i_{\mathrm{fin(on)}} - i_{\mathrm{ini(on)}}} \,. \qquad (20)$$

Properties of measuring station cause that the determined vehicle length is bigger than the real one. A vehicle obscures for some time a camera view after leaving of the detection field. Fig. 9 shows vehicle position immediately after a change of the state of final detection field from “detection field occupied” to “detection field free”.

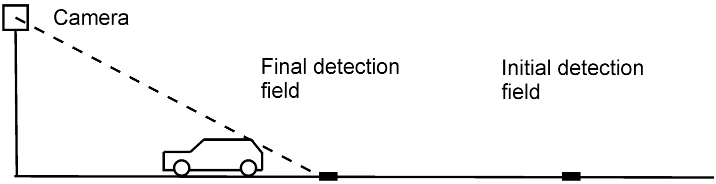


Fig. 9. Vehicle position after a change of the state of final detection field from “detection field occupied” to “detection field free”

Accurate determination of vehicle length requires corrections appropriate for the geometry of measuring station. Introduction of the shape coefficient given

$$k = \frac{i_{\mathrm{fin(off)}} - i_{\mathrm{fin(on)}}}{i_{\mathrm{fin(on)}} - i_{\mathrm{ini(on)}}} \qquad (21)$$

allows to avoid the necessity for corrections of vehicle length. Applying the shape coefficient vehicles can be classify on the basis of ranges of values which can be calibrated depending on the geometry of measuring station.

8 Experimental results

A value of the shape coefficient is calculated for selected vehicles at the measuring station. Examples of images from the input image sequence including vehicles of various types are shown in Fig. 10 (a motorcycle, a passenger car, a minibus) and in Fig. 12 (a truck, a bus, an articulated lorry) [3]. The same images after conversion into the binary form of the two-layer image model show Fig. 11 and Fig. 13.

(a) (b) (c)

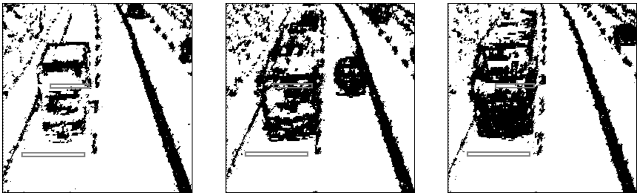
Fig. 10. Examples of images from the input image sequence including vehicles of various types: (a) a motorcycle, (b) a passenger car, (c) a minibus

(a) (b) (c)

Fig. 11. Examples of images after conversion into the binary form of the two-layer image model including vehicles of various types: (a) a motorcycle, (b) a passenger car, (c) a minibus

(a) (b) (c)

Fig. 12. Examples of images from the input image sequence including vehicles of various types: (a) a track, (b) a bus, (c) an articulated lorry



(a) (b) (c)

Fig. 13. Examples of images after conversion into the binary form of the two-layer image model including vehicles of various types: (a) a track, (b) a bus, (c) an articulated lorry

Appropriate differences between image ordinal numbers in the input image sequence and calculated values of the shape coefficient for considered vehicles at measuring station are placed in Tab. 1.

Tab.1. Values of the shape coefficient

Vehicle type	$i_{\text{fin(on)}} - i_{\text{ini(on)}}$	$i_{\text{fin(off)}} - i_{\text{fin(on)}}$	Shape coefficient k
Motorcycle	17	9	0,53
Passenger car	20	13	0,65
Minibus	20	17	0,85
Truck	18	24	1,33
Bus	26	57	2,19
Articulated lorry	17	41	2,41

The determined values of the shape coefficient is in the range 0,53-0,85 for a motorcycle, a passenger car, a microbus and in the range 1,33-2,41 for a truck, a bus and an articulated lorry. Simplified division into two classes: passenger cars and large vehicles gives usually good results (at the considered measuring station the limiting value of the shape coefficient could be assumed equal to 1). Division into a bigger number of classes also is possible but results in similar classes can take on the approximate character.

9 Conclusions

Vehicle classification and counting for road traffic measurement can be carried out with the use of a video stream from the camera placed in a measuring station. The input image sequence consists of consecutive images obtained from the video stream. Each image of the input image sequence is converted into the binary form of the two-level image model. Vehicle classification and counting is performed by analysis of a state of the detection fields. The state of the detection fields is determined on the basis of sums of the encompassed base points.

The method of vehicle classifications and counting using image conversion into the binary form of the two-layer image model is fast and computationally simple. Application of the simple algorithm and small number of operation allows effective processing and causes that this method is attractive computationally. The proposed video-based method of vehicle classification and counting is suitable for road traffic measurements.

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LABORATORY TEST STAND OF TRACTION DRIVE FOR FAULT OR NON-STANDARD OPERATION CONDITIONS

Ondřej Černý [1], Radovan Doleček[2]

Abstract: This paper deals with research couplings and dependence relations between electric traction motor, which is fed by traction converter, and mechanical transmission at the rail vehicle during fault conditions or non-standard operation conditions. The current research is focused mainly on conditions caused by traction electric accessories of a rail vehicle. The mechanical and electrical effects of individual components of traction drive of a rail vehicle are known and described, but time and amplitude characteristics of these variables during fault conditions or non-standard operation conditions are not mapped completely at a new traction drive. For this purpose the test stand is built at University of Pardubice, Jan Perner Transport Faculty, Department of Electrical and Electronic Engineering and Signalling in Transport (DEEST) where mentioned conditions and their effects will be possible to map and verify experimentally.

Keywords: traction drive, mechanical transmission, rail vehicle, fault conditions, non-standard operation conditions.

1 Introduction

At the present the public mass transport means are used in urban agglomerations more and more for dynamic transport of people. The traffic jams, heavy traffics and also producing emissions from combustion engines are reduced and eliminated not only in urban centers but also in other city area due to this public mass transport. Other effect of this fact is decreasing of needs of parking

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places into city centers. The public mass transport vehicles are still developed and improved for current meet the passenger's requirements for comfort and convenience as passenger vehicles. The continual improvements of these vehicles is also in the field of reducing of energy consumption and operating costs, increase of drive and dynamic characteristics with respect to mentioned passenger comfort, comfortable boarding and so on. The fulfillment of these requirements and parameters can be reached by many ways. The traction drive, which is placed in the vehicle bogie or bogies, has a big impact on reducing of operating costs and reducing of energy dependence including improving of drive characteristics of the vehicle. The traction asynchronous motors (ASM) or traction synchronous permanent magnet motors (PMSM), which are fed by converters. In the case of the ASM usage for this type of vehicle it has to be met request of installation of mechanical transmission which is represented by complex mechanical element both production and installation into the bogie of the vehicle. During the design and the construction of the mechanical transmission it is necessary to calculate with maximum values of mechanical variables which are reached only during fault conditions or non-standard operation conditions. The values of these variables are calculated from nominal values according to empirical structural constants in most cases. However these constants are not modified with respect to applied production technologies and processes not even different solutions of electric drives and their control. But these constants have significant effects on the final size of the mechanical transmission, its weight and also parameters. The values of the unsprung weight rations of the vehicle and traction intensity also relate with these parameters and effects due to the frequent starting and stopping of vehicles in this type of traffic. [1]

2 The transmission of forces in the traction drive

The problems of mutual couplings between the electric traction motor and mechanical transmission of the rail vehicle during fault conditions or non-standard operation conditions is very complicated mechatronic system properties of which depend on many external factors. These effects have to take into consideration to the laboratory test stand, where it will be possible to carry out a partial research, which is not possible to do during real operation of these vehicles. For example it was found on the base of analysis, that appropriate protection are activated at short-circuit of electric accessories of rail vehicle but these protections have own reaction time and switching capacity. The switch currents off to the traction motor should be worked on the base of this reaction of protection, in the case of ASM, this motor will be deexcitation subsequently. [1 - 3]

3 The conception of the laboratory test stand

The building of laboratory test stand is necessary for validation and verification of simulation models and their results for determination of conclusions and then also for new traction drives. So it was necessary to choose a rail vehicle such a representative sample for this stand. This vehicle has corresponded values and waveforms of forces that have representative ability of mechanical and electrical parts of traction drive. The tram vehicle type RT6N1 was chosen as a representative sample. This vehicle has approximately unladen weight of 33 t, maximum speed of 80 km/h, four traction motors with bogie arrangement of Bo'2'Bo' and total output power 416 kW. For the needs of the described research of mutual couplings it is not necessary to build up the complete model of the rail vehicle with all wheelset but only one drive wheelset is sufficient, which will be additionally accelerated by the forces correspond to adhesive transmittable forces by the wheel-rail contact. During the design of this stand the several conceptual solutions was considered including usage of dynamometers or otherwise drive sets. The insertion of mechanical flywheel or other dynamically hard structural solution with high inertia moment as the most optimal tool in terms of rapid and large changes were necessary in all considered proposals. Therefore it was decided on the basis of analysis to use an appropriately sized rotating flywheel which will replace both its own wheelsets and energy corresponding to the kinetic energy of the rail vehicle or rail units. The usage of flywheel its energy of which would be comparable to the whole rail vehicle or rail units is not necessary because the time processes are with maximum length of tens of milliseconds. This substitute flywheel has to cover energy only for this short time, but the real rail vehicle changes kinetic speed negligibly during these monitored conditions. According to the performed analysis the change of angular speed can be up to 10 % in the case of this substitute flywheel. The effect of value of this change in comparison with other errors of measurements of electrical and mechanical quantities is minimal and it does not have a significant effect. [3 - 5]

The test stand is designed for real traction mechanical transmission type TR-NP-45 by Wikov MGI, which cooperates on these research activities. This transmission is used for operation of light rail vehicle (tram vehicle). The load spectrum of this transmission is based on the characteristics of the traction motor and the drive cycle of a typical tram vehicle with stop distances of 350 m.

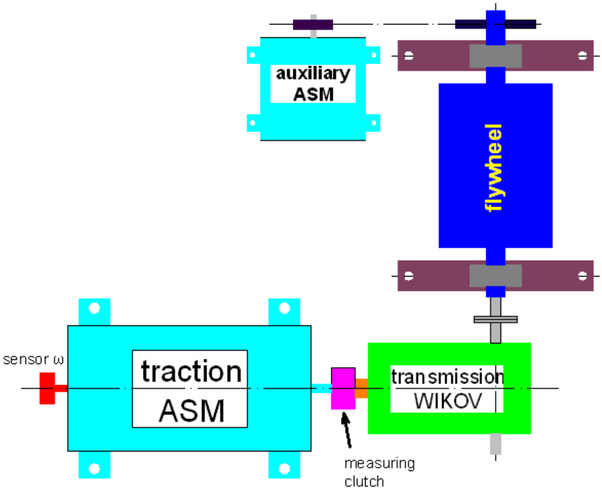

Fig. 1. The conception of the laboratory test stand

The main type parameters of this mechanical transmission:

- torque on the input shaft (pinion) - accelerating period is 625 Nm
- torque on the input shaft (pinion) – braking period is 695.5 Nm
- nominal speed on the input shaft (pinion) is 2 900 rpm
- maximal speed on the input shaft (pinion) is 4 708 rpm

The stand will be equipped with plenty of sensors for mechanical and electrical variables for measuring of mutual effects between the traction motor and the mechanical transmission. For monitoring of the main effect it will be used torque sensor located between the motor and mechanical transmission including the sensors for measuring of reaction forces at transmission. The standard strain gauges will be used for these sensors. Furthermore, the stand will be equipped a speed sensor on the side of the traction motor and also sensors for scanning and recording of current and voltage waveforms. The sensors LEM with galvanic isolation between the measured power part and measuring system will be utilized for monitoring of electrical quantities. The card type NI 6341 will be used for control system of the stand and SW developed in LabView will be used for measuring and evaluation. [6 - 10]

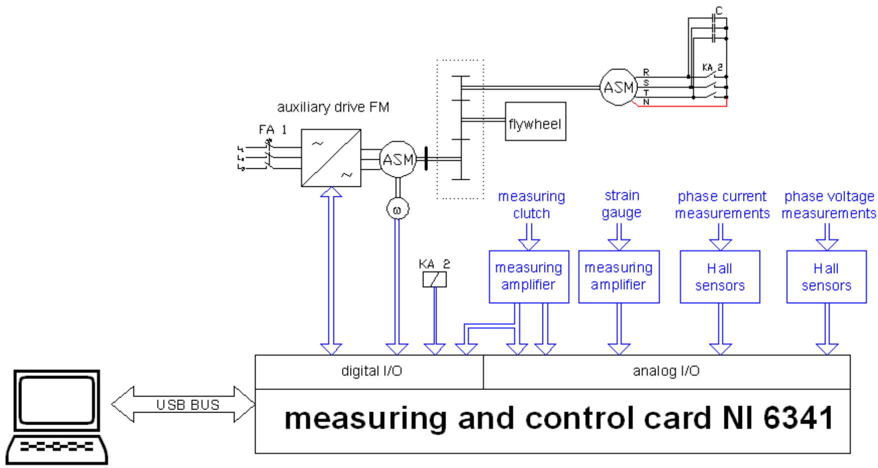

Fig. 2. The electrical structure of the laboratory test stand

4 Conclusion

The current research is focused on design including dimensioning and building of the laboratory test stand and the convenient accurate measuring equipment including sensors. The design of methods and processing of results and their verification including calibration of parts are prepared. The first measuring results from this stand will be in October 2015. They will be focused on the main electrical variables of asynchronous motor and mechanical effects between the motor and mechanical transmission during short-circuit at the asynchronous motor. Due to these experiments the correctness of methods and the design of the stand will be verified. Experimental data for validation of the mathematical simulation mode will be obtained as well.

Acknowledgement

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RETURN TRACTION CURRENT CONDUCTION

Ivan Dobeš[1], Radovan Doleček [2]

Abstract: The paper focuses on the AC traction systems, in particular from the point of view is using auto transformers a booster transformers in return traction line. Part of the paper is devoted to protection against touch voltages. This is also very important problems from the point of view electromagnetic compatibility, especially from couplings.

Keywords: AC traction system, auto transformer, booster transformer, touch voltage

1 Introduction

The problem of this paper mainly focuses on the AC traction systems, in particular how to measure the return traction current and earthing. In Europe and over the world there are mostly used for the return traction current return conductors, which hang on poles in the height of conductors of contact lines. Further there are used conductive, earth connected or in earth stored parts such as armouring of tunnel constructions, construction foundations, pole foundations, earthing net and so on. The purpose of this method is to eliminate the amount of return traction currents running through rails and earth. Higher person safety will be reached this way and negative impacts will be hold in acceptable limits. The auto transformers and the booster transformers are used as supportive instruments. The required measures are stated in European standards, especially ČSN EN 50122–1 and ČSN EN 50122–2. These European standards [1, 2] deal

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with return current in electrified track of AC and DC, earthing in connection with person safety and device protection. In contrary to the general electrification equipment in the return current lines of electrified railway system runs operating current in a range of kA. The rails are always part of return current way. The return current way is made in our conditions almost purely of rails and earth. In the most of other countries, there are return conductors connected to the rails, especially conducted on poles approximately in the height of trolley wire and supporting rope. In some cases there are used other parallel earthing conductors.

2 Definition terms

- Touch voltage (Ute, effective) - voltage between conductive parts when touched simultaneously by a person or an animal
- Voltage-limiting device (VLD) - protective device whose function is to prevent existence of an impermissible high touch voltage
- Earth - the conductive mass of the earth, whose electric potential at any point is conventionally taken as equal to zero
- Structure earth - construction made of metallic parts or construction including interconnected metallic structural parts, which can be used as an earth electrode
- Rail to earth resistence - electrical resistance between the running rails and the earth or structure earth
- Open connection - connection of conductive parts to the return circuit by a voltage-limiting device which makes a conductive connection either temporarily or permanently if the limited value of the voltage is exceeded
- Return circuit - all conductors which form the intended path for the traction return current
- Track return system - system in which the running rails of the track form a part of the return circuit for the traction current
- Traction return current - sum of the currents returning to the supply source, the substation or regenerative braking vehicles
- Rail potential (URE) - voltage occurring between running rails and earth
- Track circuit - electrical circuit of which the rails of a track section form a part, with usually a source of current connected at one end and a detection device at the other end for detecting whether this track section is clear or occupied by a vehicle

- Contact line system - support network for supplying electrical energy from substations to electrically powered traction units, which covers overhead contact line systems and conductor rail systems; .the electrical limits of the system are the feeding point and the contact point to the current collector.

3 Signs and differences between DC and AC traction system

The return circuit must be solved in a way to confidentially, without negative influences on safety and confidentiality conducts the traction current, eventually recuperative return currents, alternatively short circuit and other faulty circuits to the power supply station. The resistance of return currents must be as low as possible, so that the negative influence of return currents, i.e. especially the rail potential against earth and touch voltage, stays in allowed limits. Therefore must be the single rails provided with lengthwise and cross bonds, Fig. 1.

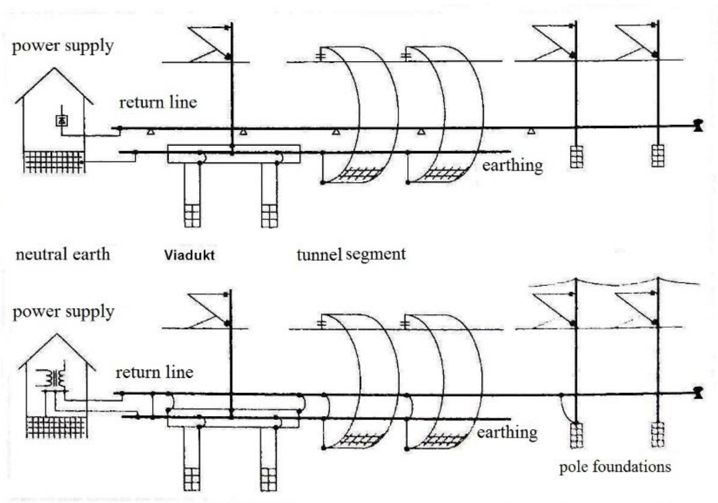

Fig. 1 The diagram of the earthing on electric rails (up…..DC system, down…AC system) [3, 4]

3.1 DC system

On the railway powered by DC systems there is the priority demand on fulfillment to the highest resistance of rail against the near earthing equipment. The long term maintenance of this resistance is also very important. The aim of these precautions is to prevent the outflow of stray currents and avoid the damages caused by continuous stray currents. There comes up to the voltage decrease on the longitudinal rail resistance, that is by higher operating currents or by short-circuits the reason for increasing of rail potential. The danger of creation the dangerous touch voltage against earthing parts is getting higher by longer tracks and higher currents.

3.2 AC system

On AC return rail conductors there are arising the inductive voltage decreases that are almost the same as in DC by frequency of 16.7 Hz and by frequency of 50 Hz almost twice as high as in DC. In higher length of powered AC lines (in contrary to DC) it results, even by proportionally lower track currents, to the higher rail potentials against the earth. The decrease of these potentials under the allowed values is reached by earthing of return current, i.e. rails and added parallel cables, eventually by using the parallel earthing alongside the track. There is a similar procedure by using the booster transformer and auto transformers. As consequence of earthing the return currents there flows part of the track return current through earth and earthing parts (building foundations, track poles and so on). This shows negative implication on intrusion of electronic systems.

4 Track Supplied by AC System

In the AC railway system there is the demand on higher traction power. There is also a pressure on lowering of the investments and operating cost. That all demanded the change of concepts for return conductible way of AC system, Fig. 2.

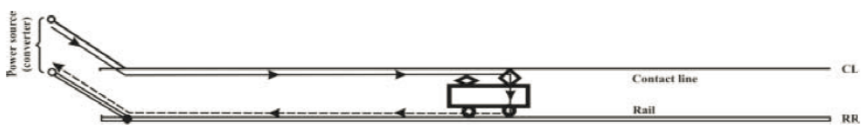

Fig. 2 The return current way on AC system through rails without other return conductors [7]

The safety of persons and electrical equipment has risen. The intensity of magnetic pole was decreased. The return conductive way meant new technical solutions. By original system of return, wholly rail conduct (as so far practiced in our country), leaks away by regular earth rates to the earth more than half of track return currents. The new solutions of return way was caused by auto transformers (AT), Fig. 3, and booster transformers (BT), Fig. 4, [3, 4, 5, 6, 7].

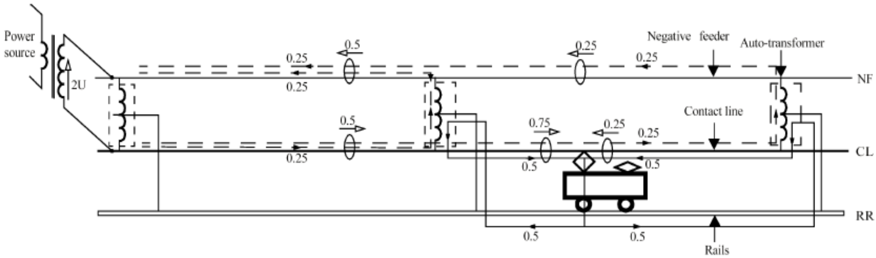

Fig. 3 The return current way on AC system with the auto transformers [7]

When used the AT system, the traction power supply station feeding the traction section two-phase (the angle of phase movement is 180°). The traction transformers and also auto transformers centre of winding is connected to the return rail conduction. One phase is connected to the contact line, the other phase is connected to the so called negative feeder. The auto transformers are connected in the same way in the relative distance 10 – 20 km on the system with the frequency of 50 Hz, or 20 – 40 km on the system with frequency of 16.7 Hz. Two nearby auto transformers work basically as two classical traction supply stations and supply the particular sections two-way. In this type of connection occurs the decrease of leaks of return currents from rail conduct. The length of feeding section can be considerably extended. This solution was used prior in Japan and France for the power supply of high speed rails, where this solution brought large investments savings. There can be reached the greatest length of power supplied sectors by using the auto transformers.

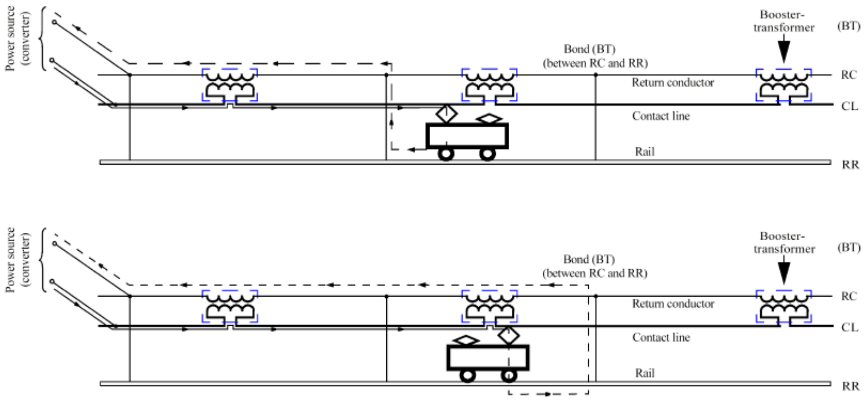

Fig. 4 The return current way on AC system with the boostertransformers[7]

The booster transformers are used to eliminate the stray currents and the disturbances, obliging the return current to flow to the return conductor. The booster transformers are single-phase transformers with the ratio 1:1. They have low impedance values, but despite that, they must tolerate the stresses of short-circuit currents. Primary voltages are typically 15 kV or 25 kV, which are the usual nominal AC voltages of catenary feeders in railways around the whole world. The nominal current is usually between 200A and 800 A. Frequencies in electric railways are 16.67 Hz, 25 Hz, 50 Hz or 60 Hz, and the power ratings of booster transformers are 100 - 800 kVA. Sometimes they are inserted to the trolley conduct in the distance of 3 - 5 km. The primary winding bridges over the electric dividing in track conduct (there is track voltage of contact line going through it), secondary winding is connected to the rails approximately in between the two nearby BT and the current of the same size but different direction goes through it. This current “exhausts” the return current from the rails and from earth to the return conductor through which it flows to the supply station. The return conductor is hanged up by itself on the poles. In Fig. 5, there is the scheme of BT.

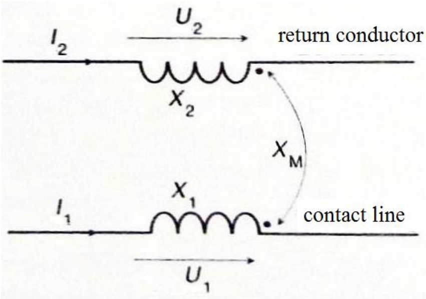

Fig. 5 The scheme of the booster transformers [7]

The following formulas for the BT calculations are based on, same as by calculating the rates on common transformers, the simplifying assumptions, such as particularly omission of the losses in iron [8].

$$U_1 = I_1.R_1 + I_1.jX_{\sigma 1} + I_1.jX_1 + I_2.jX_M \quad (1)$$

$$U_2 = I_2.R_2 + I_2.jX_{\sigma 2} + I_2.jX_2 + I_1.jX_M \quad (2)$$

where

U_1, U_2	…	voltage on winding
I_1, I_2	…	winding current
R_1, R_2	…	winding resistence
$X_{\sigma 1}, X_{\sigma 2}$	…	stray induction
X_1, X_2	…	winding induction
X_M	…	mutual induction

The negative impacts on other electric equipment near the rail are effectively eliminating by using the BT. By all means the solution when using the BT is more expensive and by operation more complicated and less useful.

The cheaper system of return conduct constructions, which is also connected to the favorable impacts on the return current conducts, was used for the first time on the construction of high speed rail Madrid - Sevilla and later on the new and reconstructed rails of DB. It is characterized by connecting the parallel conductors alongside the return rail conduct in regular distance of some hundred meters. There are all other earthing systems, such as track´s poles with its armouring concrete base, armouring building foundations, bridges, part of viaducts, armouring of tunnels, safety earthing on equipment etc. connected to these parallel conductors. The components of return conductive way connected with this technique build the general earthing protective system, which is used for electric equipment of low and high voltage, for control and command signaling and communication equipment.

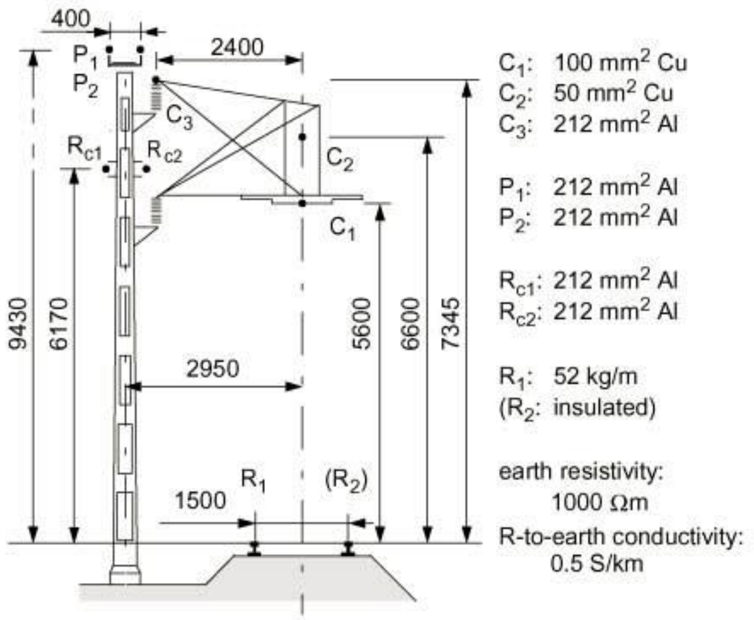

Fig. 6 The return conductors – the line configuration [3]

There are cable return conducts lead in upper parts of poles, also regularly (after 200 m to 600 m) connected to the rail. On two-rail tracks, there are the return conducts of both rail connected not only to the rails, but to also to each other. Due to this lay-out especially because of the influence of return conductor near the conduct line, there is reached the excellent inductive link, magnetic poles reduction and reduction of rail voltage against the earth. There is also reached the considerable better return current allocation [9].

4.1 Person Protection

The return rail conduct must be made on AC tracks so, that it would prevent the danger of electric shock and the person protection would be provided. The connection of lifeless conductive parts near the traction mains is used as the main precaution. These lifeless conductive parts can be used in case of the break-down under the voltage with traction rails. The same holds for the parts, which can be under voltage in case of the overhead contact line breakdown or in case of vehicle derailment. Earthing of these parts leads to the certain cutoff of the after-short-circuit current and ensures the person protection. When the direct earthing on return conduct AC system of supplied track is not possible, e.g. when comes to the concourse of tracks that are electrified by direct current, it is necessary to use the current limiters that are connected to the return track conduct, that is electrified by AC system. In this case it is called the open earthing. This way of earthing is used especially for the lifeless parts of smaller sizes, where its length in longitudinal direction does not exceed 2 m and which do not carry any electric equipment. The rail potential against the earth must agree with the requirements to the contact and accessible voltages. It depends on the operating or short-circuit currents, on the rail resistance against the earth and on the distance of the drive vehicle, eventually the distance between the short-circuit and supply station. Its amplitude is usually expressed in relation to the 100 A (current in traction mains).

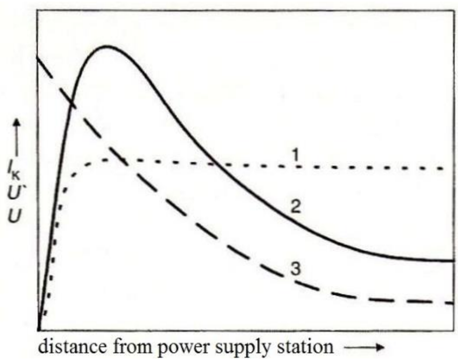

Fig. 7 The voltage run on rails in dependence on the distance from power supply station (1 … [U‘]- when the traction current is constant; 2 … [U] - when there is a short-circuit; 3 … [IK] - process of short-circuit current) [3,4]

The short-circuit current reaches the biggest values when there is a short-circuit in the supply station. In this case there is the zero rail potential against the earth. The rail potential reaches the highest values over some kilometers from the supply station. To establish the threat of dangerous rail potential, there is the graph that shows the process of rail potential against the earth growth in dependence to the length of supply section.

Table 1: The permitted allowed and the touch voltages [3, 4]

Permitted allowed and touch voltages	UT [V]	URE=2UT [V]
Operating contact voltages … t > 300 s	60	120
Operating contact voltages … t = 300 s	65	130
Faulty contact voltages … t = 100 ms	842	1684

For some new equipments the time for cutoff the faulty currents can go under the 100 ms. In this cases are also considered the values form the Table 1. The dangerous potentials from the strange systems can be, due to conductive connections, brought to the traction systems. To avoid the uprise of dangerous touch voltages, it is necessary to use in this cases the additional precautions, such as extra appliance isolation or protective isolating surface.

4.2 Influence on other equipment

The return traction lines can influence the function of other rail equipment by:

- Ohmic effects
- Capacity effects
- Inductive effects,
- Electric and magnetic poles effect

The ohmic effects originate from conductible connections with the return current system and they are mostly not dangerous. The capacity effects are dismissible from the practical interest. The impact of inductive effect and magnetic pole effect is important on the rails that are supplied by AC systems. These values depend, such the allocation of return currents, on own and mutual impedance and on the configuration of traction mains. The return current that flows through earth represents the measurement of negative influence. Return conductors reduce the return current that flows through earth and reduce this way the influence on other neighboring equipment. This impact relates not only to the traction equipment, but also to the other electric equipment near the track. In dependence to the sensitivity of this equipment there can come to their influence or also to their damage [10].

4.3 Executing constructions works

The precautions for return current conduction and for earthing affect above all the steel concrete constructions. For each construction must these precautions be establish in time. Already in the first construction phase there is the need to install enough-current-proportioned connectors with armouring. All the current connections of armours of concrete parts must be done by welding, because all the spiral connections are not enough reliable in the corroding environment.

4.4 Measurement before operating

Before coming into operation it is necessary to prove the integrity and good dimensioning of return current line and the person protection. To prove this, there is used the calculation in the project phase and during handover also the measurements on the hand over equipment. It is practical to make the resistance measurements during the starting-up, further also rail potentials and induced voltage measurements. These measurements can be used as the base to the measurements during the operation. The resistance of earthing equipment governs the operating and faulty contact voltage and rail potential. To be able to measure the rail potential, it is necessary to provide the constant current in traction rails between the two current connections. The very rail potential is measured against the far (neutral) earth. The distance from the point of measurement to the lateral ramification of return current should be the longest the possible. Supply to the one rail represents the operating status, supply to one track represents the most disfavourable short-circuit current. Measured rail potentials are able to be recalculated on the operating or break down currents.

5 Conclusion

The construction of parallel return current conductions follows all the requirements for the person protection also in high power and voltages. Additional return currents (return wires) reduce influence, keep down the necessary precautions for earthing and enable easy surface service and service of fixed traction equipment.

Acknowledgement

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RECUPERATION AT TRACTION POWER SUPPLY SYSTEM OF AC 25 kV

Radovan Doleček[1], Ondřej Černý [2]

Abstract: The paper deals with behavior of traction power supply system of AC 25 kV used at the Czech Railways during recuperation mode of traction vehicles. The main problem is transient effects, which can arise during short-circuits in traction circuit at this recuperation mode. For these effects the protections of traction circuit have to be set as well. This problem can be studied only by mathematical simulation in the given range with partial verification of results by real measurements. The building of physical model would be high financial-intensive and could be lost the possibilities of monitoring in some selected points of traction circuits during these effects. The method of solution including parameters of elements of individual traction circuits are also described in this paper.

Keywords: traction circuit, recuperation mode, transient effect, short-circuit

1 Introduction

Nowadays the efficiency of usage of traction energy is discussed more and more at the regular rail transport. This has also relation with usage of energy from recuperation braking which can be consumed by electric rail vehicle or transformed to the contractor´s mean network of 110 kV. The recuperation energy can be represented up to units of MW during units of minutes. These energy sources in traction system bring new requirements for protection settings under the keeping of standards and operational regulations. For understanding of

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behavior of traction circuits during these effects the mathematical simulations are used and allow to monitor the states and points of traction circuit, which cannot be monitored during operation conditions in real traction circuit (e.g. identifying the root causes of short-circuits). [1-4]

2 The Solution Method

Traction circuit of traction power supply system of AC 25 kV at Czech Railways (CR) contains the main elements, see Fig. 1.

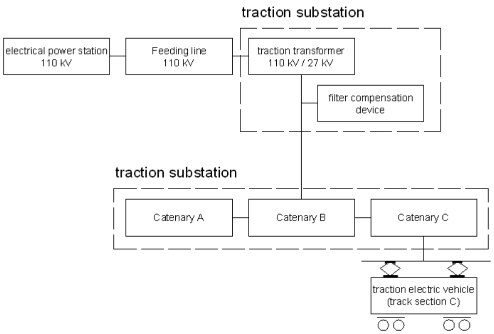

Fig. 1: Traction circuit of power supply system of AC 25 kV

All elements of traction circuit have effect to behavior of the whole systems and each section of electrified track has own specific characteristics. The recuperation to the network of 110 kV, which is not allowed for all traction substations in the CR network, is solved on the side of contractor. [5-8]

The solution of transient a fault effects are analyzed by simulation program PSpice which utilizes mathematical models of elements of traction circuit. It is necessary to create quality models, which represent real devices, because the simulation results could be distorted by unsuitable substitutions or simplifications of traction circuit. Therefore models of traction circuit were made for all parts of traction system of AC 25 kV at CR the following way:

Model of feeding line 110 kV is based on a homogenous long electric line with distributed electrical parameters (i.e. inductivity, capacity and resistance), without line leakage. This line is as standard three-phase overhead line. This means without industrial interference of voltage or current and nonsymmetrical character of line.

Model of traction substation contains the traction transformer 110/27 kV with 10 MVA and filter-compensation device (FCD). The model of the traction transformer 110/27 kV can be presented by a series inductance L_{TT} in energetic harmonic area, which is given short-circuit voltage of traction transformer and series resistance R_{TT} represents active losses. In the case of higher harmonic it is necessary to add a passive filter with inductance and series resistance.

Current harmonics pass through traction transformer and they are changed only used winding ratio. The characteristic parameters of model transformer are: short-circuit active losses of 53 kW, series inductance $L_{TT} = 28$ mH, resistance $R_{TT} = 0.42\ \Omega$.

Model of FCD placed into traction substation is represented by two series LC branches of the 3rd and the 5th harmonic and a decompensation branch. The tuning of the LC branches is not adjusted to the number of the harmonic exactly but it has to be made for lower of value. This adjustment of LC branches is necessary because harmonics from feeding line of 100 kV could overload these LC branches. The parameter values used for this model are: capacity $C_3 = 8.8\ \mu$F, inductance $L_3 = 132$ mH, $R_{L3} = 1.3\ \Omega$, resonance frequency $f_3 = 147.7$ Hz and $C_5 = 2.5\ \mu$F, inductance $L_5 = 163$ mH, $R_{L5} = 1.7\ \Omega$, resonance frequency $f_5 = 249.5$ Hz. Decompensation branch has a reducing transformer 27 kV/6 kV, air-core choke and semiconductor controller which control power factor angle near to DPF = 0.98

Model of catenary with standard structure of 100 Cu + 50 Bz with intensive line has the same character as homogenous long electric line with distributed electrical parameters, but there are considered all main parameters (i.e. resistance, inductivity, capacity and leakage). This presumption can be taken because sections of catenary are longer in comparison with sections of station catenary. The parameter values used for this model are (for the whole length of catenary): series specific resistance $R_C = 0.3\ \Omega$/km, series specific inductance $L_C = 0.8$ mH/km and parallel specific capacity $C_C = 20$ nF/km.

The model of the traction electric vehicle is represented by power source with waveforms corresponding to recuperation vehicle with semiconductor converter and recuperation power 0.5 MW. [4 - 7]

3 The Simulations of Monitored Effects

The simulations are done for transient effects during recuperation mode of traction vehicles at short-circuit in the most serious points of traction circuit. For these effects in the traction circuits the protection setting has to able to cover the whole spectrum of effect characteristics. This problem can be studied only by mathematical simulation in the given range with partial verification of results by real measurements. Output data of simulation program represent voltage and current waveform. The critical states are deduced from knowledge of individual waveform. Input parameters for protection settings of traction circuit can be gained by the analysis of these states. [6], [10]

In the case of short-circuit between traction vehicle with recuperation mode and traction substation the rapid exchanges of energy occur between this traction vehicle with recuperation mode and point of arising of short-circuit and also between traction substation with FCD and point of arising of short-circuit. At the beginning the shot-circuit is fed from two points and the energy from recuperation vehicle is absorbed in units of ms, Fig. 2. In the case of the energy from traction substation the current wave is absorbed in tents of ms (without protection off). During this time the large amount of energy will be transferred through the catenary, for example the FCD supplies almost 20 kJ during the first units of ms to this short-circuit.

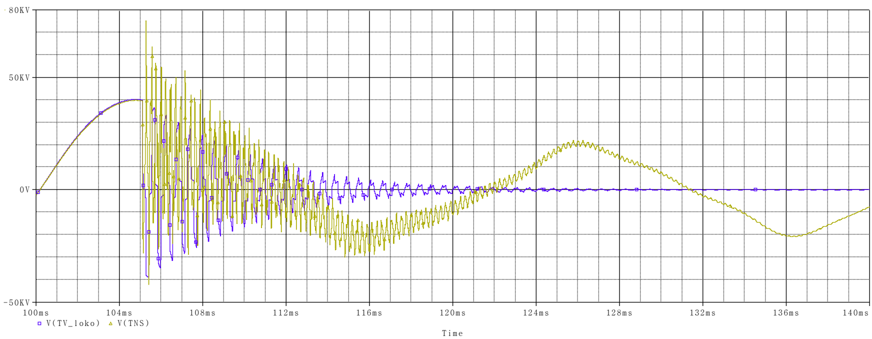

Fig. 2: The voltage waveform at FCD and recuperation mode of vehicle

The energy transferred from network to the traction system is in the event of a very high for this case. At the short-circuit the characteristics of the traction transformer 110/27 kV and impedance of lines are only limiting circuit elements. The resistive impedances are decreased from viewpoint of achieving of high efficiency of traction system, but for the short-circuit these impedances are suitable added for decreasing of short-circuit current and also for decreasing of harmonics by modern electric vehicles propagating to the network.

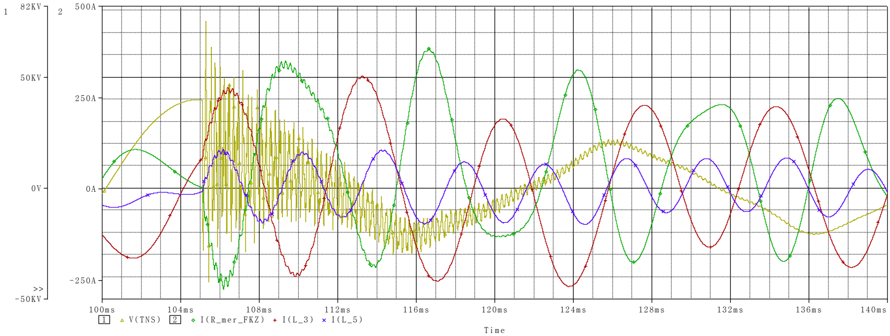

Fig. 3: The voltage and current waveform at FCD

4 Conclusion

The current research is focused on short-circuits without building up of physical model of traction power supply system of AC 25 kV. Therefore simulation program was chosen. The design of protection settings can be possible to use for all protections in traction circuits in particular in traction substation with FCD. Simulation diagrams, which are represented by voltage and current waveform, can be also used as a main tool for particular project of traction substation of protection settings process. This paper is part of large research work in the effect problems.

Acknowledgement

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SOCIAL ASPECTS OF CONGESTION PRICING IN URBAN AREAS

Monika Eisenhammerová[1], Ivo Drahotský[2]

Abstract: The article deals with the relationship between pricing, mobility and social exclusion. The basic question is whether the charges negatively affect specific social groups. It compares opposing views and it finds unresolved issues.

Key words: pricing, urban areas, social exclusion, deprivation.

1 Social exclusion and road pricing in cities

Personal mobility is constantly cheaper and faster and it has become a usual part of human life. This fact contributes positively to the development dynamics of the industry in cities and to cohesion of society, but the current pace of development of transport in the future will becomes unsustainable. Rapid development of transport is not affected, only cities in strong economically developed countries, but the problem is occurring in large cities in less developed countries. Cities are threatened by negative externalities.

Negative externalities can be solved by two basic instruments - economic instruments and normative instruments. Nowadays, economic instruments are being used more frequently. The most common economic instruments are charging for entrance to the city, kilometric charges, parking fees or fees for pollution.

Reasons for pricing are regulatory, fiscal and environmental. But there are not social reasons. This is not in accordance with one of the foundations of sustainable transport – with social equity, despite the fact that a sustainable transport system is therefore one that provides for safe, economically viable, and socially acceptable access to people, places, goods and services; meets generally accepted objectives

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for health and environmental quality; protects ecosystems by avoiding exceedances of critical loads and levels for ecosystem integrity, and does not aggravate adverse global phenomena. [1]

Sustainable transport system is a complex of three elements. Elements are interrelated. It is often discussed about the first two elements and equity is marginalized. The term "equity" in transport constitutes the social dimension of sustainable transport. It is focused on the fact that an individual has not been previously disadvantaged by their characteristics or conditions.

Social equity is closely related to the availability of transport and the exclusion of the use of transport – with the social exclusion. The social exclusion is a social process. This process gives rise to the fact that some individuals can not engage in usual activities. It is a dynamic process because the concept of "normal activities" is changing over time. [2]

Factors that affect access to mobility and social exclusion are e.g. a social group, gender or age. These factors influence physical (personal) exclusion, fear-based exclusion or temporal exclusion. According to Europe 2020 the most affected are women, children, young people, people living in single-parent households, lower educated people and migrants. [3] It can be supposed that these individual and family characteristics influence the choice of place of residence, place of work, social activities, the decision to travel and choice of transport modes. [4]

These characteristics are added to the circumstances that individuals cannot influence. These include the access to public transport and from these factors resulting geographic exclusion, space exclusion and exclusion from facilities. The possibility of social exclusion increases/decreases with the possibility/impossibility to use a car. It is possible to introduce a presumption that car ownership influences the choice of transport mode. Car ownership is an opportunity to adapt to the limited availability of public transport. Adaptation is individual (to a certain extent). The degree to which individuals without car are disadvantaged relative to drivers can be measured using mobility gap analysis, which measures the difference in travel between households with and without automobiles. [5]

The last issue is economic exclusion. This is related to the affordability of services and mobility costs. The question is whether the pricing will affect social inclusion and access to mobility as a whole or will have a greater impact on a selected group of users. [6]

2 The impact of road pricing on social exclusion

The general hypothesis is that road pricing is a financial obstacle to mobility and has a different impact on different social groups. Whittles (2003) states: “While richer motorists may be able to afford to pay the charge, low income motorists may feel they still need to drive yet cannot afford to pay more. Thus, there is a fairness issue.“ [7]

Also Banister (2002) has argued that: „while the impact of road pricing on all travellers is progressive, the impact on low income car owners is regressive“. [8]

The same conclusions present Di Ciommo et al. (2011): „Road pricing inevitably increases the cost of travel for all drivers but this will disproportionately affect low-income drivers.“ [9]

It is possible to deduce that the introduction of road pricing clearly has a negative impact on low-income groups of the population, deteriorating accessibility of mobility, sustainability of the transport system and increases the risk of social exclusion. The reason is that a fixed (regressive) tax takes a larger percentage of the income of low income people than of other social groups. This causes increase the gap between social groups.

However, it should be considered that income influences the transport behaviour irrespective of the existence/absence of charging system. National Travel Survey (Great Britain) presents that income is closely related to the travel behaviour and people with low incomes travel less than people with high incomes. [10] As well is a possible to present that people with lower incomes use the car less than people with higher incomes, and they often travel by public transport (more details Santos and Rojey, 2002). [11] Titheridge et al. (2014) present: „More bus trips and walk trips are made by the lowest income group than any other group whereas more rail and bicycle trips are made by those from high income group than others (but there is not a large difference in the bicycle use across the income groups).“ [12]

Although the charging system is introduced, its impact is greater on social groups that are less socially vulnerable (more details Transek, 2006). The impact is greater in families with higher incomes than families with lower incomes: "the average economic net loss varies between SEK 106 for the group with the lowest and SEK 405 for the group with the highest income." And so: "Households with high discretionary income pay nearly three times as much as households with low discretionary income." Higher-income households own one or more cars and use them. Another vulnerable group may be women, but research has found that: "Men pay about 50 % more than women." Men took a larger percentage of their journeys by car (68 % of their journeys), while women took 52 % of their journeys by car and 48 % by public transport. Research also presents: "Women gain the most if revenues are used to reduce public transport fares because they use public transport more often." [13]

Therefore, it is necessary to consider the use of revenues from the charging system. Revenues can be use for development of public transport. Transek (2006): „..if the revenues are used for public transportation, those who gain the most from the pricing scheme are young people, low-income individuals, single people, women, and residents of the inner suburbs. These groups pay relatively little in congestion charges on average and use public transportation more often than do other groups.“ [13]

Also other studies support this idea. Teubel (1998) has argued: „Users of public transport ... benefit from an increase speed while paying little or no charge.“ [14]

3 Indeed pricing reduces mobility and causes exclusion?

It can be said that most cities that have successfully introduced a system of pricing, uses revenue from the system for financing public transport, cycling or walking. It supports the preservation of mobility and social inclusion. This support of public transport is used in Norway, the USA and the UK. Here is an example of the charging scheme in London.

The London congestion charging system was introduced on 17 February 2003. The main aim of the system is to reduce congestion. Simultaneously the system allows revenues to invest in public transport in London. All revenues of the scheme are hypothecated towards the improvement of public transport in London, as is required by the Greater London Authority Act 1999. [15] The following figure (number one) shows net revenues of the system. Approximately 80 % of this revenue is invested in the bus network, the remaining 20 % is invested in development of walking, cycling or safety.

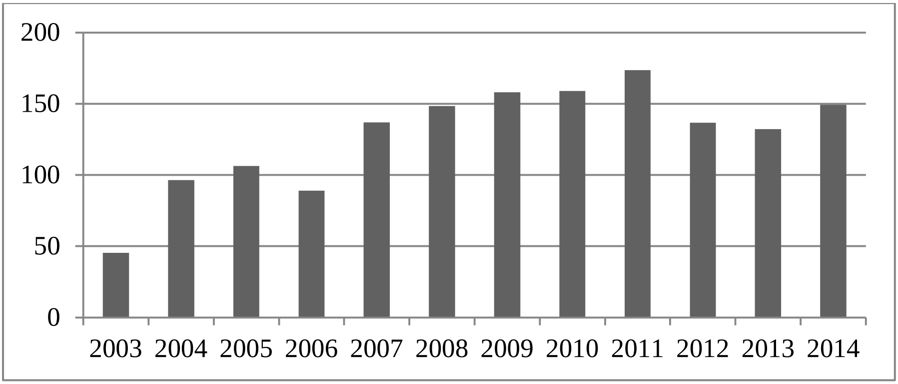

Fig. 1: Net revenues (millions of pounds)

Source: Annual Reports. *Transport for London* [online]. 2014 [cit. 2015-08-17]. Available from: https://tfl.gov.uk/corporate/publications-and-reports/annual-reports-past-years

After the introduction of the system began in recent years to alter the balance between public and individual transport (see the following figure number two).

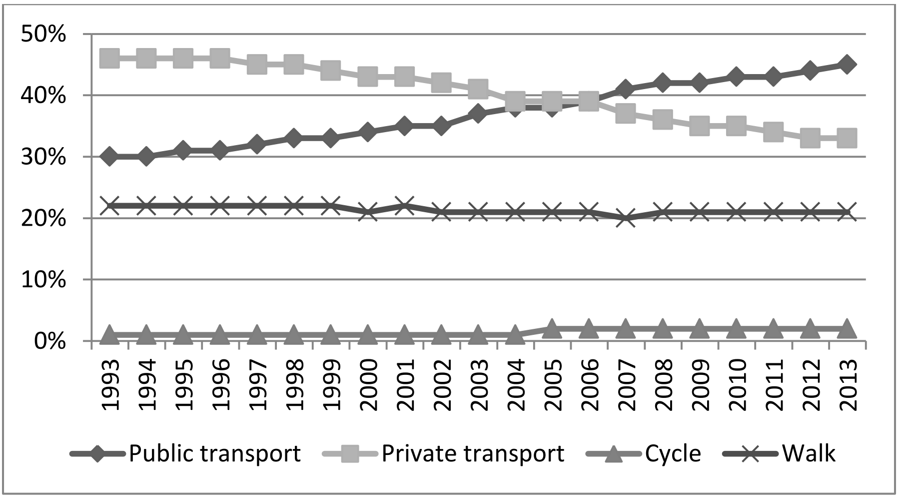

Fig. 2: Percentage shares of journey stages by type of transport

Source: Travel in London: Report 7. *Transport for London* [online]. 2014 [cit. 2015-08-17]. Available from: https://tfl.gov.uk/cdn/static/cms/documents/travel-in-london-report-7.pdf

Using of public transport has increased and travel by car has decreased. Car driver trips was in 2013 13,5 % lower than in 2001, despite the 15 % increase in London's resident population over the same period. The volume of road traffic in London has fallen by a similar amount, with traffic in 2013 10,7 % lower than in 2001. This is clearly driven by the decrease in car traffic, which makes up almost 80 % of all vehicular traffic on London's roads. Transport by underground grew once again, although at a somewhat slower level than in recent years. Bus transport also grew, with 2,382 million bus journey stages made in 2013/2014, 3,1 % more than 2012/2013. Rail transport 2013/2014 was marked by continued growth and cycling grew by 176 % between 2000/2001 and 2012/2013, with a further growth of 7 % between 2012/2013 and 2013/2014. [16]

In other words, total trips increased, while car driver trips decreased (see the following figure number three).

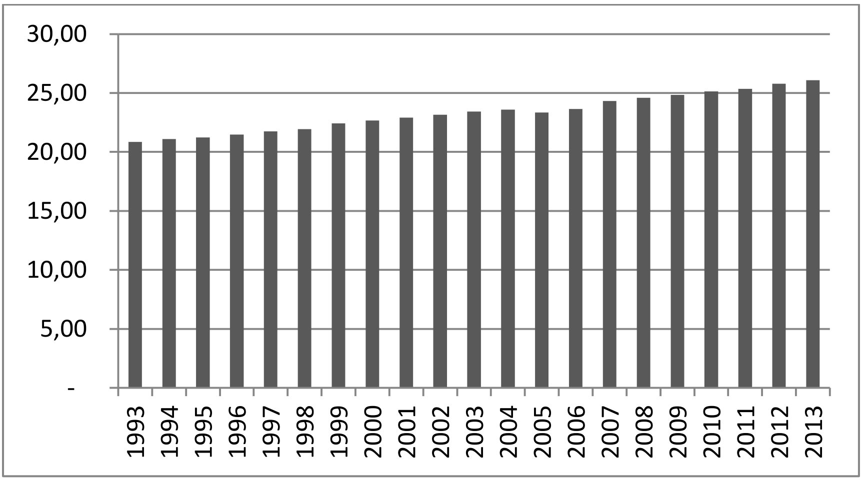

Fig. 3: Total trips in London per day per all modes (millions)

Source: Travel in London: Report 7. *Transport for London* [online]. 2014 [cit. 2015-08-17]. Available from: https://tfl.gov.uk/cdn/static/cms/documents/travel-in-london-report-7.pdf

At the same time, the number of households that own a car has been gradually decreasing. According to recent data, 46 % of households do not own a car, and in 2005 it was 43 % of households, and in 1995 39 % of households. It is possible to state, car ownership and the need to use a car has to do with the availability of public transport. The data show that despite the decrease in the number of cars and a decrease in the number of journeys undertaken by car, introducing of pricing does not lead to a reduction in the total number of trips. Improvement of public transport can have a positive influence on this state. [17]

This conclusion is consistent with the Small (1983): „revenues from road pricing schemes can be used to improve public transport alternatives, which can then (theoretically) serve to remedy any decrease in accessibility to the road network for lower income groups.“ [18]

But it is not at all clear that the data fully captures the problems of transport in relation to social exclusion. Quality of life indicators mostly consider the percentage of the resident population who travel to work by private motor vehicle, by public transport, on foot or cycle or they alternatively evaluate number of journeys/car ownership. [19] And therefore these indicators or indices of deprivation consider the impact of transport on social exclusion is only marginally. And they do not include the influence of pricing.

4 Conclusion

The issue of sustainability of transport is not only environmental and economic, but also social. The road pricing in cities affects the social equity and the the availability of mobility. Influence of pricing on particular social groups is researched mainly theoretically. Most authors note that pricing deepening social exclusion of at-risk social groups. Limitation of which that conclusion is based mostly on the fact that losses caused by pricing are expressed as absolute values (as a percentage of revenues). The charge is from this point of view regressive payment and negatively endangers specific social groups. But these conclusions do not cooperate with transport behaviour of different social groups and do not consider the use of revenues from pricing. If we consider this, then improving the public transportation lines would offset the regressive nature of the congestion charge and could actually benefit lower income workers more in the long run.

It is therefore not possible to state clearly that the pricing system deepens social exclusion. And monitoring the social impacts of road pricing will require a range of researches.

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Summary: The article is focused on influence of road pricing in cities on particular social groups. There are many theoretical researches that are focused only on road pricing and its negative impacts on social exclusion. This conclusion is incompatible with some practical researches and it is not possible to give a definite conclusion. Monitoring the social impacts of road pricing will require a range of researches.

HUMAN RESOURCE MANAGEMENT AS A TOOL FOR SUSTAINABLE DEVELOPMENT FROM THE PERSPECTIVE OF WORK PROFESSIONAL DRIVERS

Dalibor Gottwald[1], Pavla Lejsková[2]

Abstract: The issue of human resource is actually very topical theme in terms from shortage with insufficient number of professional drivers. It is very necessary to start with resolving this problem in relation to ensuring the sustainability of transport. The paper is based on an analysis of relevant indicators, that are possible to use for confirmation of topicality of problem and then predict the measures that need to be taken in order to eliminate potential negative impacts on transport sector.

Key words: human capital, sustainable development, prefessional drivers.

1 Introduction

The issue of human resources as part of the intellectual capital is absolutely a key area for ensure sustainable development in transport sector, respectively all sectors of the national economy. The area of intellectual capital is gaining on interest in almost all fields of human activity in the last few years, especially in order to ensure effective management of the enterprise value [1, 2, 3, 4]. Stewart defines area of intellectual capital in terms of some main categories - human capital is one of the key components of this structure [5]. The apllied instruments to ensure effective management of human capital have undergone a change – simple registration of staff position in company, in-house reward system, in-house system of sanctions, in-house system for education of employees atc. The current trend in the field instruments and methods to ensure the sustainable development of human resources is the global management of all activities that can be

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importance in the context of ensuring the development of human potential [6, 7, 8, 9].

Professional drivers work is one of the importance area of transport development in terms of human resources. This trend is clearly justifiable from the perspective of the continual increase in demand for transport, both within the national and international levels. Continuously rising pressure on the quality of transport (rate, punctuality atc.) has a clear impact on the current state of the quality of human potential in the work of professional drivers [10]. The current state of human potential in this field (in the Czech Republic) is not in a satisfactory condition in terms of ensuring sustainable development – actual numbers of new professional drivers do not meet market requirements [11]. This trend can be regarded as absolutely crucial from the perspective of the sustainability of transport in terms of demand for the professional drivers. In an effort to maintain sustainability for the development of transport must be apply (deliberately and consistently) a set of measures that will lead to increasing of the quality of human potential in this area [12].

With the above propositions are linked goal of the article – to highlight on the current problems in terms of human resources in the context of work professional drivers. Demonstrated data are based on survey results of first specialized recruitment consultancy company in the field of transport - ČESMAD Bohemia ltd. The conclusion of article will be devoted of describing the current state of action plan for improving the critical situation in the field of human resources in transport.

2 Analysis of the state of human potential in the field of work professional drivers

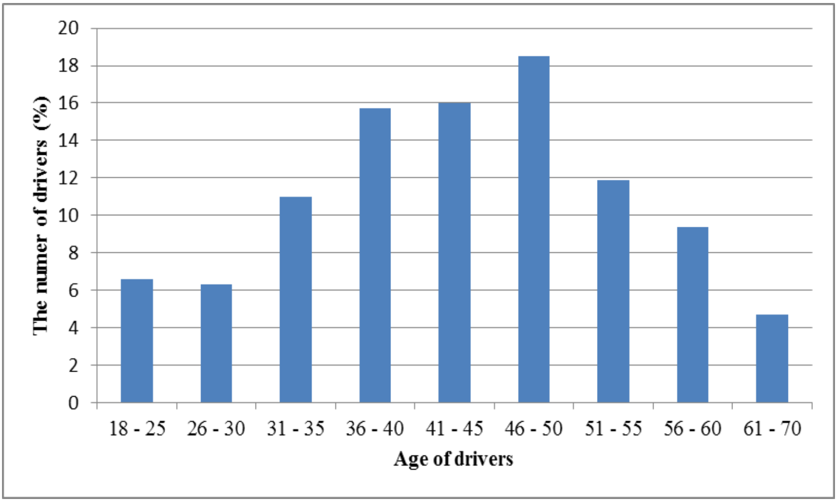

Fig. 1: The age distribution of drivers in freight transport
Source: [11]

From the graph above is obvious trend about unbalanced situation in terms of age of professional drivers in freight transport. This situation confirms the assumption about the unefficient management of human resources as a potential for future development. This situation in distribution of the age structure of professional drivers is supporting a major problem in terms of human capital – lack of professional drivers.

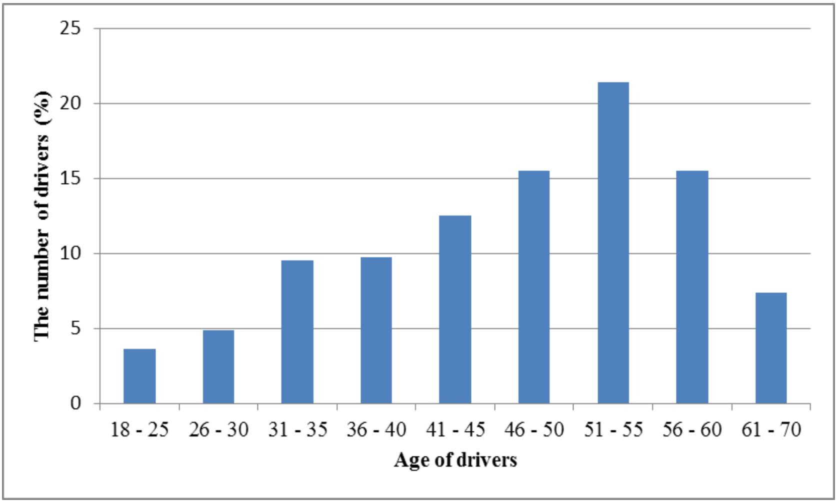

Fig. 2: The age distribution of drivers in passenger transport
Source: [11]

The situation in the field of passenger transport is similar as in the previous graph. This trend clearly supports the fundamental problem in development of human potential - an insufficient number of new professional drivers to ensure sustainable development.

Outputs from the graph no. 1 respectively no. 2 are confirming the trend of an impending shortage of human potential to ensure sustainable development in transport – at least in the field of work professional drivers.

This trend is supported by the outcomes of research conducted in 2012 on a sample of 2.500 drivers (road freight and passenger transport). It has been found:

- natural annual variation of drivers: **2.5 %;**
- the annual need of new drivers caused by the natural variations and other factors: **5 %.**

The total volume of newcomers does not cover the overall need. Given result supports the fact that the current state of human potential is not sufficient to cater for the needs of the present generation.

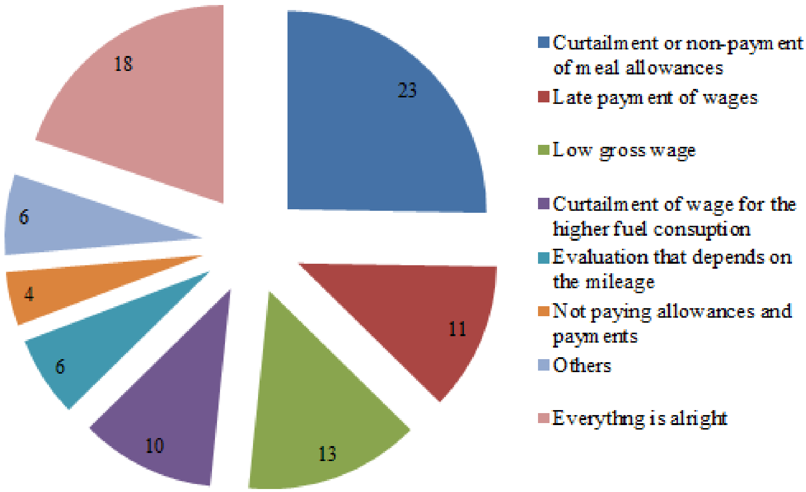

Fig. 3: Exploration of problems related to work performance of professional drivers (%)

Source: [12]

Above graph demonstrates the outcomes of the research that deal the perceived shortcomings in terms of professional drivers. Most of these reasons are related to dissatisfaction with wage conditions in general.

3 Action plan for addressing the shortage of professional drivers

Based on the aforementioned is clear that the declared results are very dismal in order to ensure sustainable development in guaranteed sufficient number of professional drivers. On the base on defined conditions it was published "Action Plan for addressing the shortage of professional drivers" in the framework of European structural funds "Sectoral agreements as a tool of social dialogue in solving long-term problems in the area of human resource development" in 28th of April 2015. The main objective of document that was attended by ISD ČESMAD Bohemia and the Association of Road Transport ČESMAD BOHEMIA project is strengthening of mutual cooperation of stakeholders in order to effectively training new professional drivers, increasing image of this profession in general. Specific measures relate in particular to:

Strengthening cooperation between employers and secondary and primary schools:

- to achieve a cooperation in recruiting new students and promoting industry,
- to contribute to the modernization of school education programs,
- to improve targeting and practical education of students,
- to create a system for providing practical training of students and teachers.

The strengthening of cooperation between employers, employment agencies and other stakeholders:

- to bring an exchange of information about grant programs,
- to ensure cooperation in recruiting workers,
- to set cooperation in the selection, motivation and retraining of job seekers.

Regional sectoral agreement for addressing the shortage of professional drivers in Středočeský region was signed on 18th of June 2015. ISD ČESMAD Bohemia has already started with working on the project. The main effort of association is to extend the pilot project activities to other regions. The aim is therefore to solve the problem completely with nationwide coverage.

3.1 Evaluation of action plan for addressing the shortage of professional drivers

Mentioned action plan to tackle problems with the lack of quality human resources was signed recently. For this reason, it is not possible to assess the effectiveness of any measures that could be compared with the state of the current and previous. However, it is possible to limit the evaluation of the content of action plan from the perspective of the problems that were identified in the survey in 2013 (graph no. 3). On the base of this output, it is possible determine that the major problems (as a problems that increase the level of dissatisfaction with the performance of professional driver) are wage conditions (the amount of wages, do not respect pay out day, unreasonable wage cuts etc.). In connection with the above there is possible to ask two legitimate questions:

- Will be removed barriers of labour conditions in connection with the use of the aforementioned action plan?
- To what extent will be active state authorities, especially in the process of legislative adjustments, that would help to eliminate any unfair activities by employers?

4 Conclusion

The contribution dealt with one of the major challenges in ensuring sustainable development in transport. Specifically, it was the issue of human resources from the perspective of work professional driver. On the basis of demonstrated outcomes of a recently conducted research, it is clear that the area is in an unsatisfactory condition for achieving sustainable development in the transport sector. An allegation of inadequate condition of human potential is mainly based on indicators of age structure of professional drivers in road passenger and freight transport. Another aspect that confirmed the condition about actual situation, were outputs from research that was interested about reasons of dissatisfaction of professional drivers. Based on the findings of researches was demonstrated the prevailing negative trend in management of human resources, especially in terms of labor conditions.

Under the above mentioned findings it was analyzed an action plan in the end of article that is currently the only supporting document for achieving improvement in quality of human resource management in long time period. For ensuring improvements in the area, it is necessary that all the specific activities that will be applied in relation to a defined action plan reflected the common discussion among all stakeholders (employers, government authorities, potential job applicants for professional drivers etc.).

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POSSIBILITIES OF GENERATING CALENDAR TEXTS IN RAIL TRANSPORT

Karel Greiner[1]

Abstrakt: The article describes possibilities of generating train calendar text for the needs of compiling the annual timetable in the conditions of the Czech Republic. Based on the analysis of the types of texts of calendars that appear in various print outputs, a heuristic algorithm was designed to generate a text from a set of the calendar days. The algorithm is a part of an application that also provides a tool to define the text of the calendar by using a mask of sub-periods and calendars to be displayed in them. The algorithm was tested on real data of the timetable. In most cases, the algorithm shows the same or better results than previously used tools. In several cases, however, a better result can be obtained by the user.

Key words: railway calendar, railway timetable, generating text.

1 Introduction

One of the basic data of a train is a calendar containing the days it operates. Within the compilation of the annual timetable of trains the calendar includes days over a period of one year approximately. Passengers and rail workers learn about restrictions on the train running through a text formulation that usually does not contain a simple list of days, but variations of shorter and more meaningful texts.

The role of a modern information system is not only to record a set of train operation days, but also provide a corresponding textual representation the user would not have to modify for output sets.

The article describes the possibilities of generating train calendar text for the needs of designing the annual timetable in the conditions of the Czech Republic.

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2 Types of calendar texts

The annual train diagram in the area of the Czech Republic is compiled using the KANGO information system [1]. The train calendar is a part of the train data entered in the KANGO-Vlak module [2] by the railway undertaking.

The annual timetable is in most cases valid from determined Sunday in December of one year to determined Saturday in December of the next year. It concerns usually the second week in December. The following examples of calendar texts refer to the 2008/2009 timetable period that was valid from December 14, 2008 to December 12, 2009.

Calendar texts appear in various outputs of the KANGO system. The main ones among them are the following:

- Book timetable – the timetable in the form of a book for passengers. It contains passenger trains only. It is created in the KANGO-GVD program and before printing it requires adjustment by the user. The current version in PDF format is available on the Web [3].
- Overview of restrictions on running of trains – an annex to the order to implement the train transport diagram. It includes calendar texts of both passenger and freight transport trains. It is intended for official use only. It is printed from the KANGO-Vlak program usually without any further adjustment.

In the calendars texts there are in addition to individual days of the year also symbols of predefined calendars. They are listed in Table 1.

Tab. 1: Symbols in calendar texts

Symbol	Meaning
1 to 7	Monday to Sunday
x	Weekdays – Monday to Friday except public holidays
+	Holidays – Sunday and public holidays

Each day of the year in the calendar text is represented by an Arabic number of the day of the month and a Roman number of the month separated by a period, such as 23.IV.

Public holidays in the 2008/2009 timetable were: 24., 25., 26.XII., 1.I., 13.IV., 1., 8.V., 5., 6.VII., 28.IX., 28.X., 17.XI.

As public holidays vary in each country, for international trains the symbols x and + are not used and the symbols of days in a week are used instead.

Calendar texts can be divided into the following types:

1. The calendar includes all days in the timetable validity period (hereinafter referred to as TVP):

   "operates daily"

2. The calendar is empty:

   "operates on demand"

3. The calendar includes all days from the beginning of the TVP to a certain date within the TVP:

   "operates until 30.III."

4. The calendar includes all days from a date within TVP until the end of the TVP:

   "operates from 1.IV."

5. The calendar contains most days within the TVP:

   "no service 24., 31.XII., 1.III. – 13.VI."

6. The calendar includes a minority of the days within the TVP:

   "operates 1.V. – 13.VI., 13. – 27.IX."

7. The calendar includes days represented by a symbol of the predefined calendar or combinations thereof, and alternatively other days (positive days of exceptions) or does not include some days represented by an appropriate symbol of the calendar (negative days of exceptions):

   "operates 1 – 5"

   "operates x, 6 and 24.XII., 1., 8.V., 28.X., 17.XI., no service 31.XII."

8. The calendar includes days represented by a symbol of the predefined calendar or combinations thereof, and contains most days of the validity period and also alternatively contains negative days of exceptions – it is used for freight trains only:

   "no service 6 and 7"

   "no service 6, + and 29.XII. – 2.I., 1.VII. – 28.VIII."

9. The calendar is composed of sub-periods in which there are days represented by a symbol of the predefined calendar or combinations thereof:

   "operates x from 1.VII. until 28.VIII."

   "operates x until 26.III. and from 2.XI., from 30.III. until 29.X. operates 1– 4"

10. The calendar is composed of sub-periods in which there are days represented by a symbol of the predefined calendar or combinations thereof and one or more periods that include all days:

"operates x until 13.III. and from 2.XI., from 14.III. until 1.XI. operates daily"

11. The calendar is composed of sub-periods of the 9 and 10 types and also includes positive or negative days of exceptions:

    "operates 6 from 25.IV. until 26.IX. and 1., 8.V., no service 2., 9.V."

    "operates x from 22.XII. until 27.III. and 26.XII., no service 31.XII., from 30.III. operates daily and 14. – 19.XII."

3 Algorithm for generating text

A single calendar can have many variations of text representation. For example, the following texts represent the same set of days:

- "operates x until 30.VI. and from 1.IX. and 24., 25.XII."
- "operates x and 24., 25.XII., no service 1.VII. – 31.VIII."
- "operates 1 – 5, no service 26.XII., 1.I., 13.IV., 1., 8.V., 1.VII. – 31.VIII., 28.IX., 28.X., 17.XI."
- "operates 1 – 5 until 30.VI. and from 1.IX., no service 26.XII., 1.I., 13.IV., 1., 8.V., 28.IX., 28.X., 17.XI."

Which version to select? The algorithm usually selects the shortest version of the text except for some special cases described below.

The main problem related to text generating is to determine sub-periods. The ideal would be to generate a text for all possible sub-periods and select the shortest possible text. However, the number of variants is very large and it is not possible in real time to explore all the options. Therefore, a heuristic algorithm has been designed.

In the literature the algorithm for calendar text generating used on Slovak Republic railways is briefly described, but it does not solve cases of consecutive sub-periods [4].

We introduce the following notation for the symbols of the predefined calendars:

$b_1, b_2, \dots, b_7$ Calendars for the symbol 1 to 7.

$b^{\times}$ Calendar for the symbol x.

b^{+} Calendar for the symbol +.

The following text uses the following symbols and functions:

$|A|$ The number of elements of the set A.

D The set of all days within the TVP.

C	A set of calendar days, the text of which is to be generated.
B	A set of all predefined calendars $\mathrm{B} = \{\mathrm{b}_1, \mathrm{b}_2, \dots, \mathrm{b}_7, \mathrm{b}^{\times}, \mathrm{b}^{+}\}$.
G(x)	A set of days of the predefined calendar x ∈ B that belong to the set D.
$\Gamma(\mathrm{x}, \mathrm{y})$	The set of all days in the period x to y: $$\Gamma(x, y) = \{d \in D: x \le d \le y\} \quad (1)$$
$f(d)$	Textual representation of the day d ∈ D, for example 20.XII.
$\mathrm{c_i}$	Integer constants.

Sub-periods occurring in the text are represented by a set of sub-calendars. A sub-calendar is an arranged tetrad $[x, y, B^+, B^-]$ where:

x	The starting day of a sub-calendar period.
y	The final day of a sub-calendar period.
B^+	A set of predefined calendars when the train operates.
B^-	A set of predefined calendars when there is no service.

For the sub-calendar $[x, y, B^+, B^-]$ it is true that

$$x, y \in C, \;\; x < y, \;\; B^+ \subset B, \;\; B^- \subset B$$

The set of sub-calendars is arranged – the elements are sorted in ascending order by x.

The set of days for sub-calendar $s = [x, y, B^+, B^-]$ shall be $H(s)$:

$$H(s) = \left[\bigcup_{u \in B^+} G(u) \setminus \bigcup_{v \in B^-} G(v)\right] \cap \Gamma(x, y) \quad (2)$$

Text representation of a calendar that contains the set of days C and the set of sub-calendars X is provided by the function $g(X)$.

3.1 The main part of the algorithm

The procedure to generate a calendar text from the set C is as follows:

1. If $C = \emptyset$, the result is the text "operates on demand".
2. If $C = D$, the result is the text "operates daily".
3. If $\exists b \in B[C = G(b)]$, the result is the text containing a symbol of the predefined calendar. For example, "operates x".
4. If the calendar contains all the days from the beginning of the TVP until a date within TVP and, at the same time, the number of the calendar days is

greater than 2, while the difference of the number of TVP days and the number of the calendar days is greater than 2, i.e.

$$C = \Gamma(\min C, \max C) \wedge |C| > 2 \ \wedge \min C = \min D \wedge |D| - |C| > 2 \qquad (3)$$

the result is the text

$$\text{"operates until "}\ f(\max C) \qquad (4)$$

For example, "operates until 30.III.".

If the number of the calendar days is less than or equal to 2, the result will be a list of calendar days, for example, "operates 14., 15.XII.".

If the difference of the number of TVP days and the number of the calendar days is less than or equal to 2, the result will be a list of days that are not included in the calendar, for example, "no service 29., 30.XI.".

5. If the calendar includes all days from the date inside the TVP until the end of the TVP while the same conditions are met as in Step 4, i.e.

$$C = \Gamma(\min C, \max C) \wedge |C| > 2 \ \wedge \max C = \max D \wedge |D| - |C| > 2 \qquad (5)$$

the result is the text

$$\text{"operates from "}\ f(\min C) \qquad (6)$$

For example, "operates from 1.IV.".

6. We create an initial set of sub-calendars S (see Chapter 3.2) taking care that two requirements are met:

that every day from the set C belongs to a period of a sub-calendar of the set S, i.e.

$$C \setminus \bigcup_{s \in S} H(s) = \emptyset \qquad (7)$$

and at the same time, that the sub-calendars in the set S do not overlap, i.e.

$$H(u) \cap H(v) = \emptyset \quad (u, v \in S) \qquad (8)$$

7. We merge the group of sub-calendars from the set S – see Chapter 3.3.
8. The resulting calendar text is obtained through the function $g(S)$.

3.2 Creating an initial set of sub-calendars

The initial set of sub-calendars S is created as follows:

1. We set $S = \emptyset$.
2. Into the set S we add each sub-calendar $s = [x, y, \{b_1, b_2, \dots, b_7\}, \emptyset]$ that represents the maximal subset of consecutive days of the set C and has at least c_2 days. These sub-calendars represent the daily operation period.

3. In the set C we go through periods that do not belong in the period of sub-calendars contained in the set S. For each such a period we go through individual weeks (even partial, with which such a period begins or ends) and we find consecutive weeks in which the set C contains the same days of the week (Monday to Sunday). From these consecutive weeks we create sub-calendars $s = [x, y, B^+, \emptyset]$ where x is the first day of the first week of consecutive weeks containing the same days of the week and y is the last day of the last week of consecutive weeks containing the same days of the week.

   For the sub-calendar s it is also true that

   $$B^+ \subseteq \{b_1, b_2, \dots, b_7\}, \quad H(s) = C \cap \Gamma(x, y) \tag{9}$$

   We add these sub-calendars to the set S.

4. For each sub-calendar $s = [x, y, B^+, \emptyset]$ $(s \in S)$ for which it is true that $y - x + 1 \geq c_1$, we perform these operations in the set B^+:
   - If the set B^+ contains calendars b_1 to b_5 and in the sub-calendar period is the set of days of the calendars b_1 to b_5 equal to the set of days of the calendar $b^\times$, we replace the calendars b_1 to b_5 with the calendar $b^\times$.
   - If the set B^+ contains the calendar b_7 and in the sub-calendar period is the set of days of the calendar b_7 equal to the set of days of the calendar b^+, we replace the calendar b_7 with the calendar b^+.

5. We merge each group of the sub-calendars $s_i = [x_i, y_i, B_i^+, \emptyset]$ to $s_{i+k} = [x_{i+k}, y_{i+k}, B_{i+k}^+, \emptyset]$ from the set $S = \{s_1, s_2, \dots, s_n\}$ to the sub-calendar $s^* = [x_i, y_{i+k}, B^+, \emptyset]$, for which it shall be true that

   $$y_{i+k} - x_i + 1 \geq c_1 \wedge H(s^*) = \bigcup_{j=i}^{i+k} H(s_j) \wedge B^+ \subset B \qquad \text{for } k = 1, 2 \tag{10}$$

   First, we merge adjacent couples of the sub-calendars $(k = 1)$ and only then the adjacent triads $(k = 2)$. The set B^+ of the merged sub-calendar s^* contains at least one of the pre-defined calendars $b^\times$ or b^+ alternatively supplemented with predefined calendars of the days of the week.

   There is no point in merging more than 3 adjacent sub-calendars, because there are more than 3 consecutive weeks that include public holidays (for example, Week 1: Sunday 24.XII., Week 2: Monday 25.XII. and Tuesday 26.XII., Week 3: Monday 1.I.).

   From the merging we exclude:
   - Sub-calendars s_i whose set $B_i^+ = \{b_1, b_2, \dots, b_7\}$.

- Couples of sub-calendars s_i and s_{i+1} that include at least one blank week, i.e. $y_{i+1} - x_i > c_3$.

6. For each sub-calendar from the set S, having at least c_1 days, we extend its period. We perform the extending at the expense of the previous or subsequent sub-calendar, whose period is at most one week long. The extension is performed only on days that belong to the set C and also belong to a set of the days of predefined calendars of the extended sub-calendar.
7. For each sub-calendar from the set S we modify its period so that the starting and final day belonged to the set of its predefined calendars and also to the set C. If the period of the sub-calendar $s_i \in S$ has transformed into the beginning of the TVP, we exclude from the set S all sub-calendars s_j for $j < i$. Similarly, if the period of the sub-calendar s_i has transformed into the end of the TVP, we exclude from the set S all sub-calendars s_j for $j > i$.

3.3 Merging the group of sub-calendars

The algorithm is used to merge groups of consecutive sub-calendars from the set $S = \{s_1, s_2, \dots, s_n\}$, so that the text of the calendar was as short as possible. The procedure is as follows:

1. We set $t^* = g(S)$ and $k = 1$.
2. We set $m = 1$.
3. We set $S^* = S$.
4. For each group of the sub-calendars $s_i = [x_i, y_i, B_i^+, \emptyset]$ to $s_{i+m} = [x_{i+m}, y_{i+m}, B_{i+m}^+, \emptyset]$ from the set S (for $i = 1, \dots, |S| - m$), with the exception of the following groups, we create sub-calendar $\dot{s} = \left[\dot{x}, \dot{y}, \dot{B}^+, \emptyset\right]$ for the period from x_i until x_{i+m}.

   This group must represent a period longer than or equal to c_1, i.e. it must be true that $y_{i+m} - x_i + 1 \geq c_1$.

   The mentioned group must not include sub-calendar $s_j = \left[x_j, y_j, B_j^+, \emptyset\right]$ $\left(s_j \in S\right)$, for which it is true that

   $$B_j^+ = \{b_1, b_2, \dots, b_7\} \land y_j - x_j + 1 \geq c_2 \quad (j \in \{i, i+1, \dots, i+m\}) \qquad (11)$$

   This means that you cannot merge a longer daily operation period with another period.

   If $k = 1$, that group must not include couples of adjacent sub-calendars, between which there is a period of longer than or equal to c_4. This means that we exclude the group, if it contains sub-calendars $s_j = [x_j, y_j, B_j^+, \emptyset]$ and $s_{j+1} = [x_{j+1}, y_{j+1}, B_{j+1}^+, \emptyset]$, for which it is true that

$$x_{j+1} - y_j - 1 \geq c_4 \quad (i \leq j < i + m) \tag{12}$$

For the sub-calendar $\dot{s}$ we take these steps:

a) We set $\dot{S} = (S \setminus \{s_i, s_{i+1}, \dots, s_{i+m}\}) \cup \dot{s}$.

b) We include in the set $\dot{S}$ at most two sub-calendars $\tilde{s} = [\tilde{x}, \tilde{y}, \emptyset, \emptyset]$, where $\tilde{x}, \tilde{y} \in C$ and the period of this sub-calendar does not overlap with a period of another sub-calendars in the set $\dot{S}$.

c) We set $t = g(\dot{S})$.

d) If the text t is shorter than the text t^* (according to the string length), we set $t^* = t$ and $S^* = \dot{S}$.

5. We set $m = m + 1$ and $S = S^*$.
6. If $m \leq 3$, we proceed with Step 3, otherwise we set $k = k + 1$.
7. If $k \leq 2$, we proceed with Step 2, otherwise the algorithm ends.

The algorithm performs merging of at most 4 consecutive sub-calendars. In testing it was found that for $m > 3$ there is no merging of sub-calendars taking place anymore.

4 Text created by user

Since the algorithm generating the text of the calendar from a set of days does not always have to provide a text that is suitable for users, the KANGO-Vlak program allows the user to define sub-periods and calendars to be displayed therein.

Figure 1 shows a part of the dialog box that is used to enter the sub-calendars. In the "Operates" field we can enter the name of predefined calendars, when the train operates, and in the "No Service" field we can enter the name of predefined calendars, when there is no train service. These fields correspond to the sets B^+ and B^- of the sub-calendar. After clicking an appropriate button the corresponding days are marked in the calendar control and the calendar text is generated. For the sub-calendars shown in Figure 1 the result will be the text "operates 2 – 6 from 1.I. until 28.II., from 2. until 31.III. operates x". After generating the text, the user can mark or unmark individual days in the calendar control, adding or removing positive or negative days of exceptions.

Fig. 1: Fragment of a dialog box designed for entering sub-calendars

The actual text of the calendar is read-only. The user can only affect the definition of sub-calendars and individual days included in the calendar.

5 Verifying the algorithm

The text generating algorithm was tested on real data of the 2008/2009 timetable. Before the introduction of the algorithm described, a tool was used for creating text by the user (see Chapter 4) and a simplified algorithm that failed to identify sub-calendars immediately following each other. The simplified algorithm was part of the CEV program [5], which was used prior to the implementation of the KANGO system.

The proposed algorithm was applied to all the calendars contained in the test database. Texts were generated on the computer Intel Core i7 3 GHz with the results listed in Table 2.

Tab. 2: Results of generating the texts of the calendars

Indicator	Value
The total number of calendars in the database	2835
The number of calendars, the text of which got abbreviated	359
The average number of characters, by which the texts of calendars got shortened	20
The number of calendars, the text of which got extended	76
The number of calendars, the text of which got extended and the original text did not contain a daily operation sub-period while the new text contains it	27
The average number of characters, by which the texts of the calendars got extended to the exclusion of calendars, whose original text did not contain a daily operation sub-period while the new text contains it	6
The number of calendars with the same length of text, but with a different text	22
The average time of generating a calendar text	5 ms
The maximum time of generating a calendar text	231 ms

The time of generating a calendar text (both the average and maximum) allows using an algorithm in real time. When marking days in the calendar, the user is not impeded by generating text, and therefore the text can be generated automatically after each change of the calendar days.

The introduction of the algorithm significantly shortened the texts of calendars that contained multiple sub-periods (on average by 20 characters).

However, some user-defined calendar texts were shorter (about 3%). Firstly, these are calendars differing in the daily operation period. In the test database there are calendars that do not contain a daily operation period, but the algorithm included such a period in the text.

A part of generating the daily operation period cannot be omitted from the algorithm, because there are a large number of calendars in which there is a daily operation period.

If we exclude the calendars that differ in the presence of a daily operation period, there are 49 calendars, whose text is longer when using the algorithm, on average of 6 characters. Thereof, 26 calendars differ in use of predefined calendars of working days and holidays. The algorithm will use these calendars, if the number of days of positive and negative exceptions is smaller. However, this may result in some cases in a longer text.

The remaining calendars with a longer text (23 calendars) usually differ in confines of the sub-periods. Sub-periods that do not represent a daily operation are primarily determined by full weeks, but sometimes it is better to move the confines.

Another problem is the fact that the algorithm provides a daily operation sub-period as the maximum period of consecutive days. If it is immediately followed by another sub-period, it can sometimes be more suitable to include the last day or days of the daily operation sub-period in the follow-up period.

6 Conclusion

Information system of train timetable must not only work with the set of train operation days, but also provide a corresponding textual representation. Calendar text usually does not contain a simple list of days, but variations of shorter and more meaningful texts, which require use of a certain algorithm.

Types of calendar texts that appear in various print outputs in the Czech Republic were analyzed at first. Calendar texts were divided into 11 types.

Based on the analysis a heuristic algorithm was designed to generate a text of calendar. The main task of the algorithm is to determine sub-calendars from which texts of sub-periods of train running are generated. The algorithm shows in most cases the same or better results than the previously used tool to define the text by the user or the simplified generation algorithm. In several cases, however, a better result can be obtained by user interference.

The described algorithm is a part of the KANGO-Vlak program that is used for compiling the annual timetable of trains in the Czech Republic. Calendar texts generated by this algorithm appear in various outputs of the KANGO system, which include especially book timetable, marshalling plan for freight trains and overview of restrictions on running of trains.

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THE NEW INTERMODAL UNIT FOR THE TRIMODAL USE

David Hrdý[1], Jan Chocholáč[2], Martin Šustr[3], Petr Průša[4]

Abstract: The article focuses on new trends in intermodal transportation. It deals with intermodal systems, aiming to present new intermodal unit called TelliBox. This unit tries to remove the disadvantages of the currently used units, connecting the main advantages of ISO container, European standards swap body and bulk trailer.

Keywords: intermodal transportation, intermodal transport, TelliBox, MegaSwapBox.

1 Introduction

The requirements for transportation grow, as the volumes transported and the overall amount of transports increase, but the growth cannot continue indefinitely. Transport infrastructure is subject to limiting external geographic factors. Although it can be built and expanded extensively, the possibilities are still limited to some extent. It is thus inevitable for the development of transportation to be turned towards higher effectiveness and reorganisation of current system. Another problem is that the traffic depends primarily on consumption of fossil fuels that need to be used as effectively as possible too.

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One of the possible solutions that meet the mentioned criteria is intermodal transportation. Apart from overall description of the combination of two or more transport sectors where the cargo, not directly manipulated with in any way, is loaded on one transport unit, its description also contains topics on integrated connection of transport sectors which should consider costs and impacts on environment.

This article deals with project of a new intermodal transport unit MegaSwapBox, or TelliBox. These units aim to remove the disadvantages of the units used today, or more precisely aim to connect the main advantages of ISO container, European standards swap bodies and bulk trailer.

2 Systems of intermodal transportation

2.1 System of container transportation

The basic element of this system is the use of containers, standardized and unified transport units. It is by far the most commonly used system and probably also the most perspective one. Manipulation with containers is considerably easy and timesaving due to the standardized size. [1, 2]

2.2 System of swap bodies

Swap bodies for road vehicles were primarily designated for simple and safe manipulation with cargo in road transport. Its main advantage compared to container is higher loading rate and lesser weight with same external size. In most cases however, they cannot be stacked. [1, 2]

2.3 Barge systems

Barge Carrier systems are systems characteristic for combined inland and marine shipping. [3] Transport units are boats acting as containers. These are transported in special ships, so called carriers, on sea. They are loaded and unloaded with gantry cranes, platforms or enter the carriers themselves. It represents a significant time saving measure when dealing with palletized piece-goods. [1, 2]

2.4 System of intermodal trailers

Intermodal trailers can be used for intermodal transport as well. The road trailer can be transferred on railway. It can be an ordinary trailer or special semitrailer fit adjusted for manipulation with small cranes. The railway transport is conducted in railway wagons adjusted for vertical loading. [1, 2]

2.5 RollendeLandstrasse – Rolling Road (ROLA)

This system also deals with connection of road and railway transports. Principle of this system is based around road vehicles being loaded on railway wagons as whole and transported in them; therefore it is an accompanied intermodal transport. The transport unit is whole road vehicle. [1, 2]

Tab. 1: Development of intermodal transportation in 2010 – 2014

	2010	**2011**	**2012**	**2013**	**2014**
Large containers	7 442	8 001	7 129	8 436	8 824
Swap bodies	170	167	137	230	254
Intermodal trailers	25	25	49	102	302

Source: [5]

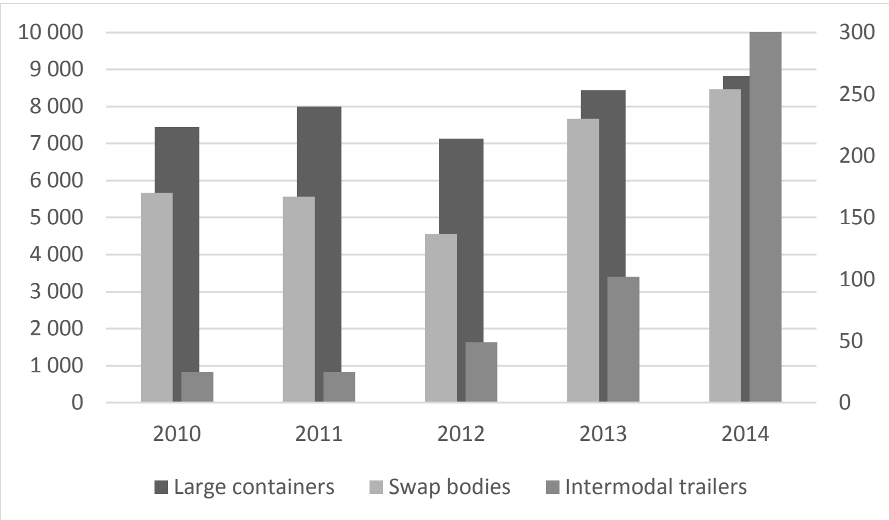

Fig. 1: Development of intermodal transportation in 2010 – 2014 [5]

3 TelliBox Project

Project called Intelligent MegaSwapBoxes for Advanced Intermodal Freight Transportis joint European project of several various entities associated with intermodal transport.

Official name of the intermodal unit, so called MegaSwapBox (dale MSB), derived from the name of the project, is TelliBox. The new unit should connect the advantages of containers, swap bodies and intermodal trailers.

Their basic properties are:

- internal volume 100m^3,
- internal height 3m,
- three openable sides,
- vertical manipulation,
- stackablility
- usability in road, rail, river and sea transport,
- sufficient protection of cargo. [6, 7]

Legislative restrictions of European countries have to be met as well, especially when loading on chassis in road transport. Some requirements are partly contradictory and it is thus necessary to find an optimal ratio of meeting the individual criteria.

The project was established in 2007 and passed the testing phases successfully in the beginning of 2011. First public presentation was took place in March of 2011 on intermodal terminal in Duisburg, where the MSB was introduced to the public. Preparations for putting the project into practice are currently conducted.

Project is financed from the funds of European Union under the 7th Framework Programme for Research and Technological Development. The calculated overall cost of the project is 4.37 billion euros of which 4.1 billion euros is covered by the support.

3.1 Technical solutions of the Tellibox project

As a new type of intermodal unit, the MSB is constructed from scratch so that it meets the placed criteria. The schematic of the final structural design is shown at Figure 1.

The whole construction of MSB holds its own weight. Important elements are the side walls which are the main parts of the whole model. Other parts are upper and lower frame where the upper frame is designed to be relatively more solid. The roof is movable and enables higher loading weight. The column in the middle of both sides also strengthens the whole construction.

Both side walls can be opened. There is a pair of doors on each side with the middle ones always mounted on the column in the middle of wall, the other are mounted on sides. All doors are made of two parts and can thus be collapsed.

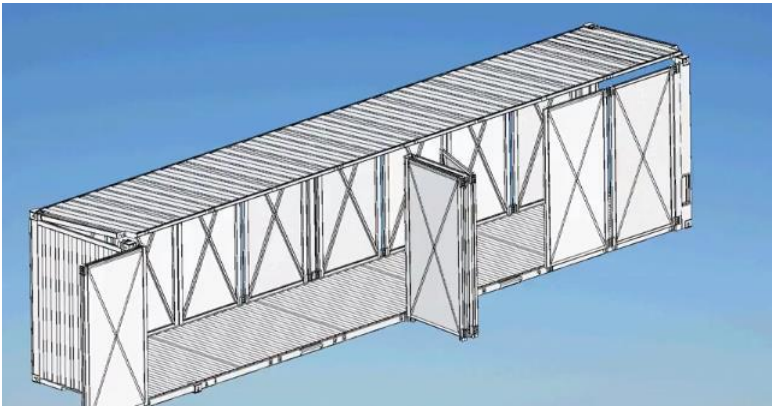

Fig. 2: Schematic of structural design (ShoeBox) [5]

Below is showed the opening of one side.

Fig. 3: TelliBox on low Sffggmrrss type train [6]

The weight of the MSB itself is 7.5 tons with 23 tons of capacity. Internal capacity is 100 m^3 and 33 europallets can be fitted inside in one layer. As for the external size, the MSB is 3.023 m high, 2.45 m wide and 12.6 m long. The movable roof can increase the height of back loading doors up to 3.223 m. [6, 7]

It can be used on the current low Sffggmrrss type cars and the unit can be transported on roads on special trailer bytruck with turntable height up to 875 mm. It has corner fittings in lower parts in 45 ft length and in upper parts in 45 and 40 ft for better stacking with ISO containers. MSB itself is stackable in 4 layers. [6, 7]

4 Conclusion

The new MegaSwapBox project introduces new technological solutions while respecting the basics of unification and standardization in reference to already used systems as well. New technologies, such as TelliBox, are one of the ways to support intermodal transport. Enhancing the technological aspects of intermodal system can help improving conditions of intermodal transport and thus improve its efficiency. The future will show if the project will really be successful in practice.

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DEVELOPMENT OF ROAD FREIGHT TRANSPORT IN THE CZECH REPUBLIC IN THE PERIOD 2005 – 2014

Roman Hruška[1], Jindřich Ježek[2]

Abstract: This article deals with development of the performance of road freight transport in the Czech Republic from the point of view of transported tons, realized tonne-kilometers and traveled transport distances for the period 2005 – 2014. Performances (in tonnes and tonne-kilometres) are analyzed from point of view of national and international transport. This paper points out to the major share of road freight transport compared to other modes of transport.

Key words: road freight transport, national transport, international transport.

1 Introduction

Freight transport is the important element in the economy of the state. Thanks to low-cost and reliable movement of goods, businesses become more competitive. The important policy of this issue is to minimize total transportation costs to ensure the efficient transport of goods. During the last decade, freight transport has had amazing progress. Thanks to the improvement of infrastructure and technological innovation, transport became more efficient and productive in terms of prices, time of transport and safety.

2 Road freight transport in the interdisciplinary comparison of transport performance of freight transport

Structure of freight transport performances by types of transport in the Czech Republic is similar to that in other European countries. Road transport takes

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approximately three-quarters of transport performances, about one fifth of railway transport. Pipeline transport (2.7 %) transports to us oil and natural gas. Water transport (mainly Elbe) in the Czech Republic realized less than 1 % of total transport performance, the importance of air transport in freight transport in the Czech Republic is quite marginal. Table 1 shows interdisciplinary comparison of transport performance of freight transport from 2005 to 2014, according to the Czech Statistical Office.

Tab. 1: Interdisciplinary comparison of transport performance of freight transport

	2005	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Tonnage of goods carried (thous. t)	**560 075**	**565 748**	**540 766**	**458 368**	**451 724**	**448 707**	**435 500**	**447 416**	**491 132**
Goods transport by Rail	85 613	99 777	95 073	76 715	82 900	87 096	82 968	83 957	91 022
Goods transport by Road	461 144	453 537	431 855	370 115	355 911	349 278	339 314	351 517	386 243
Goods Transport by inland Waterways	1 956	2 242	1 905	1 647	1 642	1 859	1 767	1 618	1 780
Airport traffic - air freight and mail commercial transport	57	61	56	54	66	70	59	58	58
Tariff tonne-kilometres (mil.)	**61 397**	**67 463**	**689 528**	**60 571**	**68 495**	**71 817**	**68 087**	**71 509**	**69346**
Goods transport by Rail	14 866	16 304	15 437	12 791	13 770	14 316	14 266	13 965	14 575
Goods transport by Road	43 447	48 141	50 877	44 955	51 832	54 830	51228	54 893	54 092
Goods Transport by inland Waterways	781	898	863	461	679	695	669	693	656
Airport traffic - air freight and mail commercial transport	50	43	42	27	20	21	14	24	23

Source: Ministry of Transport, CSO

Table 1 shows that road transport has the largest share. In 2014 this share is 78.6 % at transported tonnes. Road transport performance has been increasing since 2009, when there was a decline due to the economic recession. Rail transport performance decreased rapidly this year on average with previous years to 17.7 %. The overall transport performance in 2009, rail transport accounted only for 21.1 %. Much more serious, however, the impact it had on the Slovak Republic, which was supposed to drop to 50%. In 2010, transport by rail began to slowly increase again. In inland waterway transport and air transport seen in the last three years, just drop and proportion of total transport performance is minimum compared to road and rail transport.

3 Road freight transport in 2005-2014

In the Czech Republic by Roads and Motorways Directorate was on 1 January 2014 total of 55 761 kilometers of roads and motorways. Out of that 61 % are roads III. Class (34 169 kilometers), 26 % are Class II. Class (14 566 kilometers), 11 % are first class roads (6 250 km), and only 2 % are motorways (776 km) and highway (458 km)

Development of goods transport by road of international and national freight transport in the years 2005 - 2014 is shown in the following figure 1.

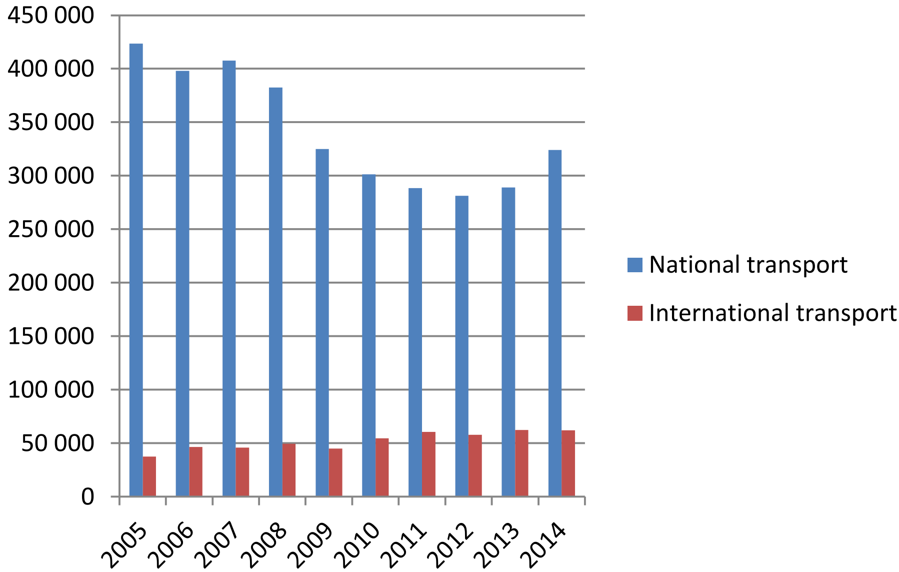

Fig. 1: Goods transport by Road (tonnes)

Source: Ministry of Transport, CSO

Based on Figure 1, we can conclude that the national transport of goods by road has since 2005 a decreasing trend. In 2012, the transport of goods decreased compared to 2005 by 33.6 %. In 2014, transport of goods by road freight transport amounted 386 243 thousand. tonnes of which were national transport 83.9 % share. International transport of goods has growing tends. Except for the already mentioned 2009, when was the economic crisis. In 2014 compared to 2005 was an increase up to 65.4 %. International road transport has a small share of the total transport of goods compared to the national road transport. Export has the largest share on international transport. The average for all these years it is 40.8 %. 62 114 thousand. tonnes of goods was transported by road international transport in 2014.

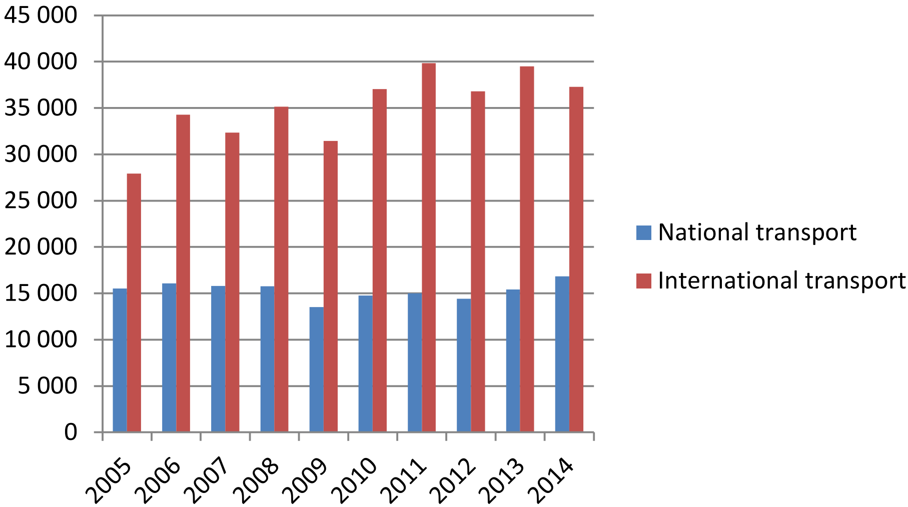

Fig. 2: Total transport performance (mil. tonne-kilometres)

Source: Ministry of Transport, CSO

International transport has main share of transport performance and long-term growth. For national transport we can rather speak about stagnation. Total transport performance in 2014 amounted to 54 092 miles. tonnes. This was by 24.5 % more than in 2005. Another indicator is the development of the transport distance of national road freight transport in the years 2005 – 2014 as shown in the following Figure 3. In Figure 3 is only recorded transport of vehicles registered in the Czech Republic.

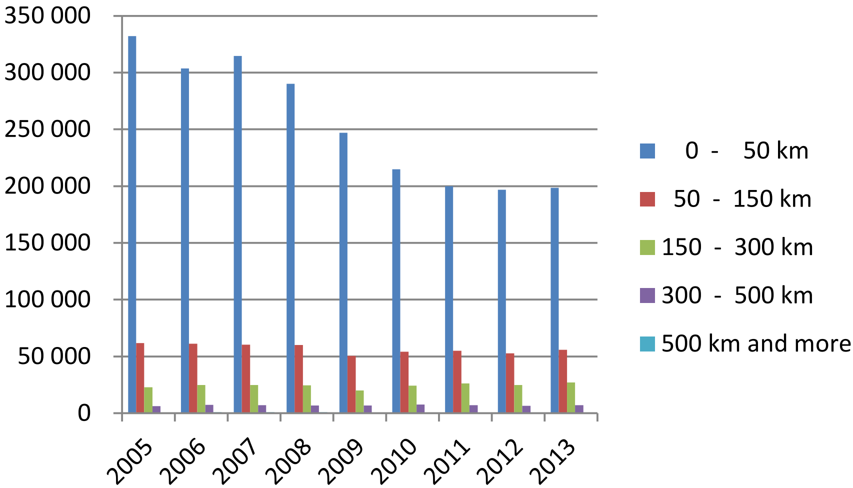

Fig. 3: Overview of national road freight transport (km)

Source: Ministry of Transport, CSO

The Figure shows that most goods on our roads are transported to a distance 0-50 km. Although every year decreases it still has the largest share of distance national transport of goods. Second is distance of 50 to 150 km. That has stagnated since 2005 and is not extremely exerted. Moderate growth was recorded in transportation to 300 km. In 2013 the increase was 19% compared with 2005. The distance 300-500 km and more have a tendency to stagnation

It is also interesting comparison of how Czech Republic stands in comparison with other countries. For comparison, were chosen by some EU countries and that France, Italy, Lithuania, Germany, the Netherlands, Poland, Austria, Slovakia and Hungary. The Figure 4 shows an overview of goods transport by road.

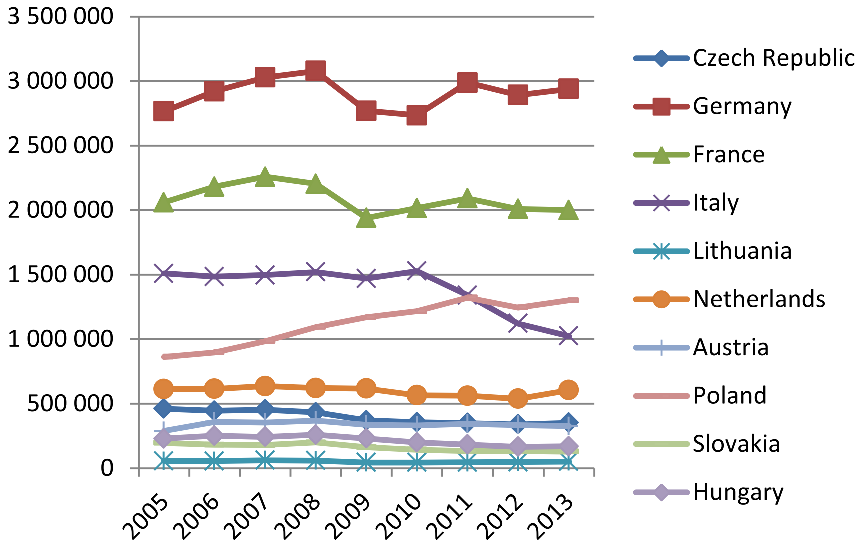

Fig. 4: Overview of transport of goods by road (tonnes)

Source: Eurostat

According to Figure 4 we can say that from selected countries is the smallest number of tonnes transported by road in Slovakia and Lithuania. The Czech Republic is represented in fifth. The most of tonnes recorded in Germany and France. Italy is third, where in 2009 is the decline in values, because was measured only one quarter, and not whole year. We can monitor the decrease in 2009 for all countries except Poland. Here is an increase compared to 2008 by 7 %.

4 Conclusion

We can say about the freight transport that is very closely connected with the economy of our country. The change came after 1989 and our economy has changed. The market is now focused more on services and international trade. This also increased the share of road freight transport and vice versa rail freight performance decreased. The above figures shows that road transport has a share of around 75 % on freight transport performance. A similar trend is in the Czech Republic and other EU countries. However, we must not forget what effects road freight transport entails. The high accident rate, environmental pollution, worsening quality of infrastructure and heavy traffic on our roads and highways.

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THE COMPARISON OF THE SELECTED METHODS FOR DEMAND FORECASTING AND THEIR APPLICATION IN THE FOOD STORES WITH THE EMPHASIS ON SUSTAINABILITY

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Abstract: All participants in the supply chain want to be maximally effective. It is possible to achieve this goal using the quality and elaborate process of demand forecasting. It is very important especially in a food industry, because this market segment is very unique and it has many significant specifics.

Keywords: inventory management, demand forecasting, food industry, moving average, exponential smoothing, Holt´s method, sustainability.

1 Introduction

Generally, the inventory management is very important in terms of a company because it affects satisfaction of costumers. It is essential to hold

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stocks of right items in a right quality and quantity. It does not matter whether it is some material, semi-finished products or finished products. The problematic of the inventory management goes through the whole supply-chain, because inventories can be found on all places within the logistic chains. The key is a satisfaction of customers who are at the end of the logistic chain.

The food industry has a large number of specific features and characteristics which make it necessary to approach this segment in a quite unique way, because it is not possible to apply the same principles used in other sectors. Absolutely crucial is the fact that the sale of all food products is limited by their expiration which corresponds in the most cases with the time when food products can be offered to customers. Products are unsalable after their expiration and such products can cause losses for a company. These products become objects of the reverse logistics.

The most problematic group of food products is the group with a very short period of its life called perishables. This group includes for example: pastry, dumplings, fresh milk, baguettes, sandwiches, vegetables, fruits, meat, poultry and fish.

The most critical products from perishables are pastry, because this group of food is highly sought by customers, but it has the durability about 24 hours in a case of unpacked pastry. The unpacked pastry is ordered only by food stores. The responsibility for the optimal order and potential corrections are just on food stores.

The correct demand forecasting is very important for companies especially if they use some forecasting methods. Companies can reduce the difference between real and predicted demand after applying a suitable method.

This article deals with the comparison of the selected methods for demand forecasting and their application in the food stores with the emphasis on sustainability. This article compares these methods which are applicable for demand forecasting and these are: subjective estimation, moving average, exponential smoothing and Holt´s method. Every method will be used for demand forecasting for the next period. Then there will be compared the real demand with the predicted demand.

The second chapter of this article deals with the research methodology, where will be presented every used exact prognostic methods and its application. Then there will be presented some methods for the evaluation of the prediction accuracy. The third chapter deals with the application of methods from the second chapter in the real operation of the company and it consists of some calculations. The last chapter deals with the comparison of the selected exact methods for demand forecasting with the accent on the identification of strengths and weaknesses of each used method. The conclusion will present some options for the improvement of demand forecasting processes and other applicable methods.

2 Research methodology

For all the companies participating in the segment of food industry it is very important to correct demand forecasting, because they are able to satisfy their customers with minimal losses. [1, 2]

Ways to predict demand is quite a lot, while they may be divided into two basic groups on ways intuitive and exact. [3]

In the Table 1, there is the overview of methods for demand forecasting by Jirsák et al. (2012).

Tab. 1: The overview of the selected methods for demand forecasting

Category	**Subcategory**	**Method**
Intuitive methods		Method of analogies
		Brainstorming
		Delphi method
		Subjective estimation
Exact methods	Time series	Moving average
		Exponential smoothing
		Holt´s method
	Causal methods	Regression analysis
		ARIMA

Source: [4]

2.1 Intuitive methods

Among the intuitive methods we include: method of analogies, brainstorming or using the Delphi method. All of these methods can be used if we present a new product on the market in specific promotions for new customers etc. [4]

It is therefore always a situation when there are no continuity conditions affecting demand from the past to the present. [5]

2.2 Exact methods

According to Jirsák et al. (2012) the intuitive methods are compared with the exact methods based on mathematical-statistical system through which they involve the processing of data about demand from the last year and their extrapolation into the future. [4]

For our research we use these methods which will be presented in detail in the next subchapters and which will be compared in the last chapter:

- subjective estimation,
- moving average,
- exponential smoothing,
- Holt´s method.

2.3 Subjective estimation

The method of the subjective estimation is based on the decision of employee of a food store about the size of order. This employee uses this information in his decision-making process: the number of sold units in the last period, time when was the last unit sold and how many units remain.

This employee does not use any mathematical, prognostic or statistical tools. The advantage of this method is employee's knowledge of the operation in such food store. The significant disadvantage is the inability to find some trend in the demand.

2.4 Moving average

The moving average method is very simple and it is calculated as an average demand for exact amount of time-period (known as n) from the past. The oldest time-period is excluded and the new time-period (known as D_{t-n}) is added. Predicted value of demand F_t is equivalent to the relation Eq. 1. As an issue of this method is considered that this method is not able to express any trend. [6]

The explanation of the variables in the relation Eq. 1 is:

- n – number of the period [-],
- F_{t+1} – predicted value of demand [-],
- D_t – youngest period [-],
- D_{t-n} – oldest period [-].

$$F_{t+1} = \frac{1}{n} \times \left(D_t + D_{t-1} + ... + D_{t-n} \right) \quad (1)$$

2.5 Exponential smoothing

Exponential smoothing removes some shortcomings moving average in a way which allows amplifying effect of the youngest period at the expense of the oldest. Predicted value of demand F_t is equivalent to the relation Eq. 2. Problem is the fact that it does not cover the trend component enough. [7]

The explanation of the variables in the relation Eq. 2 is:

- α – gain coefficient [-],
- F_{t+1} – predicted value of demand [-],
- F_t – predicted value of demand on the last period [-],
- D_t – real demand in the last period [-].

$$F_{t+1} = F_t + \alpha \times \left(D_t - F_t \right) \quad (2)$$

2.6 Holt´s method

The method of exponential smoothing compared to the Holt’s method is not separate the trend of demand. Aligning the basic component of demand responsible Eq. 3. Aligning of the trend of demand responsible Eq. 4. Predicted value of demand F_{t+k} is equivalent to the relation Eq. 5. Problem, however, is the fact that it does not cover the seasonal component enough [8].

The explanation of the variables in the relation Eq. 3, 4, 5 is:

- α – gain coefficient [-],
- β – gain coefficient of the trend [-],
- k – period [-],
- F_{t+k} – predicted value of demand [-],
- B_t – predicted value of demand on the last period [-],
- D_t – real demand in the last period [-].

$$F_{t+k} = B_t + k \times T \quad (3)$$

$$B_t = \alpha \times D_t + (1-\alpha) \times (B_{t-1} + T_{t-1}) \quad (4)$$

$$T_t = \beta \times (B_t - B_{t-1}) + (1-\beta) \times T_{t-1} \qquad (5)$$

2.7 Research technique

We have chosen the food store of a discount chain which is focused on the sale of food and goods of daily use. We focused on the most critical products from perishables. It is the group of pastry, because this group of food is highly sought by customers, but it has the durability about 24 hours in a case of unpacked pastry. The unpacked pastry is ordered only by food stores. The responsibility for the optimal order and potential corrections are just on food stores. We have chosen the most critical item in the terms of losses – unpacked bread.

Then we got some information about selling of this item between 1. 2. 2015 and 31. 3. 2015. This information is presented in the Table 2.

Tab. 2: The information about the sale of an unpacked bread (pieces)

Date	Sale	Date	Sale	Date	Sale	Date	Sale	Date	Sale
1. 2.	42	13. 2.	89	25. 2.	51	9. 3.	57	21. 3.	74
2. 2.	46	14. 2.	71	26. 2.	59	10. 3.	46	22. 3.	46
3. 2.	32	15. 2.	50	27. 2.	87	11. 3.	48	23. 3.	48
4. 2.	52	16. 2.	52	28. 2.	67	12. 3.	50	24. 3.	39
5. 2.	57	17. 2.	38	1. 3.	45	13. 3.	87	25. 3.	45
6. 2.	82	18. 2.	54	2. 3.	53	14. 3.	72	26. 3.	60
7. 2.	66	19. 2.	62	3. 3.	36	15. 3.	53	27. 3.	75
8. 2.	59	20. 2.	92	4. 3.	54	16. 3.	47	28. 3.	64
9. 2.	56	21. 2.	70	5. 3.	54	17. 3.	36	29. 3.	46
10. 2.	48	22. 2.	48	6. 3.	98	18. 3.	47	30. 3.	47
11. 2.	55	23. 2.	49	7. 3.	70	19. 3.	57	31. 3.	45
12. 2.	55	24. 2.	40	8. 3.	62	20. 3.	91		

Source: authors based on [9]

We applied methods described above (subjective estimation, moving average, exponential smoothing and Holt´s method) for demand forecasting of an unpacked bread for the period between 2. 4. 2015 and 30. 4. 2015.

3 Application

This chapter consists of forecasting method application for the sale of an unpacked bread during the period between 2. 4. 2015 and 30. 4. 2015.

3.1 Subjective estimation

In the Table 3 there are presented values of forecasted sales by employee's subjective estimation in the food store. This employee used this information in its decision-making process: the number of sold units in the last period, time when was the last unit sold and how many units remained.

This employee did not use any mathematical, prognostic or statistical tools. The employee was limited by the condition about the minimal number in the box which is three pieces.

Based on his subjective estimation the employee ordered between 2. 4. and 30. 4. 2015 totally 1635 pieces of an unpacked bread.

Tab. 3: The forecasting values of sales by the subjective estimation (pieces)

Date	**Sale**	**Date**	**Sale**	**Date**	**Sale**	**Date**	**Sale**	**Date**	**Sale**
1. 4.	(48)	7. 4.	45	13. 4.	48	19. 4.	42	25. 4.	63
2. 4.	81	8. 4.	45	14. 4.	39	20. 4.	48	26. 4.	45
3. 4.	99	9. 4.	60	15. 4.	42	21. 4.	39	27. 4.	54
4. 4.	90	10. 4.	72	16. 4.	63	22. 4.	45	28. 4.	42
5. 4.	69	11. 4.	57	17. 4.	66	23. 4.	60	29. 4.	45
6. 4.	42	12. 4.	45	18. 4.	60	24. 4.	75	30. 4.	54

Source: authors based on [9]

3.2 Moving average

The Table 4 shows values of forecasted sales by the moving average. These calculations were taken in Microsoft Office Excel by the function Data Analysis. Every value was rounded to whole numbers.

The application of this method proposed some orders in the total amount of 1 675 pieces.

Tab. 4: The forecasting values of sales by the moving average (pieces)

Date	**Sale**	**Date**	**Sale**	**Date**	**Sale**	**Date**	**Sale**	**Date**	**Sale**
1. 4.	xx	7. 4.	74	13. 4.	72	19. 4.	58	25. 4.	45
2. 4.	44	8. 4.	62	14. 4.	80	20. 4.	77	26. 4.	55
3. 4.	39	9. 4.	57	15. 4.	60	21. 4.	81	27. 4.	73
4. 4.	42	10. 4.	52	16. 4.	51	22. 4.	59	28. 4.	77
5. 4.	54	11. 4.	51	17. 4.	45	23. 4.	48	29. 4.	56
6. 4.	69	12. 4.	55	18. 4.	46	24. 4.	44	30. 4.	49

Source: authors

3.3 Exponential smoothing

Table 5 presents values of forecasted sales by the exponential smoothing. These calculations were taken in Microsoft Office Excel by the function Data Analysis. The gain coefficient was determined on the value 0.8. Every value was rounded to whole numbers.

The application of this method proposed some orders in the total amount of 1 591 pieces.

Tab. 5: The forecasting values of sales by the exponential smoothing (pieces)

Date	**Sale**	**Date**	**Sale**	**Date**	**Sale**	**Date**	**Sale**	**Date**	**Sale**
1. 4.	xx	7. 4.	52	13. 4.	54	19. 4.	54	25. 4.	55
2. 4.	42	8. 4.	55	14. 4.	61	20. 4.	56	26. 4.	54
3. 4.	42	9. 4.	56	15. 4.	63	21. 4.	63	27. 4.	55
4. 4.	40	10. 4.	56	16. 4.	60	22. 4.	64	28. 4.	61
5. 4.	42	11. 4.	54	17. 4.	59	23. 4.	61	29. 4.	62
6. 4.	45	12. 4.	54	18. 4.	54	24. 4.	58	30. 4.	59

Source: authors

3.4 Holt´s method

Table 5 presents values of forecasted sales by Holt´s method. The application of this method proposed some orders in the total amount of 1 674 pieces.

Tab. 6: The forecasting values of sales by Holt´s method (pieces)

Date	Sale	Date	Sale	Date	Sale	Date	Sale	Date	Sale
1. 4.	xx	7. 4.	70	13. 4.	82	19. 4.	59	25. 4.	47
2. 4.	46	8. 4.	62	14. 4.	75	20. 4.	86	26. 4.	56
3. 4.	34	9. 4.	57	15. 4.	55	21. 4.	75	27. 4.	81
4. 4.	47	10. 4.	49	16. 4.	51	22. 4.	54	28. 4.	72
5. 4.	55	11. 4.	52	17. 4.	39	23. 4.	48	29. 4.	51
6. 4.	77	12. 4.	54	18. 4.	49	24. 4.	40	30. 4.	51

Source: authors

3.5 Real demand

In the Table 7 there is presented the real demand in the period between 2. 4. and 30. 4. 2015. We have to say, looking at the proposed orders that the biggest number of orders (for a whole month) was designed by the moving average (1 675 pieces) and Holt´s method (1 674 pieces). The minimum number of orders was designed by the exponential smoothing (1 591 pieces).

Tab. 7: The real demand (pieces)

Date	Sale	Date	Sale	Date	Sale	Date	Sale	Date	Sale
1. 4.	xx	7. 4.	38	13. 4.	42	19. 4.	37	25. 4.	57
2. 4.	75	8. 4.	44	14. 4.	36	20. 4.	62	26. 4.	40
3. 4.	123	9. 4.	50	15. 4.	41	21. 4.	28	27. 4.	58
4. 4.	82	10. 4.	67	16. 4.	53	22. 4.	40	28. 4.	35
5. 4.	66	11. 4.	52	17. 4.	75	23. 4.	55	29. 4.	41
6. 4.	67	12. 4.	43	18. 4.	53	24. 4.	69	30. 4.	52

Source: authors based on [9]

In the next chapter there will be compared every used method for the demand forecasting by calculation of these parameters: Mean Forecast Error, Mean Absolute Deviation, Mean Absolute Percentage Error and Mean Square Error.

4 Comparison of selected exact methods for the demand forecasting

This chapter consists of the evaluation of the prediction accuracy by these parameters: Mean Forecast Error, Mean Absolute Deviation, Mean Absolute Percentage Error and Mean Square Error.

The explanation of the variables in the relation Eq. 6, 7, 8, 9 is:

- n – number of the period [-],
- D_t – real value of demand [pieces],
- F_t – predicted value of demand [pieces].

4.1 Mean Forecast Error (MFE)

The inaccuracy of the prediction is determined by the average sum of differences between the real demand and the predicted demand. The disadvantage of this method is the reduction of the inaccuracy of prediction by positive and negative deviations (Eq. 6).

$$\mathrm{MFE} = \frac{1}{\mathrm{n}} \times \sum_{i=1}^{n} \left(D_t - F_t\right) \tag{6}$$

4.2 Mean Absolute Deviation (MAD)

This inaccuracy of the prediction is determined by the average sum of the differences between real demand and predicted demand in the absolute value. In our case the result of this method is in pieces (Eq. 7).

$$\mathrm{MAD} = \frac{1}{\mathrm{n}} \times \sum_{i=1}^{n} \left|D_t - F_t\right| \tag{7}$$

4.3 Mean Absolute Percentage Error (MAPE)

The mean absolute percentage error is calculated as a percentage of the average sum of the absolute value of the share of differences between real demand and predicted demand. The result of this method is in percentage (Eq. 8).

$$\mathrm{MAPE} = \frac{100}{\mathrm{n}} \times \sum_{i=1}^{n} \left| \frac{D_t - F_t}{D_t} \right| \tag{8}$$

4.4 Mean Square Error (MSE)

This inaccuracy of the prediction is determined by the average sum of the second power of the differences between real demand and predicted demand (Eq. 9).

$$\mathrm{MSE} = \frac{1}{\mathrm{n}} \times \sum_{i=1}^{n} \left(D_t - F_t\right)^2 \tag{9}$$

4.5 The evaluation of the prediction accuracy

In the Table 8 there is presented the comparison of the prediction accuracy by these parameters: Mean Forecast Error, Mean Absolute Deviation, Mean Absolute Percentage Error and Mean Square Error.

Method of the subjective estimation is the best in comparison with other used methods. This method is the best within the parameter MAD, MAPE and MSE. The evaluation of the subjective estimation is not bad within the parameter MFE.

Method of the moving average and Holt´s method were the worst from used methods identically in two parameters (method of the moving average within parameters MFE and MAPE and Holt´s method within parameters MAD and MSE). Method of the exponential smoothing was the best within parameter MFE and within the other parameters this method did not have bad results.

Tab. 8: The evaluation of the prediction accuracy

Parameter	**Subjective estimation**	**Moving average**	**Exponential smoothing**	**Holt´s method**
MFE [-]	-1,86	-3,24	-0,34	-3,21
MAD [pieces]	7,10	21,79	17,66	21,90
MAPE [%]	13,10	40,94	16,43	21,51
MSE [-]	81,52	795,03	561,72	806,66

Source: authors

The result of this evaluation and comparison is that the best method in our case study was the subjective estimation. It is caused especially by Easter which was from the perspective of the food store from 1. 4. to 6. 4. Sales and revenues were larger. The big influence had the subjective estimation thanks to this occasion.

The regression analysis will be better for this special occasion as Easter, Christmas, new marketing action or some influence of market's competition. The regression analysis has over other methods the advantage of being able to capture all the variables that operate on demand and can be quantified. In this special occasion other used methods have failed.

5 Conclusion

This article deals with the problematic of demand forecasting in food stores. This article compared some possibilities for demand forecasting in the real operation with usage of these methods: subjective estimation, moving average, exponential smoothing and Holt´s method. The best method from our comparison is the subjective estimation, because it is caused especially by Easter which was from the perspective of the food store from 1. 4. to 6. 4. Easter is connected with larger sales and revenues, marketing events and special promotion activities.

The preferable prognostic method will be the multiple regression analysis using ANOVA, F-test and T-test, because this method can affects all links between all variables. This method is better in the case of special occasions as Easter, Christmas etc.

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Summary: This article deals with the problematic of demand forecasting in the food stores. This article compared some possibilities for demand forecasting and found a suitable method for demand forecasting in the food industry.

APPLICATIONS OF UNCONVENTIONAL DESIGN OF THE SUPERSTRUCTURE ON THE RAILWAY INFRASTRUCTURE OF THE SLOVAK REPUBLIC

Libor Ižvolt[1], Michal Šmalo[2]

Abstract: Modernization of railway infrastructure in the Slovak Republic is still current topic and is an ideal opportunity for the application of advanced systems and structural elements of railway track construction, such as slab track. In the first part, the paper deals with the origin and reasons to realize an unconventional type of the structure of railway superstructure, which is referred to as a slab track and there are characterized specific structures of slab track applied in the ongoing modernization of the railway infrastructure in the Slovak Republic. In the second part, the paper deals with the methods of diagnostics of the unconventional design of the railway superstructure around portals of tunnel Turecky vrch, where Department of Railway Engineering and Track Management deals with monitoring of sections of slab track *Rheda 2000®* and transition areas between slab track structure and standard structure of railway superstructure.

Keywords: railway track, track superstructure, slab track, diagnostics.

1 Introduction

A track with the standard structure of railway superstructure is marked such railway track where track skeleton is stored in the gravel ballast. In the case of high operating and axle load and introducing higher speeds there are proved limit possibilities of standard structure of superstructure, particularly in its ability to guarantee the long-term moving rail vehicles operationally safe, reliable and easy-to-maintain track.

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The standard structure of railway superstructure is characterized by "floating" placing of track skeleton, which causes the growth of dynamic forces during each passage of a rail vehicle or train that cause gradual degradation of track geometry, which leads to turbulent ride of rail vehicles. This phenomenon increases with increasing track speeds and thus increases the cost of maintaining and share of closure of traffic tracks, which reduce the attractiveness of rail infrastructure for its users – goods and passengers. It is sufficient, however, if there is only replaced the weakest element of standard railway superstructure in the track, and this is the gravel, with other more appropriate component which does not show particular plastic behaviour. Such substitute is a structure, where the track skeleton is concreted (monolithic structure) or fixed on a concrete or asphalt supporting layer (layered structure); structural solution, which is referred to as unconventional railway superstructure. This concept of track is currently referred to as a slab track (hereinafter referred to as "ST"), in which the required flexibility of the superstructure for the system wheel / rail is secured using elastic elements disposed between a rail and rail support or under a rail support. The term "ST", as defined in [10], represents the structure of railway superstructure, in which a spread function of railway ballast is replaced by reinforced materials, and which is placed on a concrete or asphalt supporting slab. The term slab track is also often replaced by the term ballastless railway superstructure. This concept, however, is useful only if the track ballast is replaced with a material which is resistant to deformation, but not if ballast for slab track can be used for other tasks, for example, as protection against UV radiation, required resistance against longitudinal movement of sleepers, etc.

2 The possibility of applying the structure of slab track

The essential reason for building unconventional structure of railway superstructure – a slab track – is the fact that it was set up to give high stability of the track, which is associated with the peaceful movement of vehicle and thus simultaneously driving comfort for the passenger and the operator with significantly lower maintenance requirements for the track hence lockout and finance. This driving comfort can be obtained, in case of standard structure of railway superstructure, only with very high operating costs [2].

Besides these principal profits, there are still other additional profits of unconventional structure of railway superstructure, including [6]:

- lower investment costs using more suitable parameters (possible higher cant), which are associated with smaller radii, which can promote the ideas of a parallel routing of highways, smaller geometric cross sections of ground body, bridges and tunnels,

- smaller loads of the structure of earthwork due to a better distribution of loads of supporting layer; misconception that the construction of slab track in the earthwork must be made „something more“ compared to standard structure is not confirmed, it is exactly the opposite,
- two to three times longer service life compared with the standard structure of railway superstructure, which is associated with the life cycle costs of the track,
- greater operational safety by increasing cross-resistance, no effects of track temperature are expected,
- easy deployment of linear brakes with vagabond currents as operational brakes and the greater cost savings for braking train sets,
- less wear of vehicles by permanently maintaining the track position,
- no dangerous swirling gravel,
- no problems arising with the need for removal undesirable vegetation,
- there is an increase of operational capacity and reduction of potential accidents by less maintenance.

As every engineering structural system, as the so-called slab track has not only its advantages, but disadvantages which we calculate:

- higher investment costs,
- longer construction period,
- limited possibility of adapting to changed operating conditions,
- higher noise emissions,
- expensive and time consuming renewal of track.

According to current experience it can be stated that the costs of maintenance and renewal of railway track with inbuilt structure of ST have been decreasing over a long period since the revision, as well as the cleaning of ballast can be omitted and renewal of the track can be carried out in longer intervals. Building a railway track with the structure of ST can reduce the following cost items during its operation [7]:

- track geometry revisions,

- elimination of errors and deficiencies of projected track geometry,
- vegetation in the track,
- revision of the track – it is not necessary to implement,
- cleaning of track ballast – it is not necessary to implement,
- renewal of the track – implemented in a longer time interval.

It means that it is not necessary to perform more than two thirds of annual maintenance costs on the railway track with the ST structure! At the same time the service life of ST is considerably higher compared to standard structure of superstructure. In contrast, however, a better quality ST requires higher initial investment costs than ballasted track. From an environmental perspective, further development and precise structure of ST should focus to be:

- less noisy,
- emit less vibration in the track environment,
- environmentally friendly,
- capable of recycling.

The structure of ST requires common concentration of legislators, operators and developers. Although the qualities of ST structure do not currently match capacities of ballast in terms of noise emissions and vibrations, the structure of ST disposes of unique quality characteristics that must be taken into account in the decision-making process for the application of railway.

In general, the present structure of ST applies mainly to high-speed lines and lines that have high operating load, where the cost of track maintaining with the standard structure of superstructure grows strongly. At the same time, however, this structure also promotes the upgraded sections of the standard tracks (track speed up to 160 km/h); mainly to the sections in tunnels.Furthermore, the use of the ST has a positive impact on the size of the investment costs for setting up the tunnel, given the smaller cross-section, in the case of its new building, or excluding freight tunnel extension, in case of its electrification on the existing tracks. Subgrade without a settlement is offered for application of the ST structure and bridges and therefore the application of this structure is also possible in these track sections. The structure of ST is, however, increasingly applied for urban tracks – trams or subway lines.

3 The applications of slab track in Slovak railway infrastructure

Unlike the developed railway administrations, the structure of ST was not ever applied in administration of Slovak Railways for many years. Historically, the first section of ST on the Slovak railway tracks was built in Bratislava Tunnel no. 2, located in the track section Bratislava – Lamac – Bratislava main station. The second section of ST was built also in connection with the construction of the tunnel, and new tunnel Turecky vrch, which is located on the modernized section of track Nove Mesto nad Vahom – Puchov. While last application of ST structure on the Slovak railway track is in Bratislava Tunnel no. 1 (in operation since the end of 2014).

3.1 The structure of slab track in Bratislava Tunnel no. 2

The ST structure of *SATO* type was built in Bratislava Tunnel no. 2 (Fig. 1) in the period from 09/2007 to 02/2008, in the second track of railway section Bratislava - Lamac - Bratislava city railway station according to project documentation developed by company PRODEX Ltd. and ThyssenKrupp, Road Construction Slovakia Ltd. [1]. Both Bratislava (Lamac) tunnels are the oldest tunnels in Slovakia and, moreover, they are located in important railway line to Vienna or Kuty. The section of Bratislava Tunnel no. 2, the operation of which was started in 1902 and whose length is 595.870 m, is apart from Bratislava Tunnel no. 1 directionally led in two right curves of transition curve R = 525 m (with a cant of 49 mm) and R = 600 m (with a cant of 43 mm) with interline of 315.805 m, while its longitudinal gradient is 6.7 ‰. The reason for the reconstruction are the results of the technical assessment made in 2006, in which it was stated that its isolation is significantly disturbed, what causes water penetration and due to moisture loss of the insulating ability of the track, and at the same time, considering the age of railway superstructure, the fastening of rails to wooden sleepers is also in unsatisfactory condition.

Fig. 1: Bratislava Tunnel no 1. (on the left) a č. 2 (on the right) – portal Bratislava main station

In connection with the reconstruction of the tunnel, in terms of horizontal and vertical alignment, there have been no substantial changes to the original state. These were only specified in the ST draft on the basis of detailed geodetic survey and subsequently directional conditions with respect to vertical track no. 2 were designed for speed V = 60 km/h. In order to keep the values projected within standard tolerances allowed, after laying tracks on the asphalt roadway, there were used polyethylene pads and angled inserts in the tunnel. The original structure of superstructure and its fastening in the tunnel was replaced with ST on the steel sleepers of shape "Y" ThyssenKrupp and length of 599.570 m, with new rails 60 E1 and flexible fastening using clips Vossloh Skl 15. Continuous steel sleepers are of type St 98 Y FF-No-650-60 and transition sleepers at the point of connection to transition reinforced concrete slabs before and after the tunnel are type of St 98 Y FF-Üre-650-60, or St 98 Y FF-Üli-650-60. Steel sleepers of shape "Y" are embedded in the underlying asphalt slab of thickness 150 mm and provided with corrosion-proofing.

Transitions from asphalt ST placed in the tunnel to ballast before and after tunnel are realized by two reinforced concrete slabs of length 15 m, width 3.20 m and thickness of 0.400 m. Total structural height of these slabs, including tracks and inbuilt sleepers, is 0.632 m; axial distance of reinforced concrete sleepers embedded in the slabs is 0.650 m. To ensure a smooth transition to ballasted track, there were used additional bracing rails 60 E1, which are attached to the sleepers embedded in reinforced concrete slabs of length 5 m and modified sleepers B93 stored in the ballast of length 10 m. After transition slabs, there follows standard ballast, first with modified reinforced concrete sleepers B93 then reinforced concrete sleepers B 91 S/1 and finally wooden sleepers - all divided to UIC. New rails (excluding transition) are of shape 60 E1; they were delivered in the length of 120 m and welded to double length of the resistance and after assembly to spot of termite. Finally, the track is welded to the contactless track using closing welds in the whole section. New railway ballast, of fractions 31.5/63 mm of thickness about 0.300 m below the bearing surface of sleepers, is embedded throughout the section; banquets are of stone grit of fraction 4/16 mm.

3.2 The structure of slab track in Bratislava Tunnel no. 1

Construction of ST *ÖBB-PORR* was built in the period from 10/2014 to 12/2014. The aim of modernization of track no. 1 in Bratislava Tunnel (Fig. 1) was to improve technical condition of railway superstructure. Unsatisfactory condition of the supestructure resulted from complicated maintenance of fastening on wooden sleepers in poor condition (cracks and rotten material of sleepers). There were also reconstructed all associated parts of the tunnel tube. The modernization involved elimination of leaks in the tunnel where water percolating through arch caused disturbances of catenary and icicles during winter.

Project documentation was prepared in 2012 by Prodex, s.r.o., changes in order to optimize technical solutions and technological processes due to changes in regulations and standards was carried out by TAROSI c.c., s.r.o. The construction of supestructure consist of prefabricated reinforced concrete slabs *ÖBB-PORR*, which are monolithically jointed with the invert of the tunnel. Reinforced concrete slab have dimensions of 4 760 x 2 400 x 160 mm and each have eight fastening points at a distance of 600 mm. Fastening points are made for system UIC 60 E2 in inclination of 1:40 and fastening Vossloh W 300-1. There are 124 slab boards fitted on invert. The construction is equiped with steel mandrels with a diameter 20 mm and length of 300 mm to connect levelling concrete layer and invert of the tunnel.

Transition areas between ST construction and ballasted track is according to present state (max. speed up to 60 km/h) consist of a combination of ballast glueing and track skeleton with concrete sleepers of type ZPSV. Tranistion area around portal Lamac with a length of 18.020 m is made of 30 sleepers BV 08. In the area of Bratislava main station portal ST structure is located near to switches of station head and according to spatial conditions and high rigidity of the superstructure is realized by length of 5.592 m with 7 concrete and 2 wooden sleepers. Ballast (friction 32/63 mm) has been glued by two-component resin – the first phase was realized during maintenace works (underneath surface of the sleeper), the second phase will be realized after year of operation (sleeper crib and by the end of sleeper).

3.3 The structure of slab track in the tunnel Turecky vrch

In connection with the modernization of the V. trans-European corridor Venice – Trieste / Koper – Ljubljana – Budapest – Chop – Lvov; wit the branch Va passing through the Slovak Republic in the section Bratislava – Zilina – Kosice – Cierna nad Tisou – Chop, there was proposed by the project contractor (REMING Consult, a.s.) and approved by the client (GR ZSR) the structure of ST of type *Rheda 2000*® within the construction of Slovak Railways, Modernization of railway track Nove Mesto nad Vahom – Púchov, km 100.500 – 159.100, object 24-32-01 Nove Mesto nad Vahom – Trencianske Bohuslavice. The reasons why the subjects in question decided to build unconventional structure of superstructure, although it is not the application to the speed or high speed track, where such structure has a priority use, there was the fact that there was designed new railway tunnel Turecky vrch in terms of Slovak Railways after more than 50 years. The location of the tunnel, together with the structure of portals and retaining walls addresses the issue of inevitable conflict of spatial interests between the modernization of the track and Protected landscape area (PLA) Turecky vrch. After analyzing alternative solutions of the track alignment around Turecky vrch in the current railway track and new route – tunnel variant – the builder decided for tunnel variant. It is considered that the change of track alignment through the tunnel will increase the track speed and minimize negative impacts on PLA. Another advantage of tunnel variant is that the construction of tunnel did not restrict rail transport, because the tunnel was dug outside the original track [4].

In view of the fact that in the case of necessary maintenance, or future repair of reconstruction works, the implementation of these works is complicated in the tunnel and also due to the reduction of the amount of rock excavated from the tunnel portal, which did not have further use; the structure of ST, which has a lower structural thickness as it would be when using a standard structure of railway superstructure, would be the appropriate solution.

Modernisation of already mentioned track section started in September 2009 and was completed in May 2013. The railway tunnel, which is part of the track section, is the first tunnel in Slovakia, which is designed and implemented according to the technical specifications for interoperability for conventional tracks, it corresponds to the latest trends in tunnel and railway construction and should become a model for all future tunnels that will be built in Slovakia within the modernization of railway tracks. Double-track tunnel is designed to passable diameter of UIC C with axial distance of tracks 4 200 mm. The total length of the tunnel Turecky vrch in the axis is 1 775 m. Tunnel tube of the section excavated has a length of 1 738.5 m and is followed by excavated sections of the south portal of length 25 m and the north portal in the length of 10 m. The entire length, including the portal sections, includes integrated cross-section of double-track tunnel with light radius of tunnel tube of 6.1 m, there are just two chambers for stretching traction supply with extended cross-section in the middle of the tunnel. Double-track in the tunnel is designed for the speed of 200 km/h with arcs of a radius of 2 000 m.

The structure of ST was designed, as already mentioned, due to the reduction of the area of cutting and also durability and fixation of the track position and its minimum maintenance during the operation. The structure of ST of *Rheda 2000®* system passes through different types of track subgrade. It begins before the south portal and passes through the entire tunnel. Then, the ST structure continues on bridges and earthwork behind the north portal. The structure of ST itself also includes transition areas on both ends, which ensure smooth transition (smooth change of stiffness) of rigid structure of ST, whose total length is 2 280.145 m (it starts in new km 102.459 825 and ends in new km 104.740 000), where its particular parts are: transition area – 45.175 m, tunnel – 1 775.000 m, bridges – 34.770 m and earthwork – 425.200 m.

The structure of ST of *Rheda 2000®* system is has been verified by years of smooth operation on the German railways. Due to the complex directional conditions and bridges located immediately behind the north portal, the structure of ST is established not only in the tunnel itself, but it almost continues to the railway station Trencianske Bohuslavice on the north side of the tunnel. Total length of the ST structure is up to 4 480 m. Due to the diversity of subgrade stiffness (tunnel bottom, bridge and railway substructure of ground body), the system of the ST structure is modified, which is reflected in the thickness of concrete structure and also in its reinforcement [3].

The structure of ST of *Rheda 2000®* system is made up of its own monolithic structure of ST, which is divided in its track section in question into 3 basic types:

- in tunnel: monolithic reinforced concrete slab of variable thickness (according to track elevation) – concrete class C 35/45 with concreted twin-block sleepers, lying on the concreted bottom of the tunnel tube (anchored with the underlying slab of the tunnel bottom in the place near portals,

- on earthwork: monolithic reinforced concrete slab of constant thickness 240 mm - concrete class C 35/45 with concreted twin-block sleepers (also called TCL), lying on a monolithic slab of plain concrete class C 12/15 of constant thickness of 300 mm (also called HBL). Track cant in arcs consists of an inclined plain of substructure. There is a TCL slab anchored to HBL slab in the place between the northern portal of the tunnel and bridge over the brook Bosacka,
- on bridges – Fig. 2: monolithic reinforced concrete slab of variable thickness (according to track elevation) - concrete class C 35/45 with concreted twin-block sleepers, lying on the separation layer Styrodur + foil on the construction of the bridge.

Rails used in the system of the ST are the same as in the case of standard superstructure, and the shape of 60 E2, welded into countinuously welded rail track. The rails are fastened to the structure of ST using the system Vossloh 300-1U. It is non-sole-plate flexible fastening system, similar to the normal rails on railway sleeper. Standard distribution of double-block sleepers, which were concreted in monolithic slab, has a value of 650 mm. This value was adjusted as necessary (reduced) only on bridges and areas where the location of dilatation cracks in the intersleeper spaces is needed. Double-block sleepers are a type of B 355.3 U60M of manufacturer ZPSV a.s. The transition of the structure of ST to standard structure of railway superstructure with ballast consists of reinforced concrete tubs of length of 20 m, filled with ballast of variable thickness below the bottom edge of the sleeper BP-3 (250-350 mm), lined with subgravel elastic mat. The space between the tracks in the tunnel and the bridge consists of infill concretes, outside side of the structure of ST on earthwork is filled up with ballast of fraction 31.5/63 mm [5].

The critical place of the ST structure is transition area between standard structure of superstructure and ST. In terms of dynamic effects it is a place with a change in stiffness and thus there was paid a special attention to this place. There was used a new type of transition area using standard components of railway superstructure, while without the need for stabilization of the superstructure within the transition area of bonding. The structure consists of reinforced concrete tub of concrete C 30/37 of length 20 m. Thickness of ballast under the sleepers decreases in the direction to the structure of ST, thus stiffness of the subgrade gradually increases. The bottom and walls are lined with elastic mat, whose task is to simulate the deformation properties of the soil of earthwork. There is water and moisture isolation below the elastic mat. Draining rainwater ensures both the longitudinal tub gradient and drainage facilities.

Fig. 2: Tunnel Turecky vrch – north portal

4 Diagnostics of relative track alignment design and track geometry of experimental sections around portals of tunnel Turecky vrch

Diagnostics of relative of track alignment design and track geometry of the track section was implemented six times so far – immediately before putting line tracks into operation and every six months in spring and autumn.

The experimental track sections are marked as [9]:

- section 1.1 (track No. 1, south portal of the tunnel Turecky vrch) and 2.1 (track No. 2, south portal; both sectors of length 175 m; km 102.360 000 – km 102.535 000):
  - km 102.360 000 – km 102.460 500 construction with ballast bed,
  - km 102.460 500 – km 102.480 500 construction with ballast bed in the concrete trough,
  - km 102.480 500 – km 102.535 000 slab track.

- section 1.2 (track No. 1, north portal of the tunnel Turecky vrch) and 2.2 (track No. 2, north portal); both sectors of length 640 m; km 104.200 000 – km 104.840 000):
  - km 104.200 000 – km 104.720 500 slab track,
  - km 104.720 500 – km 102.480 500 construction with ballast bed in the concrete trough,
  - km 104.740 500 – km 104.840 000 construction with ballast bed.

Diagnostics of structure layout and track geometry of the track section [9]:

- measurement before putting sections into operation (MSO) 10.07. – 11.7.2012 and 02.10. – 3.10.2012,
- the first operational measurement (PO1) 09.04. – 10.04.2013, 21.04 – 22.04.2013,
- the second operational measurement (PO2) 08.10. – 09.10.2013, 21.10. – 22.10.2013,
- the third operational measurement (PO3) 25.5.2014 and 28.5.2014,
- the fourth operational measurement (PO4) 29.10.2014,
- the fifth operational measurement (PO5) 25.3.2015 and 17.4.2015.

Comprehensive diagnostics of track alignment design and track geometry is carried out by continuously measuring trolley *KRAB*^{TM}*–Light* . The measurement is referred to as continuous, but in fact, the data is recorded with the measuring step of 250 mm [8]:

- gauge deviation *RK* (after calculating is also recorded change of gauge *ZR*),
- alignment of right rail string *SR* (after calculating is also recorded alignment of left rail string *SL*),
- rail top level of right rail string *VR* (after calculating is also recorded rail top level of left rail string *VL*),
- cant *PK*,
- quasi-twist on a short base (calculating to a quasi-twist on a base of 1.8 m long – *ZK* 1.8, on a base of 6.0 m long – *ZK* 6.0 and on a base of 12.0 m long – *ZK* 12.0),
- track distance.

Each of the sections No. 1.1 and No. 2.1 is represented by 701 samples, each of the sections No. 1.2 and No. 2.2 is represented by 2 561 samples for a comprehensive diagnostics.

5 Conclusions

The increasing population mobility and economic competition between different transport system put higher and higher requirements and objectives even before the railway. An essential precondition for the competitiveness of rail transport is, however, a reliable operation of the railway lines; it means a safer and more stable movement of vehicles on the track – rail.

Development and validation of a number of technical solutions of ST in terms of Slovak Railways have demonstrated a willingness to optimize the structure of superstructure, which would allow to ensure the quality of the track geometrical parameters, reduce maintenance costs, extend the service life of structures and increase the competitiveness and attractiveness of railway lines in the territory of Slovak Republic in longer term. The issue of modernization of railway infrastructure is an ideal opportunity for further application of advanced systems and structural elements of railway lines, where the ST undoubtedly belongs to.

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EMERGENCY SYSTEM DESIGN USING OPTIMIZATION ENVIRONMENT OF COMMERCIAL IP-SOLVERS

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Abstract: Emergency service systems as emergency medical service system, fire-brigade system and other systems, which cover demand of population for more secure life, are based on providing the service from several service centers deployed in the serviced area. As the access of population to the service is performed by transportation means operating on an underlying transportation network, the design of suitable deployment of the service centers belongs to hard combinatorial transportation problems. Optimal or near optimal solution of the emergency service system design problem requires usage of sophisticated information tools, which are usually not at disposal to a common designer in the term determined to the design. This contribution deals with the approximate approach based on a radial formulation, which enables to solve bigger instances in admissible time making use of a universal IP-solver. This approach is applied on various particular problems connected with the emergency system design as min-sum problem, fair design and emergency system design with failing centers.

Keywords: emergency system design, radial formulation, fair and system approach

1 Introduction

Efficiency of an emergency system is considerably influenced by deployment of the service centers, which send emergency vehicles to satisfy the demand on service at system users' locations. The emergency system design consists in locating a limited number of service centers at positions from a given finite set to optimize the quality characteristic of the designed system from the point of the serviced system users. As concerns the characteristic of quality, various objective functions have been formulated. If the characteristic corresponds to service

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accessibility of an average user, then the emergency system design can be tackled as a weighted *p*-median problem [1], [2]. Usage of the *p*-median problem may lead to such system design, where some minority of users are caught in locations, which are inadmissibly distant from any service center. Such design is considered to be unfair, even if it is optimal from the point of the average user. The fair designing or scheduling emerge whenever limited resources are to be fairly distributed among participants, who claim rights to equal access to the service.

Each of the systems must be suggested and built up a long time before it is able to provide the associated service. It represents a crucial way to design the system even if the solution techniques are known. Large instances of the problem described by location-allocation problem often fail, when their design is worked up on common optimization software, which represents a short cut in the design time schedule. Another way is development of specific software tool for a particular emergency system design, but this way is both costly and long term demanding. In such cases, such methods are valuable, which are easily implementable on common optimization software and able to solve big instances of the design problems in acceptable time. We want to introduce a universal approach to various types of the emergency system design. The approach is based on homogenous radial formulation of the *p*-median problem and enables a trade-off between accuracy and computational time or demanded computer memory. The radial formulation of the *p*-median problem emerged as a concept in works [2], [3]. As the authors Garcia at al. [2] used the concept to develop a special algorithm ZEBRA to reach the exact solution of the vast instances of the *p*-median problem, our research in this field [5], [6], [7] has been focused on obtaining a flexible solving technique implementable within commercial IP-solver so that it represents at-hand-kit for the emergency system design.

The remainder of this paper follows. Chapter 2 contains a concise explanation of the radial formulation of the *p*-median problem. Chapter 3 comprises the application of the radial concept to fair optimal system design approximate approach. Chapter 4 presents generalization of the radial concept to the emergency system with failing centers. Each of these chapters is accompanied by numerical experiments, which demonstrate the effectiveness of the described approach. The results and findings are summarized in Chapter 5.

2 Radial approach to emergency system design

2.1 Radial formulation of the p-median problem

The emergency system design problem is formulated as a task of location of at most p service centers so that the objective function value derived from distances between center locations and users' location is minimal. To describe the problem, we denote by I a set of possible service center locations and by J the set of possible users' locations. The symbol b_j denotes the number of users located at the location j. The distance between service center location i and users' location j is denoted as d_{ij}. The matrix $\{d_{ij}\}$ of all distances from a center location $i \in I$ to a users' location $j \in J$ contains a sequence $d^0 < d^1 < \ldots < d^u$ of all relevant values, i.e. values, which do not belong to the p-1 highest values in an individual column of the matrix.

The radial approach is based on the construction of constraint (1). In the constraint and the remainder of this paper a location binary variable $y_i \in \{0, 1\}$ is introduced for each possible service center location $i \in I$, to model the decision on placing ($y_i = 1$) or not placing ($y_i = 0$) a service center at the location i. In addition, an auxiliary variable x_{js} is used to indicate by the value of one that no service center is located in the radius d^s from the users' location j. Otherwise; the variable takes the value of one. To complete the constraint, the zero-one constants a_{ij}^s must be defined for the distance d^s and the users' location j and for each $i \in I$ so that the constant a_{ij}^s is equal to 1, if the distance d_{ij} between the users' location j and the possible center location i is less than or equal to d^s, otherwise a_{ij}^s is equal to 0.

$$x_{js} + \sum_{i \in I} a_{ij}^s y_i \geq 1 \tag{1}$$

The constraints (1) ensure that the variable x_{js} is allowed to take the value 0, if there is at least one service center located in the distance d^s from the given users' location j. In this case, the second term on the left-hand-side of (1) obtains the value corresponding to the number of located service centers in the radius d^s and if this number is greater than or equal to one, then x_{js} can take the value of zero unless the constraint is broken. When the value of variable is pushed down by an optimization process, then it takes the value of one, if the second term takes the value of zero and otherwise it takes the value of one.

If the objective of emergency system design problem consists in minimization of distance from an average user to the nearest located service center, then the associated model takes the form of the weighted *p*-median problem, and its exact radial formulation is as follows.

The variables x_{js} and constants a_{ij}^s are defined for each users' location $j \in J$ and $s \in [0..u]$ and also the symbols e_s are introduced to denote the differences $d^{s+1} - d^s$ for $s \in [0..u\text{-}1]$.

$$Minimize \quad \sum_{j \in J} b_j \sum_{s=0}^{u-1} e_s x_{js} \tag{2}$$

$$Subject\ to: \quad x_{js} + \sum_{i \in I} a_{ij}^s y_i \geq 1 \quad for\ j \in J,\ \ s = 0,1,\ldots,u-1 \tag{3}$$

$$\sum_{i \in I} y_i \leq p \tag{4}$$

$$x_{js} \geq 0 \quad for\ j \in J,\ \ s = 0,1,\ldots,u-1 \tag{5}$$

$$y_i \in \{0,1\} \quad for\ i \in I \tag{6}$$

In this model, the constraints (3) ensure that the variables x_{js} are allowed to take the value 0, if there is at least one service center located in the distance d^s from the users' location *j*. The constraint (4) puts the limit *p* on the number of located service centers. Even if the problem in the radial form is much more easily solvable than instances described by the location-allocation problem, there can occur memory insufficiency, when large instances of the *p*-median problem must be solved using commercial IP-solver. These instances are characterized by big value *u* in the sequence $d^0 < d^1 < \ldots < d^u$. In this case, the exact approach can be converted into approximate one, which pays by controlled loss of accuracy for lower memory demand and smaller computational time.

2.2 Approximate approach to the p-median problem

In the case, when the value of *u* is too high to process the complete sequence $d^0 < d^1 < \ldots < d^u$, there is a way to overcome the difficulties brought by big size of the problem (2)-(6). This way makes use of the concept of dividing points [3], [7] and converts the approach to an approximate one. The *v* dividing points can be chosen only from the set of values $d^0 < d^1 < \ldots < d^{u-1} < d^u$, where $D_0 = d^0$ and $D_{v+1} = d^u$. Let the value d^h have a frequency N_h of its occurrence in the matrix $\{d_{ij}\}$. In the suggested approach, we start from the hypothesis that the distance d^h occurs in the resulting solution n_h times and that is why the deviation of this distance value from its approximation encumbers the total deviation proportionally to n_h. The distance *d* of a user from the nearest located service center can be only estimated taking into account that it belongs to the interval $(D_k, D_{k+1}\rangle$. The maximal deviation of the upper estimation D_{k+1} from the exact value d is $D_{k+1} - D_k$. If we were able to anticipate a frequency n_h of each d_h in the unknown optimal solution, we could minimize the total deviation of the upper approximation from the unknown optimal solution by solving the problem (7) – (11). If the distance d^h belongs to the interval ending by the dividing point d^t then the decision variable z_{ht} takes the value of 1.

$$\textit{Minimize} \quad \sum_{t=1}^{u}\sum_{h=1}^{t}(d^t - d^h)n_h z_{ht} \tag{7}$$

$$\textit{Subject to:} \quad z_{(h-1)t} \le z_{ht} \quad \textit{for } t = 2,3,\ldots,u, \quad h = 2,3,\ldots,t \tag{8}$$

$$\sum_{t=h}^{u} z_{ht} = 1 \quad \textit{for } h = 1,2,\ldots,u \tag{9}$$

$$\sum_{t=1}^{u-1} z_{tt} = v \tag{10}$$

$$z_{ht} \in \{0,1\} \quad \textit{for } t = 1,2,\ldots,u, \quad h = 1,2,\ldots,t \tag{11}$$

The link-up constraints (8) ensure that the distance value d^{h-1} belongs to the interval ending with d^t only if each other distance between d^{h-1} and d^t belongs to this interval. Constraints (9) assure that each distance value d^h belongs to some interval and the constraint (10) enables only v dividing points to be chosen. After the problem (7) – (11) is solved, the nonzero values of z_{tt} indicate the distance values d^t corresponding with dividing points.

The above approach is obviously based on the "relevance" of a distance d^h, which expresses the strength of our expectation that the distance value d^h will be a part of the unknown optimal solution, which is searched for. We suggested and explored several ways of the relevance estimation. The most promising one seems so called "shifted exponential approach" [7], which estimates the relation between n_h and N_h by formulae (12) - (14).

$$n_h = N_h\, g(h) \tag{12}$$

The function $g(h)$ is equal to 1 for each $h \le h_{crit}$ and it is defined by (13) for each $h > h_{crit}$.

$$g(h) = e^{h_{crit} - h} \tag{13}$$

The constant h_{crit} is a parameter of the approach called "critical value", which can be determined according to (14) for some given parameter q.

$$h_{crit} = min\left\{ h \in Z^+ : \sum_{u=0}^{h} N_u \geq \frac{q}{p} \sum_{t=0}^{m} N_t \right\} \tag{14}$$

2.3 Numerical experiments with the weighted p-median problem

To compare exact and approximate approaches to the emergency system design with the location-allocation approach, we performed the series of numerical experiments. The used benchmarks were derived from the real emergency health care system, which was originally implemented in seven regions of Slovak Republic, i.e. Banská Bystrica, Košice, Nitra, Prešov, Trenčín, Trnava and Žilina. This pool of benchmarks was extended by the instance of whole Slovak Republic. These benchmarks cover demands of all communities - towns and villages spread over the particular regions by given number of ambulance vehicles. In the benchmarks, the set of communities represents both the set J of users' locations and also the set I of possible center locations. The cardinalities of these sets and the number p of located centers ware derived from the original design and upper limit u of subscript s was also obtained by analysis of the associated matrices $\{d_{ij}\}$. The denotations of the benchmarks together with parameters $|I|$, p, u respectively are given in the following sequence, where the region denotation is followed by triple of parameters: BB (515, 52, 165), KE (460, 46, 181), NR (350, 35, 117), PO (664, 67, 214), TN (276, 28, 133), TT (249, 25, 140), ZA (315, 32, 135), SR, (2916, 273, 476). To solve the described benchmarks, the optimization software FICO Xpress 7.7 (64-bit, release 2014) was used and the experiments were run on a PC equipped with the Intel® Core™ i7 2630 QM processor with the parameters: 2.0 GHz and 8 GB RAM. The result of experiments are plotted in Tab. 1, where column section LocAlloc contains results obtained using the location-allocation model, section Radial approximate gives results obtained by the approximate approach for twenty dividing points and Radial exact gives results of exact radial approach described in section 2.1. Inside the individual column sections, denotation "ObjF" denotes real objective function value, i.e. sum of distances multiplied by number of inhabitants given in hundreds and denotation "Time" denotes computational time in seconds. Denotation "gap" gives the difference between objective function values of the obtained solution and the optimal one in percentage of the optimal solution value.

Tab. 1: Comparison of location-allocation, approximate radial and exact radial approaches.

Region	LocAlloc (exact)		Radial (approximate)			Radial (exact)	
	ObjF	Time [s]	ObjF	gap [%]	Time [s]	ObjF	Time [s]
BB	17289	27.60	17293	0.02	2.05	17289	1.12
KE	20042	20.09	20242	1.00	1.69	20042	1.51
NR	22651	10.05	22651	0.00	1.29	22651	1.06
PO	20025	79.47	20025	0.00	2.47	20025	2.67
TN	15686	4.13	15863	1.13	0.92	15686	4.58
TT	18873	4.68	18873	0.00	0.98	18873	0.56
ZA	20995	7.41	21018	0.11	0.88	20995	0.69
SR	---	---	161993	0.34	22.30	161448	13.92

3 Fair optimal design with radial approach

3.1 Lexicographical min-max design and radial approach

If the lexicographical min-max fair problem is solved, then the distance from the worst situated user to the nearest located center is minimized first, and then the distance from the second worst situated users is minimized unless the minimal reached distance from the previously processed users is worsened. This process is repeated until no users distance from the nearest located center can be reduced.

If the fair solution is accepted, then the min-sum objective function value is worsened. Given service center deployment induces differences in users' access to provided service. Disutility perceived by an individual user corresponds to the distance from the user location to the nearest located service center, and this distance gets only a value from the sequence $d^0<d^1<\dots<d^u$. Let d^w denote the highest but one member of the sequence, which limits the distance from user location to the nearest located center. Then, the range of all disutility values can be represented by a finite set of ordered values $G_0=d^{w+1}$, $G_1=d^w$ … $G_w=d^1$ and $G_{w+1}=d^0$. A solution $\boldsymbol{y}$ can be characterized by the distribution vector $[B_0(\boldsymbol{y}), B_1(\boldsymbol{y}) \dots B_w(\boldsymbol{y})]$, where the t-th component of the vector is defined as the number of users, whose distance from the nearest located service center belongs to the semi-closed interval $(G_{t+1}, G_t]$. The lexicographic min-max problem according

to [10] consists in lexicographic minimizing of the vector $[B_0(\boldsymbol{y}), B_1(\boldsymbol{y}) \ldots B_w(\boldsymbol{y})]$ subject to $\boldsymbol{y} \in \{0, 1\}^m$ and the condition that the vector $\boldsymbol{y}$ contains at most p ones.

Solution of the p-center problem can be used as the first step of the lexicographic min-max algorithm. To obtain the solution by most effective way, we have suggested the bisection method [8], which uses the above mentioned sequence $d^0<d^1<\ldots<d^u$ of all possible distance values between possible center locations and the users' locations. The bisection process gives the lowest subscript $v+1$, where the associated d^{v+1} will not enter the solution. Let the subscript value $c=w-v+1$ correspond to the first nonzero component $B_c(\boldsymbol{y})$ of the distribution vector $[B_0(\boldsymbol{y}), B_1(\boldsymbol{y}) \ldots B_w(\boldsymbol{y})]$. The following lexicographical minimization of the distribution vector processes step-by-step the components $B_c(\boldsymbol{y}), B_{c+1}(\boldsymbol{y}) \ldots B_w(\boldsymbol{y})$. In accordance with [4], [10] we suggested an iterative process of lexicographic minimization based on solving the problem (15) – (21) for the components $B_t(\boldsymbol{y})$, where $t=c \ldots w$. Additionally to the zero-one location variables $y_i \in \{0, 1\}$ for $i \in I$, we introduce the variables x_{js}, to indicate, whether the distance from the user's location $j \in J$ to the nearest located center is greater than d^s. In the associated model, the value $\underline{B}^*_k$ corresponds to the objective function value of (15) obtained in the steps preceding the step t.

$$Minimize \quad \sum_{j\in J} b_j \sum_{s=v+c-t}^{v} e_s x_{js} \tag{15}$$

$$Subject\ to: \quad x_{js} + \sum_{i\in I} a_{ij}^s y_i \geq 1 \quad for\ j \in J, \quad s = 0,1,\ldots,v \tag{16}$$

$$\sum_{i\in I} y_i \leq p \tag{17}$$

$$\sum_{j\in J} b_j \sum_{s=v+c-k}^{v} e_s x_{js} \leq \underline{B}_k^* \quad for\ k = c, \ldots t-1 \tag{18}$$

$$\sum_{i\in I} a_{ij}^{v+1} y_i \geq 1 \quad for\ j \in J \tag{19}$$

$$x_{js} \geq 0 \quad for\ j \in J, \quad s = 0,1,\ldots,v \tag{20}$$

$$y_i \in \{0,1\} \quad for\ i \in I \tag{21}$$

In this model, the constraints (16) ensure that the variables x_{js} are allowed to take the value 0, if there is at least one service center located in the distance d^s from the users' location j. The constraint (17) puts the limit p on the number of located centers. The constraints (18) and (19) prevent the components $B_0(\boldsymbol{y})$,

$B_1(\mathbf{y})$ ... $B_{t-1}(\mathbf{y})$ from worsening. It holds that $B_t(\mathbf{y})$ takes the value of zero for t=0 … c-1 due to (19). Note that even if no integrality constraint is imposed on x_{js}, the result of (15) – (21) will contain no variable x_{js}, with value different from 0 or 1.

3.2 Numerical experiments with the lexicographical min-max design

To compare the lexicographical min-max and min-sum designs, we performed the series of numerical experiments on the same pool of benchmarks as described in the Section 2.3. To solve the benchmarks, the same optimization software FICO was used and the experiments were run on the same PC described in the Section 2.3. The results of experiments are plotted in Tab. 2, where column section Radial lex min-max (exact) contains results obtained using the above-mentioned sequential approach based on step-by-step solving the problem (15) - (21), section Radial min-sum (exact) gives results of exact radial approach described in Section 2.1. Inside the individual column sections, denotation "ObjF" denotes real objective function value, i.e. the sum of distances multiplied by the number of inhabitants given in hundreds and "Time" denotes computational time in seconds. Denotation "gap" gives the difference between objective function values of obtained solution and the optimal one in percentage of the optimal solution value.

Tab. 2: Results of radial lex min-max and min-sum approaches.

Region	Radial lex min-max (exact)			Radial min-sum (exact)	
	ObjF	gap [%]	Time [s]	ObjF	Time [s]
BB	31209	80.51362	4.65	17289	1.12
KE	35421	76.73386	14.46	20042	1.51
NR	37370	64.98168	73.42	22651	1.06
PO	41155	105.5181	25.73	20025	2.67
TN	32120	104.7686	14.71	15686	4.58
TT	27469	45.54655	10.12	18873	0.56
ZA	29576	40.87164	3.04	20995	0.69
SR	289807	79.50486	14055.5	161448	13.92

4 Generalization of the approach to the problem with failing centers

4.1 Radial model of the emergency system with failing centers

The necessity of solving large instances of the *p*-median problem has originally led to the radial formulation [1], [2], [3] and [7], which enables to design an effective emergency system for the case of simple disutility proportional to the distance from user to the nearest service center. This approach was generalized [4], [9] to be applicable on the cases, when the user's disutility is influenced by distances from the user to *r* nearest located centers. This model reflects the situation, when a user cannot be serviced by the nearest service center due to its occupation by some previously coming demand or other reason of its failing. Then the user is assigned with some probability to the second nearest center and so on. This effect is modelled by so called generalized disutility. To formulate the public service system design problem with the optimal generalized disutility, we use previously introduced denotation. The generalized disutility for a user is modeled by a sum of weighted disutility contributions from the *r* nearest centers. The weight coefficients q_k for $k = 1 ... r$ are positive real values, which meet the inequalities $q_1 \geq q_2 \geq \ldots \geq q_r$. The *k*-th weight can be proportional to the probability of the case, that the *k*-1 nearest located centers are occupied and the *k*-th nearest center is available [11]. The network distance of a possible location *i* from the users′ location *j* is denoted as d_{ij}. The decisions which determine the designed system can be modeled by location variables y_i for $i\in I$. The variable $y_i\in\{0,1\}$ models the decision on service center location at the place *i* as in the previous chapters.

The approximate radial formulation starts from partitioning of the range of all possible distance values $d^0<d^1<\ldots<d^u$ from a user to a possible center location into v+1 zones. The zones are separated by dividing points D_1, D_2 … D_v, where $0 = d^0=D_0 < D_1$ and $D_v < D_{v+1} = d^u$. The zone *s* corresponds with the interval $(D_s, D_{s+1}]$. To describe the problem, auxiliary zero-one variables x^k_{js} for $s = 0 \ldots v$ and $k = 1 \ldots r$ are introduced. The variable x^k_{js} takes the value of 1 if the *k*-th smallest distance from the customer $j\in J$ to the located center is greater than D_s and it takes the value of 0 otherwise. Then the expression $e_0x^k_{j0} + e_1x^k_{j1} + e_2x^k_{j2} + e_3x^k_{j3} +\ldots+ e_vx^k_{jv}$ constitutes an upper approximation of the *k*-th smallest disutility contribution d^k_{j*} for the customer at *j*. If the disutility d^k_{j*} belongs to the interval $(D_s, D_{s+1}]$, then the value of D_{s+1} is the upper estimation of d^k_{j*} with a maximal possible deviation e_s. To complete the associated radial model, we introduce a zero-one constant a_{ij}^s, where the constant a_{ij}^s is equal to 1 if and only if the distance d_{ij} for a user at the location *j* from the possible center location *i* is less or equal to D_s, otherwise a_{ij}^s is equal to 0. Then the model can be formulated as follows:

$$Minimize \sum_{j\in J} b_j \sum_{s=0}^{v} e_s \sum_{k=1}^{r} x_{js}^k \tag{22}$$

$$Subject\ to \sum_{k=1}^{r} x_{js}^k + \sum_{i\in I} a_{ij}^s y_i \geq r \quad for\ j\in J,\ s=0..v \tag{23}$$

$$\sum_{i\in I} y_i \leq p \tag{24}$$

$$x_{js}^k \in \{0,1\} \quad for\ j\in J,\ s=0,..v,\ k=1..r \tag{25}$$

$$y_i \in \{0,1\} \quad for\ i\in I \tag{26}$$

The constraints (23) ensure that the sum of variables x^k_{js} over k expresses the number of the service centers in the radius D_s from the user location j, which remains to the number r. The constraint (24) puts a limit p on the number of located facilities. Even though the constraints do not ensure the above declared meaning of the individual variables x^k_{js}, the objective function (22) gives the upper bound of the sum of disutility values.

4.2 Numerical experiments

To compare the location-allocation and the radial min-sum approaches to the emergency system design with failing centers, we performed the series of experiments on the same pool of benchmarks as described in the Section 2.3. The generalized disutility model was constituted for r = 3, q_1=1, q_1=0.1 and q_3=0.05. To solve the benchmarks, the same software FICO was used and the experiments were run on the same PC as described in the Section 2.3. The results are plotted in Tab. 3, where section Radial lex min-max (exact) contains results obtained using the location-allocation formulation of the problem and the section Radial min-sum (approx.) gives results of approximate radial approach described by (22) - (26). Inside the individual column sections, “ObjF” denotes real objective function value, i.e. the sum of distances multiplied by the number of inhabitants given in hundreds and “Time” denotes computational time in seconds. The “gap” gives the difference between objective function values of obtained solution and the optimal one in percentage of the optimal solution, if the optimal solution is known.

Tab. 3: Results of experiments with failing centers.

Region	LocAlloc min-sum		Radial min-sum (approx.)		
	ObjF	Time [s]	ObjF	Gap [%]	Time [s]
BB	29339.80	209.66	29439.35	0.34	2.11
KE	31673.10	153.08	32024.95	1.11	2.12
NR	36165.95	59.97	36515.00	0.97	1.45
PO	32057.20	434.91	32446.25	1.21	3.12
TN	25371.90	27.29	25799.65	1.69	1.14
TT	29962.05	22.65	30148.05	0.62	3.04
ZA	34319.55	43.03	34489.95	0.50	1.25
SR	---	---	260784.95	---	26.53

5 Conclusions

This paper was focused on mastering real sized instances of the emergency service system design using commercial IP-solver, which can fail in solving large instances of particular service system design problem. We presented here a broad spectrum of radial formulation applications to the emergency service system design, where various models of objective were considered. As can be seen in numerical results presented in Chapter 2, the suggested approach to design of emergency system with minimal disutility of an average user is at least ten times faster than the location-allocation approach, and, in addition, the suggested approach was able to solve instance of the size of Slovak Republic whereas the location-allocation approach failed due to lack of memory. The lexicographic min-max version of radial approach proved to be also usable to solve mediate instances in acceptable time and it was able to solve the big instance, but computational time exceeds four hours. The radial approach also outperformed the location-allocation approach in version for emergency system design, where possible failing of service centers is considered. The results presented in Chapter 4 show that the suggested approach obtained the solution in two orders faster than the location-allocation approach. Thus we can conclude that we present a useful tool for large emergency system design problem. The tool can be easily implemented using common commercial optimization software. Further research in this field can be focused on applying and verifying the suggested approach on very large instances and on lexicographical min-max design of the emergency system with failing centers.

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LOCATION OF THE EMERGENCY MEDICAL SERVICE CENTERS USING THE UTILITY FUNCTION

Marta Janáčková[1], Alžbeta Szendreyová[2]

Abstract: In the paper we deal with one of the tasks of public service systems, namely we deal with the location of the centers of emergency medical services. Due to the specific character of the provision of the emergency medical services, we strive not only to minimize the total time of the service availability, but also the availability of a critical period for individual customers. We solve this problem as a placement problem of the *p*-median type. Several parameters affect the placements of the centers. In this paper we present a brief evaluation of the results, which we obtained by the experiments recently.

Keywords: *p*-median, station emergency medical services, utility services for customers.

1 Introduction

Every citizen in Slovak Republic is entitled to receive an emergency medical service (EMS). The need of this service is accidental. We do not know in advance specify when or where the service will be provided. Despite this variability, the EMS centers must be somewhere placed.

Many factors have an effect on the placement of the EMS centers. These include economic opportunities, technical conditions for the center location, a condition of the road network, a population density, an availability of the required time of services and other. We have been dealt with the problem of centers location slightly longer. The EMS has a specific character. A utility from its provision may be changed in urgent medical cases in a short time.

In this paper we present a brief summary of the results that we have obtained during the search of the parameters, which are suitable for EMS. Finally, we

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compare one optimal solution from our experiments with the actually centers placement of the same region.

2 Possible approach to the design

The centers placement design can be dealt as a location problem, a *p*-center problem (min-max), a *p*-median problem or as a location problem with the limited impact of services. Minimization of the cost or the distance, or maximization of the utility or the profit may constitute the optimization criterion. Each of the approaches has its advantages and disadvantages. We consider that the best approach for location the EMS centers is the *p*-median problem with the utility function.

The proposal aims to determine the location of p centers in the network in order to achieve the optimal value of the objective function. The basic task can be formulated as follows:

Let I denotes a finite set of the possible candidates for the centers location and J denotes a finite set of the customers' locations. The distance between the candidates $i \in I$ and the customers' locations $j \in J$ is denoted as c_{ij}. Our task is to locate the exact number of p centers into the some nodes of the set I and from these centers to serve each customer $j \in J$ in order to maximize the utility value. The decision on locating or non-locating an EMS center at the location $i \in I$ models the variable $y_i \in \{0, 1\}$ for $i \in I$. The variable takes the value of one if an EMS center is located at i and it takes the value of zero otherwise. The decision on assigning the customer from the node $j \in J$ to the possible EMS center location $i \in I$ models the variable $z_{ij} \in \{0, 1\}$ for $i \in I$ and $j \in J$. The variable z_{ij} takes the value of one if the customer's location j is assigned to the possible service center location i, and it takes the value of zero otherwise.

The model of the task then will be in the form:

$$Maximize \ \sum_{i \in I} \sum_{j \in J} u_{ij} z_{ij} \quad (1)$$

$$Subject \ to \ \sum_{i \in I} z_{ij} = 1 \qquad for \ j \in J \quad (2)$$

$$z_{ij} \leq y_i \qquad for \ i \in I, \ j \in J \quad (3)$$

$$\sum_{i \in I} y_i \leq p \quad (4)$$

$$y_i \in \{0,1\} \qquad for \ i \in I \quad (5)$$

$$z_{ij} \in \{0,1\} \qquad for \ i \in I, \ j \in J \quad (6)$$

The coefficients in the model have the following meanings:

c_{ij} ... valuation of the edges between nodes i and j,

$u_{ij} = u(c_{ij})$ … utility function,

p ... required number of EMS centers,

I ... set of possible locations of the EMS centers,

J ... set of customers (nodes, dwelling places).

The utility function, which we have chosen as the most appropriate criterion for optimization, is used in our experiments in the following form:

$$u(d) = \frac{1+e^{\frac{-d_{crit}}{T}}}{1+e^{\frac{d-d_{crit}}{T}}} \tag{7}$$

The function is decreasing and has "jump" character. The variable d represents a distance between the EMS center and the customer (kilometric distance or time distance c_{ij}). The parameter d_{crit} represents the value, at which occurs the jump in the function and the utility is fundamentally changing (pass through d_{crit} brings a negligible utility). The parameter T is the shaping coefficients of the function. It affects the "steepness" of its course in a neighborhood of d_{crit}. The course of the function becomes shallower with increasing T. The significance of the jump softens and the course of the function gradually nears to linear character. The function $u(d)$ takes on its maximum for d=1 and for all values of the parameters T and d_{crit} ($u(0)=1$).

This model enables us to decide on the number of the EMS centers. The optimization criterion describes well the character of the EMS. A number of other parameters affect the best solution too.

3 Evaluation of the task parameters

We want to achieve the maximization of the whole utility by placing the centers. The total utility of the optimal solution depends on the number of customers. Therefore, we always calculate the relative utility for the relevant comparison (an average per one customer). In addition to the utility we watch the kilometrage between the center and the assigned customer.

We did many experiments. We chose either all municipalities or the municipality with higher number of populations for the set of candidates. Each model can solve the problem only on the limited size network. The processing of the design made no problem at the regional level of the Slovak Republic. When we solved the problem on the whole network of the Slovak Republic, we had to reduce the set of candidates to the district towns. In each task, the parameter p corresponded to the number of EMS centers that are actually located in the regional network of the Slovak republic.

The parameters d_{crit} and T impact on the value of the objective function. The increasing parameter d_{crit} always improves the value of the criterion u (table 1). In the case of the provision of EMS is its value given, d_{crit} = 20 minutes.

Tab. 1: Results for the maximization of utility

d_{crit}=20, p = 29			**d_{crit}=40, p = 29**			**d_{crit}=60, p = 29**		
T	**Value of the objective**	**Total of the time-distances**	***T***	**Value of the objective**	**Total of the time-distances**	***T***	**Value of the objective**	**Total of the time-distances**
3	305.86	2 161	**3**	314.99	2 161	**3**	315.00	2 153
6	287.87	2 143	**6**	313.79	2 151	**6**	314.96	2 151
9	280.24	2 143	**9**	310.06	2 151	**9**	314.45	2 151
Classical *p*-median problem, *p* = 29					**2 141**			

For comparison, the bottom row contains objective function values of the optimal solution of the associated classical p-median problem for p=29.

The shaping coefficient T changes the steepness of the utility function. We solved various tasks for T equal to the value of 1 up to 40. The value of u nears to its maximum in many tasks for T=1 and d_{crit} =20 and for parameter p that corresponds to the real number of the locations in the regional network. The best maximum distance between the customer and the assigned EMS center in optimal solution was always achieved for T=1. With increasing T reduces the total utility and the function $u(d)$ step by step loses the desired shape. This is compensated by the total distance. The distances are correlated with the classical p-median from the certain value of T. To use large values of T therefore has no meaning.

We also solved the tasks of the weighted p-median. A demand of each municipality was equal to about one hundredth of its population. Results from the location in the Žilina region are in the table 2.

There are results of weighted p-median tasks in the table 2. The number of customers is 6911 (one hundredth of the total population in the Žilina region), the number of the possible candidates for the centers location is 315, p=29 and the value of d_{crit} is equal to 20. In the columns we find these data: the value of *T*, the total and the relative utility, the total and the relative distance between centers and assigned customers (residents), the total and the relative distance between centers and assigned municipality which the customer belongs to, maximum distance (the distance between the worst placed customer and the center assigned to him).

Tab. 2: Results of weighted *p*-median for the Žilina region

T	Total utility	Relative utility	Total distance centers-customers	Relative distance per customer	Total distance centers-municipalities	Relative distance per municipality	Max distance
1	6910,63	1,00	30123	4,36	2125	6,75	17
4	6779,45	0,98	23363	3,38	2059	6,54	26
7	6609,49	0,96	22995	3,33	2067	6,56	26

For comparison, the table 3 shows the results of the same task that was solved as an unweighted *p*-median problem. The number of customers is 315 (the number of dwelling places), the number of the possible candidates for the centers location is 315, *p*=29 and the value of d_{crit} is equal to 20.

Tab. 3: Results of unweighted *p*-median for the Žilina region

T	Total utility	Relative utility	Total distance centers-municipalities	Relative distance per municipality	Maximum distance
1	314,96	1,00	2089	6,63	15
4	303,27	0,96	1949	6,19	16
7	289,61	0,92	1881	5,97	20

The table 4 compares the values of the optimal solution of the design from the table 2 with the values of the actual placement of the same task. Both rows in the table 4 correspond to the network of the Žilina region, where the number of customers is 6911 (one hundredth of the total population in the Žilina region), the number of the possible candidates for the centers location is 315, *p*=29 and the value of d_{crit} is equal to 20. The optimal solution of weighted *p*-median task belongs to the row "Optim". The row "Actual" contains the values of the actual centers location.

Tab. 4: Comparison of the optimal solution values and of the actual placement values

Type	**Total utility**	**Relative utility**	**Total distance centers-customers**	**Relative distance per customer**	**Total distance centers-municipalities**	**Relative distance per municipality**	**Max distance**
Optim	6910,63	1,00	30123	4,36	2125	6,75	17
Actual	6903.83	1,00	25610	3.71	2328	7,39	24

The table 4 shows, that the value of the total utility in both cases is almost identical. We see a saving of the total kilometrage in the actual centers location. On the contrary, the optimal solution achieves great savings in the maximum availability (the worst situated customer is 17 km away from the nearest center in the optimal solution and 24 km in actual location of centers).

4 Conclusion

A model with small values of the parameter *T* best suits for urgent medical assistance. As we expected, better relative utility was achieved, when the weighted *p*-median task was solved. The centers locations in the optimal solution are moving to more populous municipalities, if we solve the task as a weighted *p*-median problem. Thereby more residents gain an advantage. This reflects the reduction of the relative distance per customer. The relative distance per municipality deteriorated while weighted p-median was solved, but not so markedly (slightly deterioration for small values of *T*). On the other side, the maximum availability worsened, that is, the situation for some individual customers became worse.

The weighted *p*-median problem describes the situation better when the number of interventions is proportional to the number of inhabitants in the village. The classic model is mostly suitable for areas with the uniform distribution of population, but also at a time when the population changes in municipalities (e.g. Holidays).

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NEURAL NETWORKS IN MODELLING WEATHER-CYCLING RELATIONSHIP

Vojtěch Jirsa[1]

Abstract: In this contribution it is described whether the neural networks can be utilized in modelling weather and cycling relationship. The real data set is used to build the model and obtain relevant information about its reliability. Presentation of model outputs is followed by suggestions for further work to be done to achieve higher reliability of the model. The possibilities of various implementations of the model are discussed as well as the possibilities of its generalization. Examples of particular use in transport planning are described.

Key words: cycling, weather, neural networks.

1 Introduction

Weather conditions influence the use of bicycles in cities. Average daily temperature, wind velocity, sunshine intensity and daily precipitations are some of the temporal factors which one takes into account while choosing the mode of transport. In this paper we try to answer the question: What is the relationship between weather and daily intensities in one particular bicycle path in the city of Pardubice and can we model this relationship using neural networks?

The cyclists' intensities were collected from the automatic bicycle monitoring system which counts cyclists continuously (in 15 minutes steps). Selected weather factors were obtained from amateur meteorological station located 4.7km far from the counter. The sample covers 365 days in row.

In following chapters it is described how the dependency model of cycling intensities and selected weather factors was developed using neural networks. In the next chapter it is described why the neural networks seems to be the appropriate tool.

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2 Neural networks suitability

For solving analytical problems neural networks poses several advantages in comparison with conventional algorithms such as linear regression [1]:

- ability to detect complex relationships among many variables,
- ability to deal with complicated and inaccurate datasets,
- ability to find dependency without the knowledge of reasons for variability,
- ability to uncover nonlinear dependencies,
- possibility of generalization of obtained outputs.

Above mentioned reasons are all relevant for problem in question. There are many variables which mutually increase their impact and vice versa. The high precipitation may be more influential in combination with low temperature. But it can be less influential once it is below zero and the rain changes to snow. Higher wind velocity can decrease cycling intensities in low temperatures, but to certain level it may has positive effect while there is a convenient breeze during hot days. More possible interconnections can be described and many may stay uncovered. Nevertheless even if we do not know all relationships the neural network model will take them into account.

The dependency of weather factors and cycling intensities can be both linear and nonlinear. Example of approximately linear dependency is the dependency of cycling intensities and average day temperature. As an example of nonlinear dependency can be mentioned the daily precipitation. Some users may decide not to ride a bike in rain no meter how intensive it is.

Not even the above mentioned average day temperature may cause purely linear relationship. Presumably there is certain group of "weather-insensitive" users riding their bikes every day who are not influenced by any weather factors. The certain temperature can be the threshold for the "weather-sensitive" group of users to start riding. For temperatures below this threshold may occur no or very weak relationship between temperature and cycling intensities.

3 Development of neural networks

3.1 Selected inputs

Application of neural networks on given topic is illustrated in the following scheme (pic.1).

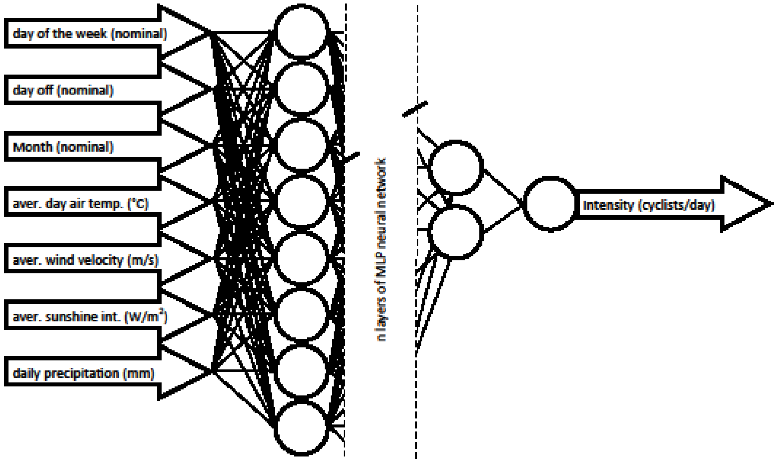

Fig. 1: Schema of neural network application on given topic

The scheme (pic.1) depicts the layer of input variables on the left side, some neurons and their connections, representation of indefinite number of hidden neuron layers and output value on the right side.

Next to the above mentioned weather factors several complementary nominal variables were added into the input layer. These variables represent qualities of the date such as day of the week, working day or day off and month. The date characteristics are important temporal factors influencing the cycling intensities. Higher intensities occur usually during working days (in the case of prevailing utilitarian cycling). Ratio of utilitarian and leisure cycling may be different in working days and weekends. Presumably utilitarian cycling may prove different sensitivity to weather conditions from leisure cycling. For some users cycling can be seasonal activity. Seasons in our scheme are represented by the month.

3.2 Developing and selecting neural networks in STATISTICA

Input and output data were processed in the SW STATISTICA which enables the function “Automated Neural Networks”. This function allows to test two types of neural networks MLP – Multi Layer Perceptron and RBF – Radial Basis

Function concurrently. Neural networks of both types with various number of hidden layers and various activation functions were tested. At the end 3 out of 300 tested neural networks which proved the lowest overall deviation were presented.

According to recommendation of software developers [2] the data were split into samples in following ratio: training (70%), testing (15%) and validation sample (15%). The comparison of input and output values and use of the training algorithm leads to changes in weights assigned to individual neuron connections in the network. This comparison is processed repeatedly as long as the deviation between the predicted and real output decreases. Above described process is called training of neural network and is performed on training sample. The testing and validation data serves to assess model performance.

4 Outputs

In table 1 the parameters of 3 neural networks with the best match of predicted and real outputs are listed. The match rate is represented by the indicators Validation Performance (5th column) and Validation Error (8th column). In the 2nd column the type of network is stated. All cases are Multi-Layer Perceptron networks. Numbers in 2nd column describe gradually the number of input variables (always 24), number of hidden layers and number of output variables (always 1). The networks with the best match use common training algorithms, error functions and activation function for output layer. They vary in the number of hidden layers and in the type of activation functions for hidden layers.

Tab. 1: Networks with the best match

Networks with the best match											
Index	Network Name	Train. Perf.	Test. Perf.	Valid. Perf.	Train. Error	Test. Error	Valid. Error	Training Algoritm	Error Function	Activ. HiddenL	Activ. OutputL
1	MLP 24-24-1	0,969	0,974	0,992	15412	16911	9449	BFGS (Quasi-	Sum.čtvr.	Exponenci	Exponencia
2	MLP 24-5-1	0,969	0,974	0,990	14983	17257	9456	BFGS (Quasi-	Sum.čtvr.	Logistická	Exponencia
3	MLP 24-22-1	0,966	0,974	0,990	16569	17237	10000	BFGS (Quasi-	Sum.čtvr.	Tanh	Exponencia

Better overview of conformity of predicted and real (observed) outputs gives the graph in the pic.2. Every couple of outputs is displayed as blue dot. The horizontal axe refers to real values and vertical axe to the modelled outputs. In the graph outputs of all samples are displayed (train, test and validation sample of neural network MLP 24-24-1). Red line symbolises the perfect match. The closer are the blue spots to the red line, the higher is the accuracy of the model. It is possible to identify the outlying values from the graph and to subtract the exact deviations sizes.

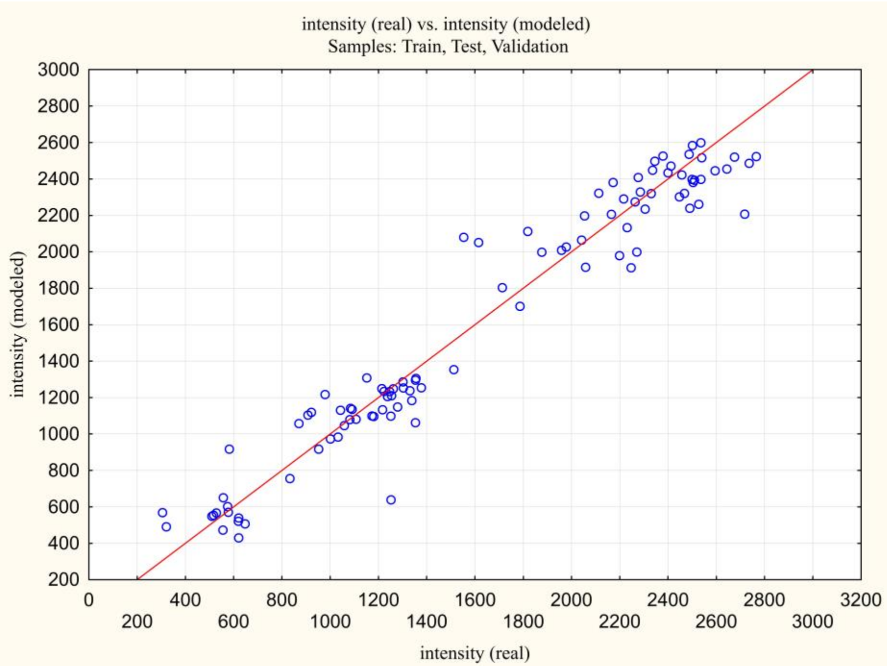

Fig. 2: Graph of modelled and real (observed values)

It is visible that the dots are grouped close to the line – modelled values correlates with observed values.

In the second column of following table (tab.2) the real (observed) values are given. The third column shows the modelled values for MLP 24-24-1 and the last column the absolute deviation for each observed case. Only 3 cases out of 14 the deviation of both values is higher than 10 % and in all cases it is lower than 15 %.

Tab. 1: Table of results for MLP 24-24-1

n.	Table of Result forMLP 24-24-1		
	intensity Real	intensity Modeled	Absolut Deviation
83	621	539	82
91	1058	1046	12
96	578	571	7
133	1330	1238	92
136	1303	1253	50
137	1217	1133	84
284	1786	1701	85
288	2765	2523	242
289	2736	2486	250
293	1151	1308	157
298	2305	2235	70
306	1261	1248	13
327	1042	1131	89
333	2271	1999	272

5 Conclusion

The neural networks are appropriate tool for modelling of weather-cycling relationship. The model predicted the intensity of cyclists with the absolute deviation not exceeding 15 %. To achieve better reliability of the model some further work needs to be done:

- the sample needs to be enlarged,
- outlying values should be analysed, removed or justified,
- more input variables may be add and their influence analysed (e.g. precipitation in particular day time, weather report from the previous day, road closures and reconstructions, various occasional events such as sport and culture, ratio of utilitarian and leisure cycling),
- impact of remoteness of the meteorological station.

6 Implementation and use in practise

One of the basics of the sustainable urban mobility planning is target setting, subsequent monitoring and evaluation. In many cities a goal to increase cycling is set. Among others the relevant indicator for this goal may be the cycling intensities in selected spots. Nevertheless the fair assessment is difficult to achieve because of weather conditions which may cause fluctuations in the order of several percent. With slight modifications the model presented above will be able to filter out the weather impacts. Trends in cycling development could be easily evaluated.

Generalization of the model for other spots in the city is another issue to be explored further. For this purpose it will be necessary to add some input variables characterising the particular spot such as location in the urban structure, road parameters or character of cycling (utilitarian/leisure). If the generalization proves the sufficient reliability it will be possible to assess the importance of selected spots on the bases of manual one-off counting.

Similar approach may be used for walking, public transport, and vehicular transport. Complex assessment of impacts of weather on traffic behaviour consists of many particular research questions and leads to many possible implementations.

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MOBILE ECOLOGICAL TRANSPORT GAME

Tomáš Kadaňka[1]

Abstract: The IMPrint is a mobile online game. It's based on the Windows Phone platform, which aims to highlight the problems of the advanced countries with the environmental impact of their behavior.

Key words: Windows Phone, XNA, Footprint, C#, Game, Game Design.

1 Introduction

The aim of the work is create mobile games on Windows Phone. The IMPrint is an online game that is build to highlight the problems of advanced countries with the environmental impact of their behavior. The game is designed as an urban simulator which solves management and development of the city and its traffic.

2 Contribution structure

Players can battle online in a thrilling seek-domination game world. On the way to progress players must tend to their environmental behavior. The player is put into the position of mayor of the city, where the aim is to ensure the needs of their people and at the same time he is forced to reduce the ecological footprint, which consistently produces each resident. The ecological footprint is basically answer to the question of whether human population lives within the boundaries of acceptable ecological capacity. This ecological-economic game is thus built on the principle of the current problem, which can be summed up by one metaphor: "Imagine the economy as a large animal. How big pasture we need for this animal feed itself?"

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Fig. 1: The main menu of the game The IMPrint

3 Game world

The game is in accordance with the storyline set in a contemporary real world. Game design is directed to the stock form. The game world consists of four types of views.

- The first view shows the city in 3D graphics. Here the player has the possibility to shoot your camera according to your own liking. The realization of this perspective is part of the job.
- Landscape view, the town and its immediate surroundings. Here is used 2D graphics.
- The continent is shown by looking at the broader landscape around, but only to a certain extent, then the player will have to move around the map. The continent consists of 2D graphics.
- World shows only continents. This view is again made up of 2D graphics.

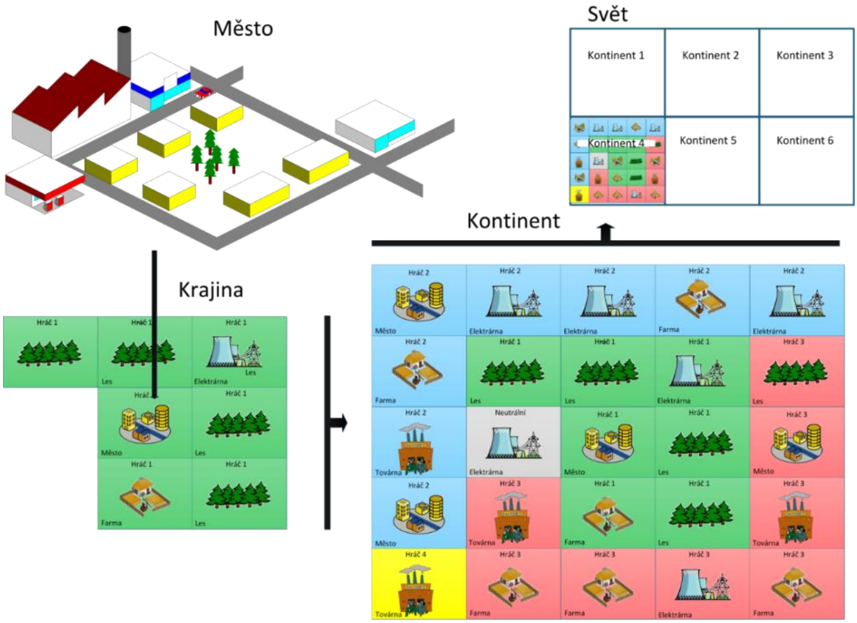

Fig. 2: Game world

4 Online game

Online principle is ensured by means of two parts. The first is a relational database to ensure data persistence. They are stored in a database with all the information necessary game to play online. Platform, which runs on the repository, was elected cloud - Microsoft Windows Azure. The interconnection of databases and mobile applications was necessary to create a service for the client (mobile applications) which ensures data transfer. Communication services are initiated from a mobile client application. For these services we are used WCF.

5 Game town

The fundamental core of the game is to build a city. To do this, the player needs to have sufficient resources and raw materials. In addition to well-known raw materials - such as money, energy and waste, the game added a new, special in its own way, a raw material. The raw material is ecological footprint that is not a means to develop, but the limiting factor. Players do not have to be worried that this material was difficult to understand. Her treatment is the same as the others. Only enhances the game.

Fig. 3: Town

6 Conclusion

Implementation of the game is done using technology XNA and C # language. The structure of the game is formed by modules and arose during the development of a universal library that can be used in the formation of other games. The game has Czech and English localization. In this thesis, in addition to the implementation of the game also designed game play design, from the creation of game principles to the motivational elements of the game.

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COMPARISON OF HYBRID DRIVETRAINS FOR DIESEL HYDRAULIC RAILCARS

Martin Kache[1]

Abstract: The hybridisation of diesel railcars offers the chance of reducing the fuel consumption significantly. The question of choosing the "right" equipment is however not easy to answer. Both electric and non-electric energy storages feature specific advantages and disadvantages with regard to power output, energy content, required space, additional mass and costs. The author has developed a simulation model in order to compare different parallel hybrid drivetrains for diesel railcars with hydrodynamic power transmission. Three different types of energy storages are discussed, including hydraulic accumulators, electric double layer capacitors and a lithium-ion battery. The performances of these different types of hybrid configurations are compared to one another using the track data of several real railway lines. The simulations show the benefits of hybridisation in general and the superiority of electric energy storages in particular. The output of the simulation process may thus help to pave the way for economic decisions.

Key words: hybrid, diesel railcar, fuel consumption, energy storage, energy recuperation, simulation, hydrostatic hybrid system.

1 Introduction

Enhancing the fuel efficiency of railcars has become a growing concern of train operating companies. This is on the one hand due to the legislation on emissions having become stricter and on the other hand to the emergence of fierce competition by intercity busses. Railways have always been an environmentally friendly means of transport. However, the gap between road and rail transportation with regard to energy efficiency is likely to close more and more unless measures are taken to further enhance the energetic performance of diesel drivetrains in railway vehicles.

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One way to achieve this is to implement hybrid drivetrains on diesel-driven rail vehicles thus enabling them to recoup energy while braking [1, 2, 3]. Unlike road vehicles, rail vehicles are designed to last for decades and therefore, it is important to choose durable equipment for storing and converting energy. While hydrostatic energy storages are inferior to electric energy storages with regard to both volumetric and gravimetric energy density, they are less prone to ageing and require less appliances for cooling or monitoring. It is thus not too far-fetched to consider a hybrid configuration based on hydrostatic technology (see figure 1) [4]. The research work that is presented in extracts aims at comparing hydrostatic to electric hybrid drivetrains by means of simulation [5].

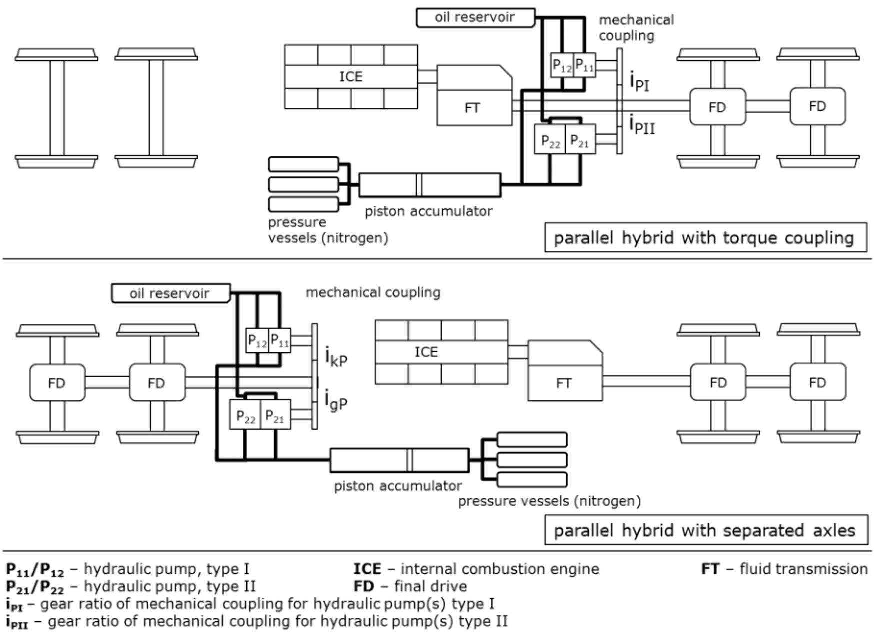

Fig. 1: Possible hydrostatic parallel-hybrid configurations

2 Simulation Model

Simulations where carried out using Imagine.Lab AMEsim. This is a simulation software tool offering a wide range of opportunities to analyse multi-domain systems. The software includes libraries with a great variety of mechanical, logical, mathematical, pneumatic, hydraulic and electric components that can be arranged to represent almost any technical system.

Most of the components can be altered and refined to serve the specific needs of different users. Moreover, the programme offers the opportunity to develop new components either by combining existing elements or defining new ones using C++ as programming language.

The simulation model used to investigate the potential of different hybrid configurations was developed in three stages. The first stage of modelling comprised a set of components representing a two-piece diesel railcar with hydrodynamic power transmission. Therefore, the diesel engine, the turbo transmission (one torque converter and two couplings), the final drives and the translatory behaviour of the vehicle had to be modelled taking into account all the relevant inertias and resistances. The simulation model of both the diesel engine and the hydraulic power transmission is based on efficiency maps and characteristic curves respectively. Furthermore, a simple driving strategy was implemented, forcing the vehicle speed to remain within the boundaries of the maximum allowable speed and to brake early enough to halt at all stops. This stage of the model is henceforward referred to as “basic model”.

The second stage of modelling comprised the implementation of algorithms to automatically adjust the driving strategy in order to save energy. Different measures are taken into account, including the insertion of coasting periods previous to speed reductions and train stops, the utilisation of steep downward slopes to accelerate the vehicle without traction power, and the skip of accelerations on short line sections with enhanced allowable speed. The decision to switch off traction power is based on estimating the acceleration (deceleration) on the track sections ahead of the vehicle. These predicted acceleration values are used to predetermine the travelling time in case of a cut-off of traction power. If the calculated travelling time stays within the limits of a given schedule, traction power will be switched off leaving the diesel engine to idle.

The third and final stage of modelling involved the development of components to represent the energetic behaviour of different kind of energy converters and energy storages. The first included a squirrel cage induction motor as well as a variable displacement pump and the latter comprised double layer capacitors, lithium-ion batteries and hydraulic piston accumulators. These components were combined to constitute different hybrid configurations based on hydrostatic or electric power trains.

Within the simulation model, the electric energy storages are represented by their equivalent circuits consisting of ohmic resistances and capacities.

The simulation of the energetic behaviour of the induction motors, of the power electronics as well as of the hydraulic accumulator is based on equations. In contrast, the performance of the models representing the remainder of the hydrostatic drivetrain is determined by characteristic curves and efficiency maps respectively.

3 Hybrid Configurations

One of the central questions that had to be dealt with was to determine a realistic size of the energy storages and to find common criteria for the creation of comparable electric and hydrostatic hybrid drivetrain layouts.

There are several conceivable criteria to make different drivetrains comparable. One could contrast different hybrid configurations having either the same costs or volume or mass or energy storage capacity.

Information on costs are hard to retrieve and must be considered as vague when it comes to life cycle costs. Considering the volume implies choosing a precise vehicle to estimate the usable installation space, which would be a less universal approach. The author has thus decided to choose the required mass as a criterion to make different hybrid layouts comparable.

Hybridisation may be an option for both, newly developed and existing railcars. Usually, it is more difficult to change an existing construction and turn a conventional vehicle into a hybrid vehicle than designing a vehicle as a hybrid right from the start. It was therefore assumed that the mass of the hybrid drivetrain could be higher in case of newly developed vehicles. The additional mass to be implemented on a bipartite railcar has thus been defined to be approximately 2.4 tons in case of existing vehicles and about 5.0 tons for new vehicles.

The hybrid configurations that have been derived based on these assumptions are specified in table 1. As shown there, two sets of comparable hybrid configurations have been defined containing two electric and one hydrostatic version each.

Tab. 1: Hybrid Configurations

Configuration	Bat 1		Bat 2	Cap 1	Cap 2	Hyd 1	Hyd 2
Mass of hybrid equipment	2421 kg		4994 kg	2390 kg	4787 kg	2400 kg	5070 kg
Type of energy converters		Induction Motor				Variable displacement pump	
Type of energy storage		Lithium-Ion Battery		Electric Double Layer Capacitors		Hydraulic piston accumulator	
Effective energy content of storage	11,2 kWh		25,6 kWh	1,25 kWh	2,5 kWh	0,9 kWh	2,3 kWh
Rated power of energy converters	260 kW		520 kW	260 kW	520 kW	581 kW	1162 kW

4 Simulation Process

Simulations to analyse the behaviour of the hybrid configurations described above need to be based on realistic track data. These could be obtained thanks to the support of Deutsche Bahn Netz for eight different non-electrified railway lines from all over Germany. The data, the author was provided with, comprised the gradients and curve radii of the track as well as the allowable speed and the position of stops and stations.

The simulation process itself includes three steps that have to be taken one after another. The first step is a simulation using the basic model (representing a conventional diesel railcar with hydraulic power transmission) to determine the minimum travelling time between two stations/stops for each line and each travelling direction. The actual running times are derived from these values by adding 3 per cent of extra time, thus allowing the model to apply an energy efficient driving style. That is why a second simulation of the train run of a conventional diesel railcar has to be carried out to achieve a realistic estimate of the fuel consumption since experienced train drivers would always include coasting into the driving cycle in order to save fuel. The fuel consumptions that are determined during this second step of the simulation are used as reference values to assess the effect of hybridisation.

The simulation model of a hybrid railcar is used in the third simulation step. In order to achieve valid results, two criteria have to be checked. The first criterion is the congruence of travelling time. Possible reductions in fuel consumption can only be assigned to the utilisation of the hybrid drivetrain when the running time of the conventional and of the hybrid vehicle are equal. Otherwise, the effects of coasting and recouping energy would overleap.

The second criterion to be considered is the energy balance of the energy storage. At the start of the simulation, the energetic state of the storage is determined by certain starting values such as the pressure and the volume of the storage gas in case of a hydraulic accumulator. To be consistent, the energetic state of the storage at the end of a train run in one direction of a railway line has to be the same as at the start of a train run into the opposite direction and vice versa.

Matching these two conditions may take several simulation runs, depending on how exact the starting state variables of the energy storages were estimated initially. As soon as the simulated travelling times are congruent and the energy balance of the storage is complete, the simulation can be regarded as valid and the results may be used to assess the effect of hybridisation and to compare the different hybrid configurations to one another.

5 Simulation Results

The simulation results for all six hybrid configurations specified in table 1 are shown in figures 2 and 3. The simulated reductions in fuel consumption range from 5 to 21 % in case of the “lighter” hybrid configurations (Bat 1, Cap 1, Hyd 1 – see table 1) and from 10 to 32 % for the “heavier” ones (Bat 2, Cap 2, Hyd 2 - see table 1). The actual fuel savings depend not only on the hybrid configuration but also on the gradient profile and the speed profile of the railway line as well as the average distance between two stops and the type of train (local train (LT) vs. regional train (RT)).

In most cases the hybrid configurations using lithium-ion batteries have proven to produce the best results, but there are few exceptions to this rule. In general, battery hybrids profit from the higher energy density of the energy storage resulting in a higher amount of energy that can be recouped while braking. A problem that has to be resolved though is the often limited charge acceptance of lithium-ion batteries. Especially on lines where there are a number of decelerations from comparatively low speeds recharging the battery becomes more and more difficult. An analysis of the cycle efficiency of the three types of hybrids (battery, capacitors and hydraulic) showed that electric double layer capacitors are clearly superior to both batteries and hydraulic accumulators. Interestingly, the overall cycle efficiency of battery and hydrostatic hybrids turned out to be on the same level of approximately 50 to 60 %. Yet, the efficiency of batteries is likely to rise in the future as the development of this type of energy storage is still in progress.

Although hybrid configurations based on lithium-ion batteries showed the best results in the simulation with regard to achievable fuel savings, it has to be pointed out that the efforts that have to be taken in order to monitor, equalise and temper electrochemical energy storages should not be underestimated.

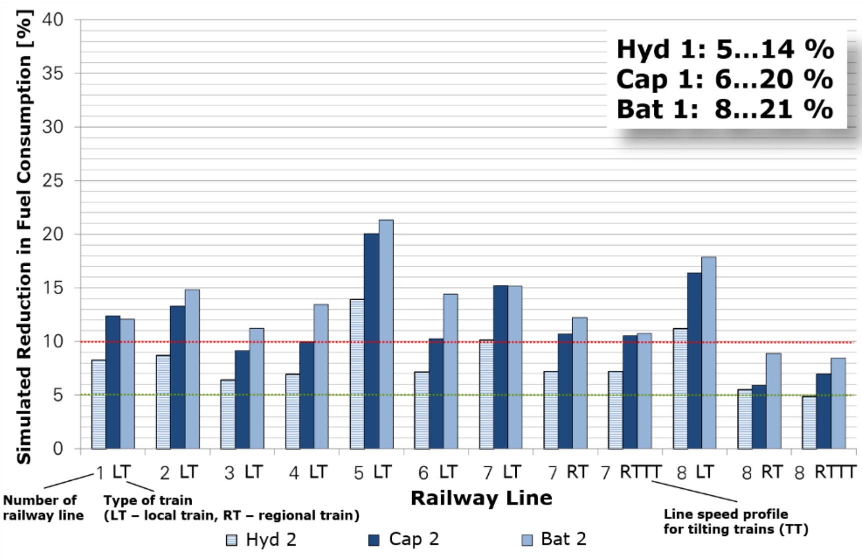

Fig. 2: Simulation results for "light" hybrid configurations

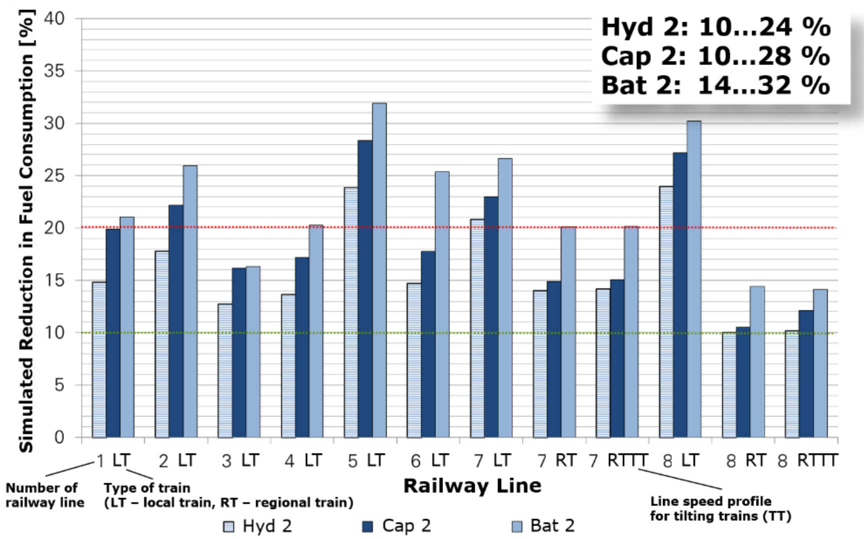

Fig. 3: Simulation results for "heavy" hybrid configurations

6 Conclusion

From a mere technical point of view, hydrostatic hybrid configurations showed to be less promising than electric hybrids in terms of reducing the fuel consumption of diesel railcars. They do, however, offer a significant fuel saving potential between 5 and 14 or 10 and 24 % depending on the allowable mass (and size) of the hydraulic accumulators. The gap between the technologies discussed here is likely to widen in the future as a lot of effort is taken to further develop electrochemical energy storages. Further enquiries will have to be made concerning the economic implications of using the different storage technologies. Hydrostatic accumulators may be cheaper to acquire and to maintain than battery storages. Furthermore, they require less peripheral equipment and are likely to show a better longevity in comparison to electric energy storages. A final decision whether or not to use hydrostatic drivetrains to recoup energy on diesel railcars can only be made after these issues have been considered in addition to the aspects covered by this research work.

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EFFECTS OF FAULTS OF TRANSMISSION AND DISTRIBUTION SYSTEMS ON TRACTION POWER SUPPLY SYSTEMS

Michal Konč[1], Radovan Doleček [2]

Abstract: The paper deals with the effects of faults at the transmission and distribution systems to the traction power supply systems including impacts on electric rail transport. The present electric rail transport is very dependent on the continual electric power supply both for transport infrastructure and also for electric vehicles and units. In the case of faults of traction power supply the transport of electric drive vehicles cannot be operated and the diesel rail vehicles have to use into operation for rail transport as alternative vehicles. This situation is incomparable with road transport due to many aspects.

Keywords: effect, power supply system, energy supply, transport, fault

1 Introduction

Nowadays the rail transport is used for mass transport of persons or goods for different places from the reason of plenty of advantages. Increasing of number of devices and vehicles, which are dependent on good quality of traction power supply, brings also higher demands on electric power from transmission and distribution systems. Each fault of power supply has to significant effect on technology and traffic management in the area without electric energy. For this reason the increasing of the reliability of power supply and the minimization of the time of the interruptions of power supply are the major tasks for rail operators but

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also for the distribution system operators. The main task of the transmission and distribution systems is safe, reliable and high-quality power supply to the final customers. If the power supply is not realized we are talking about interruption of power supply. The transmission and distribution of electric energy is done in the Czech Republic (CR) by the lines with different voltage levels: extra high voltage (EHV) of 400 kV, high voltage (HV) of 220 kV or 110 kV, middle voltage (MV) of 35 kV or 22 kV or 10 kV or 6 kV and low voltage (LV) of 0.4 kV. Each voltage level is evaluated from the viewpoint of significance of events with impact to the customers. The research activities are focused on the mapping of areas of reliability and continuity of energy power supply. The evaluation is done on the side of operator of distribution system - ČEZ Distribution in the CR with the goal decreasing of impact to the customers [3,4,5].

2 The analysis of the effects on the interruptions

The analysis (in the context of annual power supply of energy of 45 TWh) was processed for areas of distribution systems by ČEZ Distribution. These systems are used for power supply of the customers by lines with voltage levels (LV, MV and HV) [2]. From the reason of the data sensitivity and data exploitability the results of the analysis are presented only for previous years [1,6,7].

Fig. 1: The map of the areas of distribution systems and operators in the CR [authors]

The comparison of this situation in the CR (ČEZ Distribution and E-ON Distribution, PRE distribution) with other selected European countries is shown in Fig. 2 and Fig. 3. The effect on SAIFI indicators at operators has also effect of number of overhead lines or cable lines and number of customers per km^2 as well.

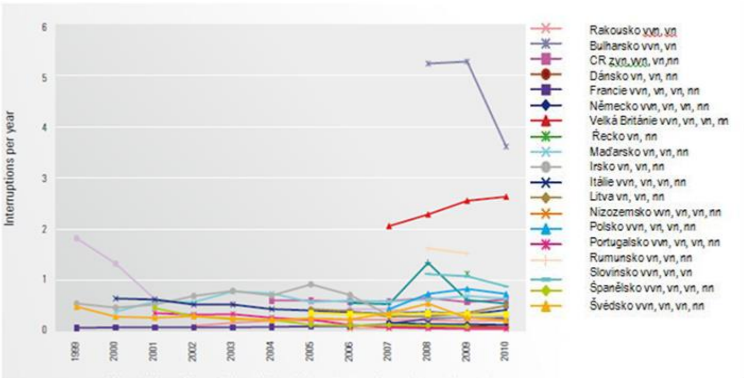

Fig. 2: The comparison of SAIFI indicators for all events - over 3 min (i.e. planned and unplanned interruptions) in the selected countries in Europe [1,6].

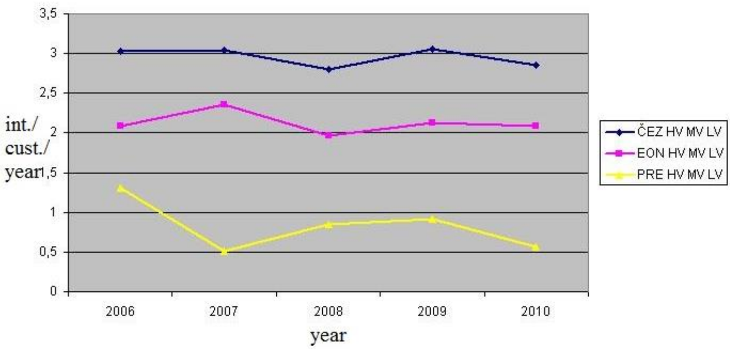

Fig. 3: The comparison of SAIFI indicators for all events - over 3 min (i.e. planned and unplanned interruptions) in the CR [authors]

The main goal of the analysis was to trace the effect on the various parts of system devices from the viewpoint of interruption of power supply. For this purpose the methods of statistics were used. The various effects on interruption in different years are shown in Fig. 4 and Fig. 5.

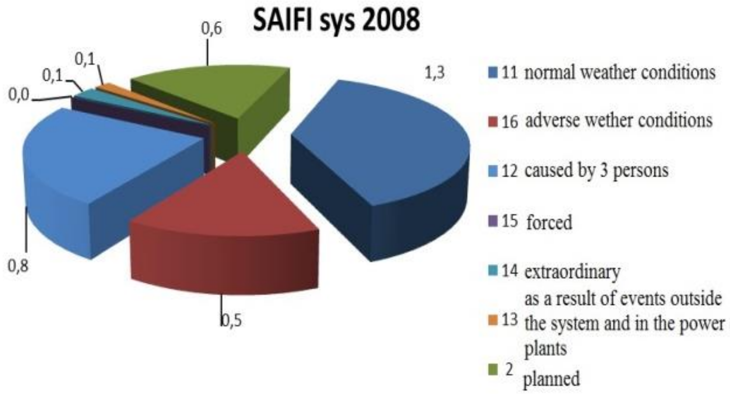

Fig. 4: The effect developm. of SAIFI indicators for all events - over 3 min. in 2008 [authors]

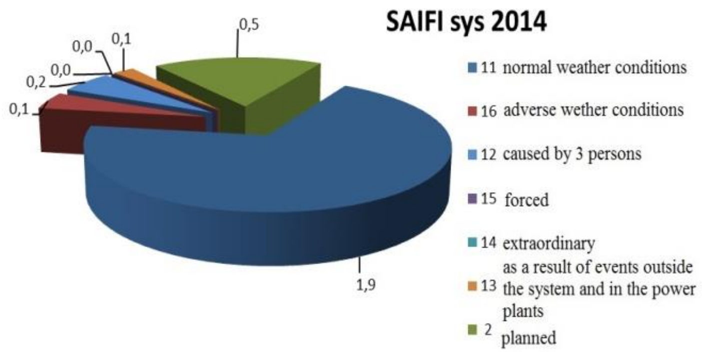

Fig. 5: The effect developm. of SAIFI indicators for all events - over 3 min. in 2014 [authors]

The other figures are shown: the effects of extreme weather on the number of faults since 2006 - Fig. 6, the distribution of the number of unplanned events at lines according to the cause of origin – Fig.7 and the distribution of the effect of selected damaged elements at SAIFI for MV (all categories) from 2008 to 2013 – Fig. 8.

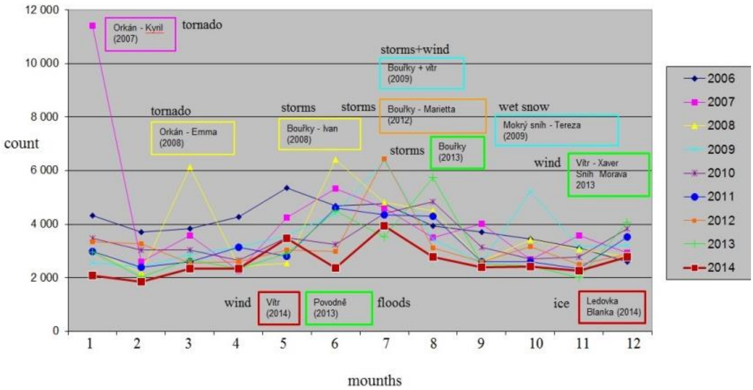

Fig. 6: The effects of extreme weather on the number of faults since 2006 [authors]

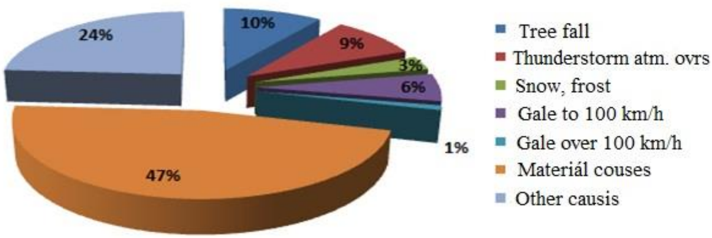

Fig. 7: The distribution of the number of unplanned events at lines according to the cause of origin [authors]

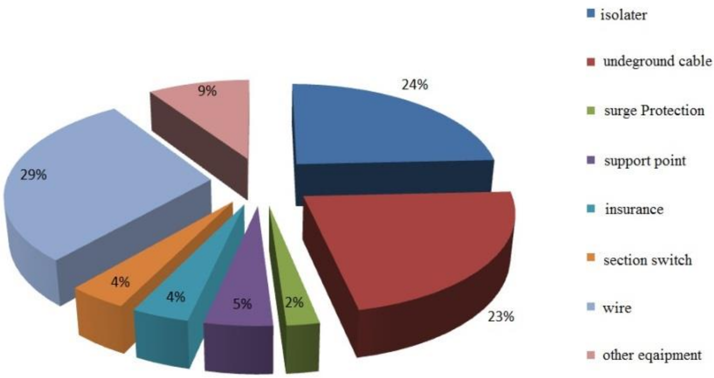

Fig. 8: The distribution of the effect of selected damaged elements at SAIFI for MV (all categories) from 2008 to 2013 [authors]

3 Conclusion

The part of research activities, which are shown in this paper, maps in particular the effects of the interrupt in the distribution systems of the Czech Republic. These effects have also impact on operation of traction power supply system and electric rail transport as well. The significant effects on interruption have faults of elements in distribution systems (e.g. isolator) and weather with direct and indirect effect to the overhead lines. The solution of the first category of effects can be reduced by regular preventive checks. The solution of the second category of effects is very difficult solve by technical measures but the number of effects can be reduced by preventive measures (i.e. by potential falling trees or their branches). The other solutions of some effects can be reached by replacement of overhead lines by cable lines, but this is not applicable for traction power supply system.

Acknowledgement

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TRACTION SYSTEM UNIFICATION ON THE CZECH RAILWAY

Tomáš Krčma[1], **Radim Brejcha**[2]

Abstract: this paper deals with DC and AC electric traction systems, which both are now used in Czech republic as a historical relic. Based on technical, environmental and economical comparsion, reasons for step-by-step conversion to AC system covering whole country are presented. Emphasis is laid on power efficiency and reliable system operation, compliance with TSI and fixed installation costs. Traction systems abroad, international train traffic requirements and prospective high speed lines development, as well as safety appliance compatibility and electrical safety are also taken into account.

Keywords: traction systems, railway infrastructure, power transmission efficiency

1 Introduction

Most of countries in the Europe employ only one fundamental electric traction system with minor exceptions (high speed lines, narrow-gauge lines). Choice of the system corresponds to technical progress at the time of electrification. During pre-war era, DC 1,5 kV (e. g. in France) and AC 15 kV 16⅔ Hz (e. g. in Germany) were mostly used. Three-phase 50 Hz AC systems (in Italy) or one-phase 50 Hz AC systems (in Hungary – Ganz-Kandó system) didn‘t become widespread. Early after war, railways mostly decided to employ DC 3 kV system (e. g. Poland), while countries, which began railway electrification later in the 60’s (e. g. Bulgaria, Romania, Yugoslavia) used already an AC 25 kV 50 Hz system. Most countries in later electrifications used existing system, in spite of its shortcomings; only some fo them converted one systems to another to achieve unification (Italy from three-phase to DC 3 kV). Only three railways decided in the 60’s to use new developed AC 25 kV system parallel to the old one DC – France, Czechoslovakia and Soviet Union. In Soviet Union both

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systems are spread irregulary, while in Czechoslovakia the border between them was roughly on the east-west axis of the country, DC system being used in the north and AC system in the south.

In Soviet Union (Russia) due to hundreds-kilometer-long distances between system change points and much smaller number of trains compared to european practice, there is nearly no need to unify the systems and even to build two-systems locomotives. However, area of our country, mostly north-south direction of freight traffic, energy efficiency demands and physical limits of 3 kV DC system force Czech Railway Infrastructure Operator (SŽDC) to deal with possible unification to AC 25 kV system. In Slovak republic, where we find only 1 system change point (south from Púchov) and AC-electrified lines longer than DC-electrified, the conversion has been already planned and is in progres.

2 AC/DC systems from the train operator point of view

2.1 Trans-european freight transport

Czech Republic can play quite important role in international freight traffic, due to its location roughly in the middle of the european continent. Both north-south and east-west traffic routes can lead via our country. However, after breaking legislation barriers for rolling stock, for many operators it is easier to past our country by trains while running through whole Europe. The reason is not only overload of czech main (corridor) lines by passenger transport, but also sections with DC-fed catenary. Although those sections are very short compared to rest of the route on AC (see Picture 1), more expensive and less common locomotives capable to 3 kV DC would have to be employed.

Therefore it is cheaper (and sometimes faster) to travel from north to south via Austria instead of our country. We can meet many freight AC 25/15 kV DB locomotives in Romania and Bulgaria, hauling trans-european trains connecting North or Baltic sea with the Black Sea. None of these locomotives ever travelled via Czech Republic from above mentioned reasons.

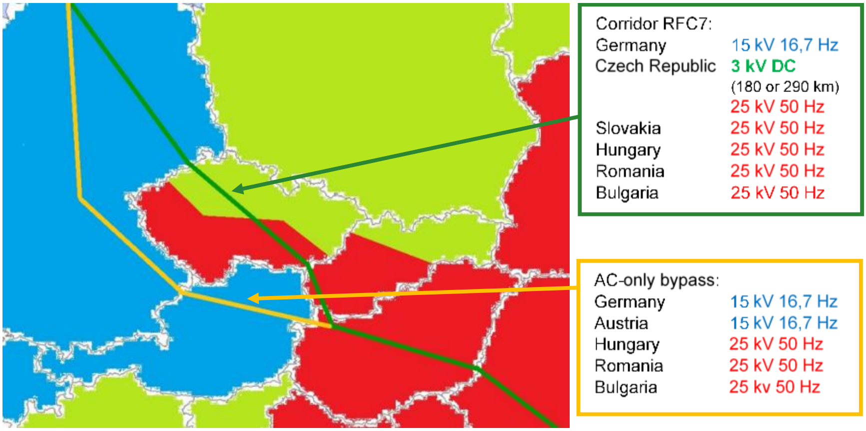

Fig. 1: Freight routes in north-south direction

2.2 *International freight transport*

Until recently, there were two DC-fed connections to Slovakia (Ostrava – Čadca, Valašské Meziříčí – Púchov). Via these lines – former 1st Czechoslovakian corridor – intensive international transport flowed using single-system DC locomotives. During Bratislava – Žilina line reconstruction, this situation will change. At the moment, station Púchov has been already switched-over to AC system, so only route via Ostrava is available for DC locomotives. When the conversion is finished, only AC/DC locomotives will be usable on the northern connection between Czech and Slovak republic. For trains connectiong eastern Slovakia with western Europe it will probably be more suitable to travel via Austria instead of our country (see Picture 2)

As for rolling stock for freight transport in the Czech republic, DC locomotives with rheostatic control had been built till begin of the 80's (classes 130, 131). Later, about 200 DC locomotives with thyristor control were built till the beginning of the 90's (class 163/162). Because complete conversion to 25 kV system will be long-term process lasting for decades, it can be expected most locomotives with rheostatic control to reach their lifetime limit before conversion is finished. Thyristor locomotives, on the other hand, can be upgraded to both systems during overhaul. Such upgrade shall not be very difficult, because those locomotives are members of unified AC-DC construction classes 163-263-363.

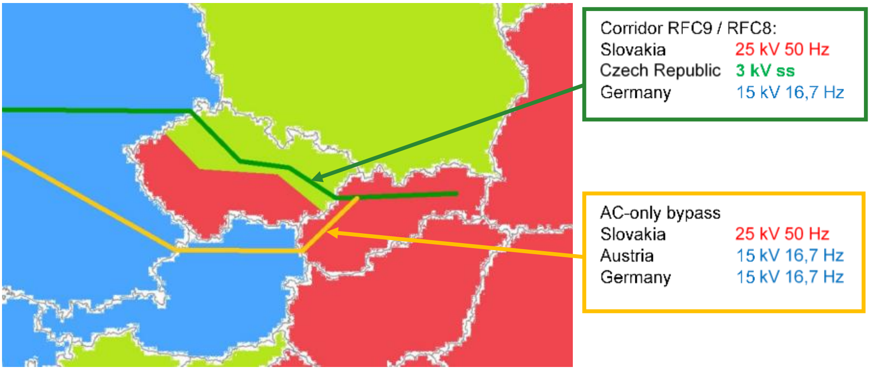

Fig. 2: Freight routes in east-west direction

2.3 Passenger transport

In international passenger transport, with some exceptions (classes 162, 151) mainly more-system locomotives are already used. In local transport the situation is completely different – DC locomotives and mainly DC electric suburban units are widely employes. Most of electric units used in Prague and Ostrava agglomeration (class 471) were build in last 5 – 15 years and shall be in operation for dozens of years in the future. There are two possibilities to solve this issue: to sell all units to country, where DC system is to be kept for future (e. g. Poland) and to buy new AC units, or to rebuild of DC units extensively to include transformer and other AC equipment, which was not proposed to be accomodated in the vehicle. This critical point shall be a task of economical investigation.

3 AC/DC systems from the infrastructure operator point of view

3.1 General comparsion of both systems

In the Czech Republic, there is 3200 km of electrified lines, from those 1800 DC 3 kV system and 1400 km AC 25 kV system. Both systems are known to have several advantages/disadvantages, which are resumed in following table. Disadvantages are marked with red colour.

Tab. 1: Comparison of AC and DC systems

AC	DC
Economical view	
Substations in mutual distance 40 – 60 km. Substation is simplier than DC, but for higher rated power. Therefore price for AC substation is similar to DC one.	Approx. 3-times more substations in mutual distance 15 – 25 km. As a result, DC system is at least 3-times more expensive than AC as for substations.
Typical conductor cross-section is 150 mm^2 Cu per track. Smaller foundations, lighter masts.	Typical conductor cross-section is 390 mm^2 Cu per track. Bigger foundations, heavier masts. Contact line 10 % – 20 % more expensive than AC.
Substation must be connected to 110 kV or higher grid with sufficient short-circuit power. Expensive 110 kV lines may be necessary.	Substation can be connected to either 22/35/110 kV grid.
Compatibility with planned high speed lines traction system. Common substations possible.	Separate substations for conventional and high speed lines must be build.
Negligible active losses in energy transmission.	Energy losses in transmission to vehicle can be up to 20%.
Safety view	
Rails can be earthed, masts can be connected directly to rails and earth. Low potential of dead parts by faults.	Rails shall be insulated from ground, masts cannot be connected directly to rails (VLD necessary). Higher potential of dead parts by faults.
Low currents in rails, return current flows via earth. No potential of dead parts in operation.	Heavy currents in rails, can appear high potential on rails and dead parts in operation.
Wide range of protections of contact line can be used (e. g. distance protection).	Only overcurrent protection is available – problems with distinguishing short-circuit and heavy load; ground faults may not detected.

Tab. 2: Comparison of AC and DC systems - continued

AC	**DC**
Return current can flow via earth without endangering pipes and cables	Stray currents can damage pipes and cables and even destroy home installations
Technical view	
Two substations cannot fed one section; only exception is parallel switching on 2-track line in switchnig stations.	Two substations can fed one section without special provisions (circuit-breaker tripping synchronization only).
Possible RF interferences due to sparking, high electromagnetic fields along the line.	No RF interferences.
Possible 50 Hz interferences to communication lines, cable shielding necessary.	No cable telephone cable shielding needed.
Regenerative braking into national grid without special provisions.	Regenerative braking into national grid impossible.
Compatibility with AT-system (2×25 kV), which allows increase of substation distance (e. g. due to lack of 110 kV feeding line).	No possibility to increase substation distance.
High design reserve and low voltage drops, which cannot disturb train operation.	Due to economical reasons nearly no design reserve. Accidental traffic accumulation leads to deep voltage drops, which disturb train operation, or even force overcurrent protection tripping.

3.2 Energetic comparsion of AC and DC systems

Not only lower investment, but also lower operational costs prove efficiency of the AC system. For quantitative comparsion, a typical case of modern locomotive hauling freight train at constant speed 100 km/h, consuming constant power of 4 MW (at cos $\varphi = 1$ on AC system) is considered. Electric parameters of DC traction circuit are following ([4], [5]):

- Substation distance 20 km, 2-side feeding,
- Contact line resistance 46 mΩ/km (contact line type „J“, conductors Ri150+Cu120+Cu120 reinforcing feeder),
- Return circuit resistance 10 mΩ/km (rails R65 or UIC60, impedance bonds DT0,75, cable bonds 2×3×20 Fe, 20 % current flowing via earth as stray current).

Electric parameters of AC traction circuit were considered following:

- Substation distance 40 km, 1-side feeding,
- Traction circuit impedance (210 + j·400) mΩ/km (according to measurements on contact line type „S“, conductors Ri100+Bz50, return circuit rails R65 or UIC 60)

Although other parameters and feeding configuration are possible, especially parallel connection of rails or contact lines on 2-track lines, above mentioned parameters have been used for the comparsion because they produce relatively „worst“ results. Therefore some reserve for contact line wear, traffic closures, faults in substations etc. is provided. Distance between AC substations twice as between DC substations has been taken from presumption, that each second substation will be removed during the system conversion. Simplified feeding diagrams are on pictures 3 and 4 (TT = AC substation, SpS = switching station, TM = DC substation).

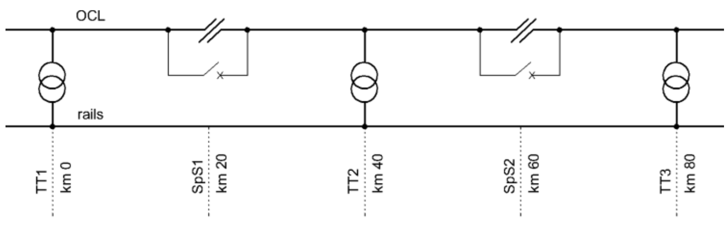

Fig. 3: Feeding diagram on AC system

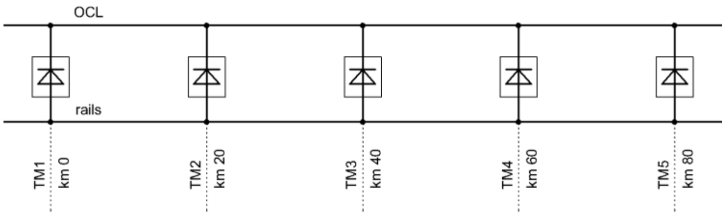

Fig. 4: Feeding diagram on DC system

Results of comparsion are in Attachments 1 to 4 at the end of this paper. Diagrams show voltage drop, power and energy losses in traction circuit (contact line + return circuit) as the train moves along the line. Substations and switching stations are located as on pictures 3 and 4. As expected, on both systems the maximum losses/voltage drops are between substations, while due to 2-side feeding on DC system voltage drop changes quadratically along the distance.

From diagrams is clear, that although absolute voltage drop on AC system higher than on DC, relative voltage drop is almost 6-times higher on DC system than on AC. It shall be considered, that although european standard EN 50163 [7] permits lowest permanent voltage on DC system 2,0 kV, according to TSI LOC&PAS [8] vehicle shall reduce consumed power automatically, when voltage falls under 2,7 kV. This measure prevents substation overloading and possible circuit breaker tripping due to overcurrent, but also prevents modern locomotives to produce full hauling force.

Similar ratio is we find by power losses. Compared to power consumed by the locomotive (4 MW), we come to conclusion, that on DC system the maximum losses are nearly 15 % compared to 2,5 % active losses on AC system. It shall be mentioned, that about 5 % reactive losses due to traction circuit inductance have no influence towards national grid, because they represent cos φ = 0,999.

The most important as for energy efficiency of both AC and DC systems is diagram in Attachment 4, which represents longitudial integral of power losses from previous diagram. At train speed of 100 km/h and locomotive power of 4 MW, during 80-km long trip locomotive consumes 3,2 MWh of electric energy. On DC traction circuit, during the same trip, 290 kWh of energy is lost in traction circuit escaping as heat in the ambient. As a result, 9 % of energy supplied from substation is lost. However, on AC system energy losses are for the same case 38 kWh, that means 1 % lost energy only.

Above mentioned comparsion is based on a very simple model with one locomotive in feeding section. Real results vary on the substation distance, contact line type and condition, type of rails and track circuits, traffic intensity etc. Practical results are generally worse, e. g. Slovak railways [2] declare average losses 17 % on DC and 11 % on AC (without specifying whether substation efficiency is included in data).

4 Example of DC-AC system conversion

In Russia, traffic practice is different than in Europe – traffic density is relatively low, while weight and power of individual trains is a multiple of the european ones. From two- to four-section locomotives are being used, e. g. class VL-10 with power of one section 2680 kW, that means 10720 kW power consumption of four-section traction unit. It is clear, that in such conditions the limits of DC system shall be much more evident and in some cases, conversion of earlier DC-electrified lines to AC is being performed.

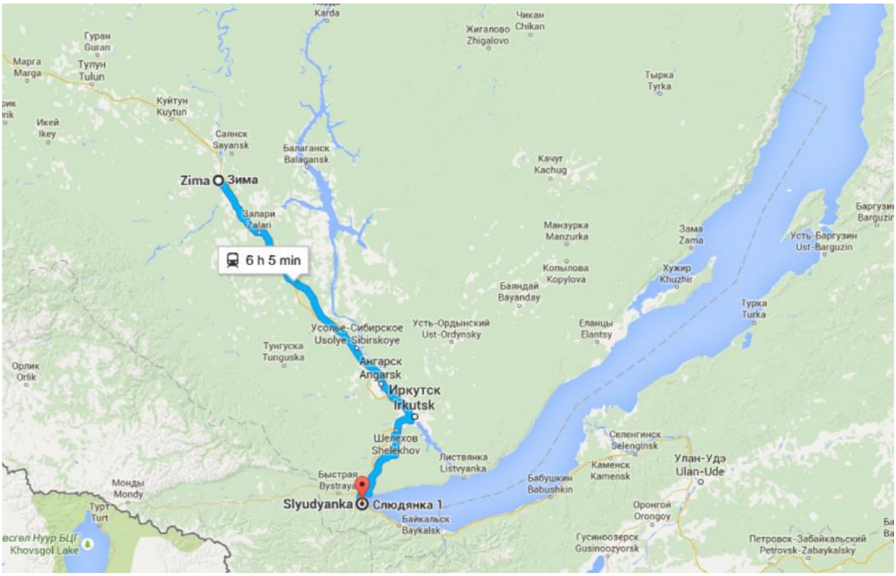

Fig. 5: Location of Zima – Sljudjanka line (source: maps.google.com)

An example of conversion [6] is 386-km long section Zima – Sljudjanka on trans-siberian railway near lake Bajkal – see map on Picture 5. It had been electrified in the 50's with DC as an island among non-electrified lines. Later complete electrification of trans-siberian railway brought AC system to connecting lines and in both Zima and Sljudjanka became system change stations. But locomotive interchange wasn't an issue – the main problem was energy efficiency and traffic economy on DC system. Soviet railways tried to increase its power to allow the trains with weight standard on AC system to be hauled on DC system also. Number of substations has growin – in the 80's twice the original. Average distance between substations was 11 km, while minimal was 6 km. Contact line was complemented with reinforcing feeders to 600 mm^2 for one track (compare with Table 1, typical cross-section on Czech Railways).

All these provisions didn't solve all problems and further train weight increase was found as impossible. After economical calculations it was decided at the end of 80's to rebuild all fixed installations to AC 25 kV. Conversion took about 5 years. Contact line was generally kept, but insulators, disconnectors and other insulating devices had to be changed. Dedicated substations were (without disturbing DC operation) complemented with AC 25 kV transformers and switchgear. From forced investments, in some tunnels and underpasses, the track level had to be lowered and ballast bed changed to allow lowering of contact line conductors as well. This was necessary to meet longer air gap to grounded structures at higher contact line voltage. Unshielded communication cables had to be changed to prevent interference.

Whole 386-km long line was switched over to AC system at once during 6-hour long traffic closure. At this time, freight traffic was partly suspended, partly shifted to BAM (Bajkal-Amur railway). Passenger traffic was replaced by busses.

After conversion, energy consumption together with costs for operation and maintenance has fallen to 20 % of costs on DC operation. After two years, investments costs for conversion were paid by operation savings.

5 Conclusion

Traction system unification is an important step towards Czech railway competitiveness. It will satisfy most of train operators, allow further traffic grow and provide lowering cost for maintenance as well as save electric energy. On example is shown, that such conversion is technically possible and investment costs can repay in very short period, especially on heavy loaded lines.

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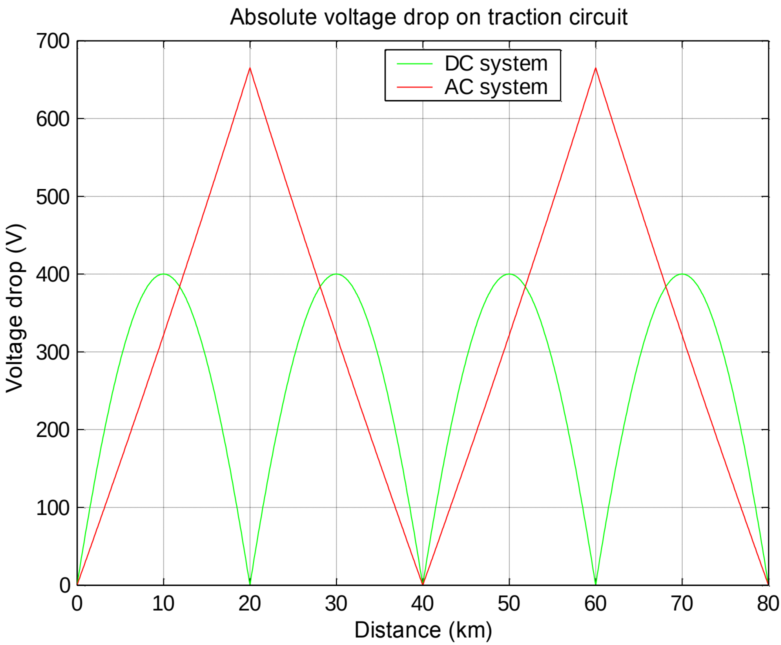
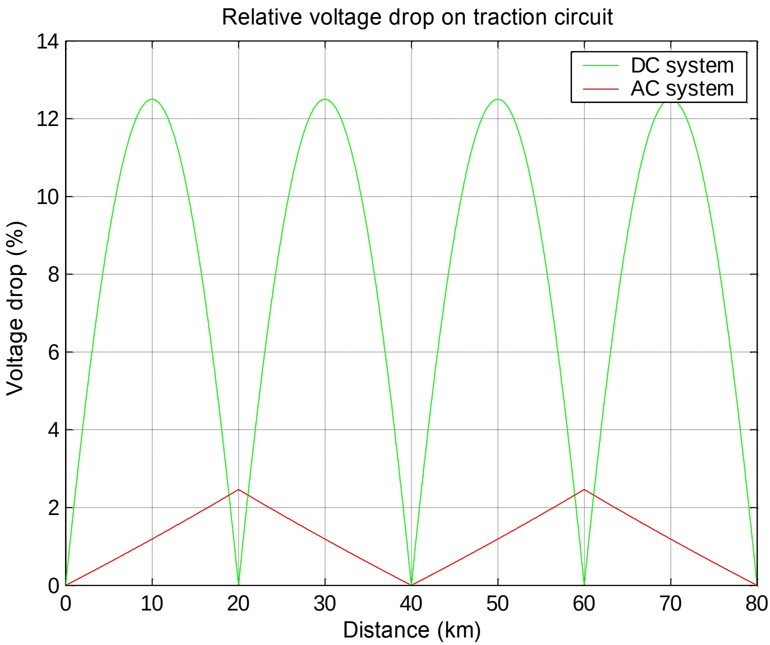
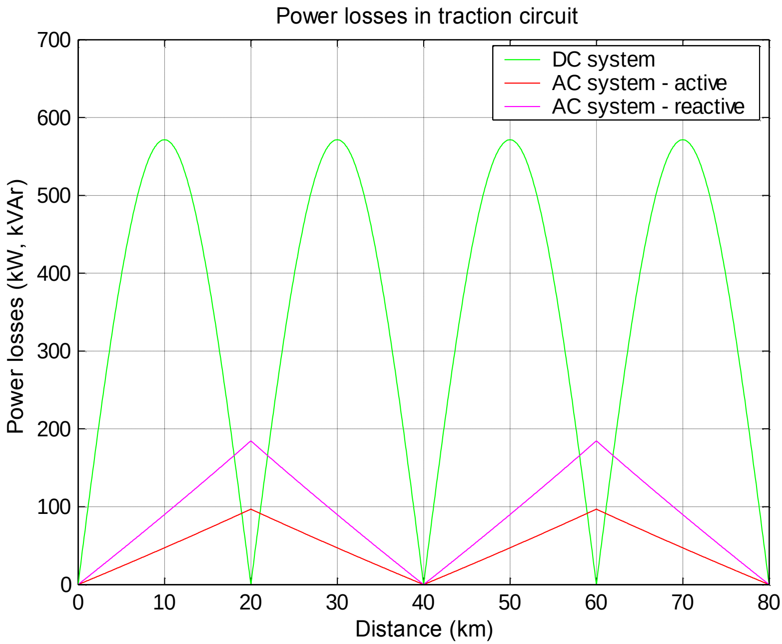
Attachment 1: Comparsion of DC/AC systems – absolute voltage drop



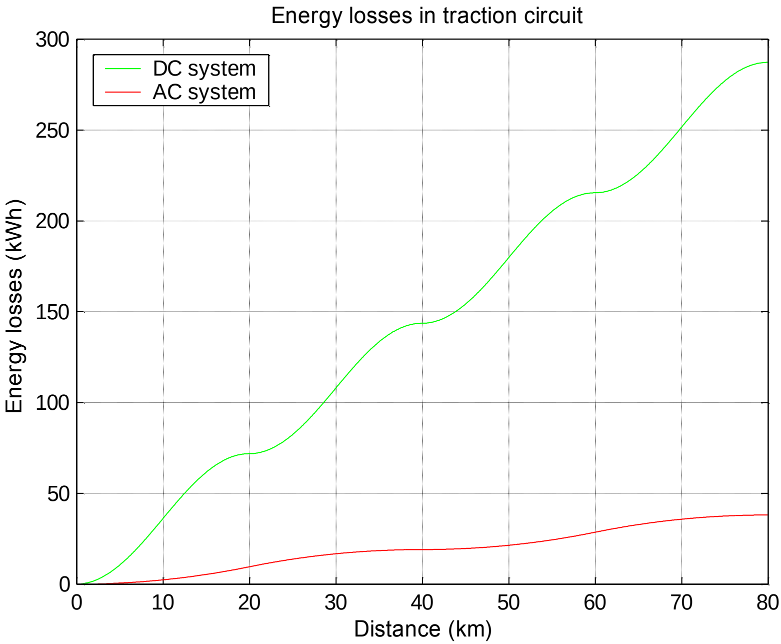
Attachment 2: Comparsion of DC/AC systems – relative voltage drop



Attachment 3: Comparsion of DC/AC systems – Power losses



Attachment 4: Comparsion of DC/AC systems – Energy losses



NEW TRENDS IN TRANSPORT MARKETING

Nina Kudláčková[1]

Abstract: The article deals with modern marketing trends in the transport area.
Key words: transport marketing, guerrilla marketing, ambient media, viral marketing.

1 Introduction

Marketing, so as transport, passes through quick chops nowadays. Obviously it started in nineties, when marketing came into the global phase and had to learn to work with demand in different ambience with specific economic conditions.

2 Guerilla Marketing in transport

In present also different forms of marketing communications quickly change and new kinds of communication ways are used more and more. One of such communication forms is called Guerilla Marketing and is based on the orientation on customer and his needs by the force of fun, courage, conception, idea and pertinacity with low requests on the money budget.

The Guerilla Marketing concept was first used by American writer and manager Jay Conrad Levinson in 1984 in his book „The Guerilla marketing“. In this book is the conception of Guerilla Marketing described as unconventional marketing campaign focused on maximum effect with minimum costs. [1]

As example is on the picture below mentioned the advertising campaign on the Jeep cars that sententiously describe basic Gureilla Marketign idea. The advertisement engage big amount of people with the only costs on time, energy, paint and paint brush.

As Thomas Patalas, the German marketing specialist and sociologist says, time of Gureilla Marketing comes when customer is not compliant to react on

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conventional marketing situations or feel nagged by these communication instruments. [2]

Marketing specialist J. C. Levinson see the position of small business companies same as position of small guerrilla groups realizing the guerrilla fight. Those have no modern marketing instruments or big money budget even so they can win in the war with big competitors by the force of good idea. Big advantage of the Gueilla Marketing he sees in the flexibility, personal relations, speed, entertainment, surprise and good reputation. [1]

Fig. 1: The JEEP advertising campaign [3].

The success of Gureilla Marketing campaign is based on the dialog with customer and on marketing combination which means using more communication media in the same time. It is important to make such Guerilla Marketing campaign that makes people feel they were not hit by the marketing campaign and if so they do not feel bad about it. Campaigns must be creative, unique, innovative and unreproducible and above all the campaign must convey message.

3 Branches of Viral Marketing

As Mark Zuckerberg mentioned in 2007 people interacts each other and there is nothing that influence them more than the recommendation from someone they know very well.

And so Word of Mouth became one of basic instruments of the Guerilla Marketing. The more that in present this form of marketing changed form by the force of social networks and different modern forms of communications from ICQ through Skype to modern communication applications using smartphones and PDA.

Word of Mouth became very quickly basic instument of Guerilla Marketing because it enables viral broadening of information.

One of other branches of the Guerilla Marketing and Viral Marketing is so called Buzz Marketing which comes out from the Word of Mouth and makes it go through different forms of communication. It is based on putting out the information that something big is coming very soon. Such campaigns are usually realized by the force of public passenger transport.

Fig. 2: KitKat campaign as example of out-of-home communication [4]

Word of Mouth so as the Guerilla Marketing is form of so called out-of-home communication as one of modern marketing instruments. The out-of-home communication is based on using common things as place of advertise but in different form than usual. One example you can see in the picture above.

4 Ambient Marketing in transport

And so here we have another kind of Guerilla Marketing called Ambient Marketing, using so called Ambient media. This term mean nonstandard or ad-hoc media which affect out-of-home so as Ambient media advertising can be used in conjunction with traditional media or as a stand-alone activity. Successful ambient media campaign is based on good media format in combination with effective message.

Fig. 3: Example of Ambient Marketing in transport [5]

And in transport area it is possible, because we have many possibilities to use ambient media in transport area and so increase demand by giving to marketers new places for point-of-sale communication with big versatility.

Fig. 4: Example of Ambient Marketing in transport [5]

Fig. 5: Example of Ambient Marketing in transport [5]

Ambient Marketing use alternative forms of media to use fun and humour to hit customers on unexpected places as for example shopping bags, means of transport or sculptures are.

Fig. 6: Example of Ambient Marketing in transport [6]

Ambient advertising is about placing advertisements on unusual items or in unusual places and so Ambient advertising can be found anywhere and everywhere.

Such advertisement campaigns make people think different about some places or even thing differently. There are many such places in transport area.

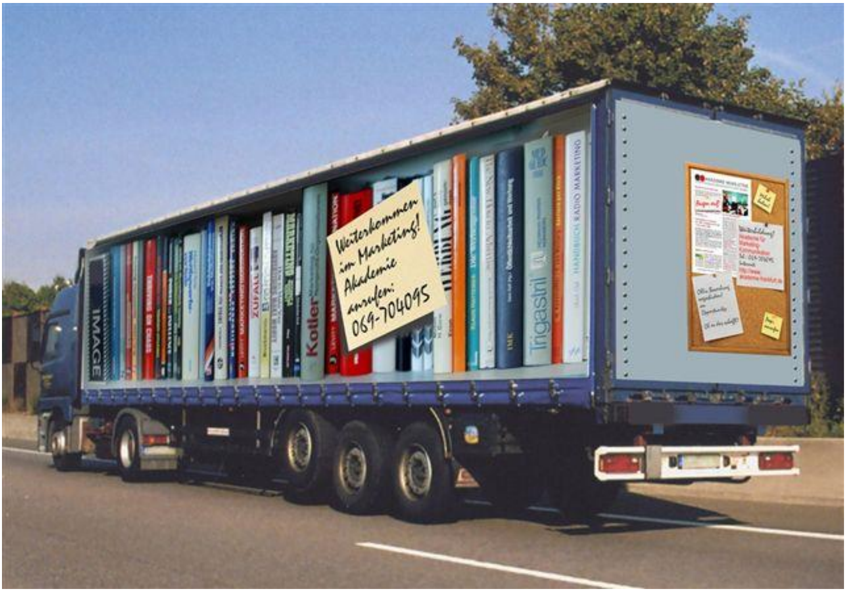

Fig. 7: Example of Ambient Marketing in transport [6]

It is simple, funny, low cost and it makes common things look interesting.

5 Conclusion

As mentioned and showed above, there are many ways how to use transport for big Guerrilla Marketing advertising campaigns because it is the way how it works in present and probably even in the future because transport is part of everyday life and it probably will still be because nothing stay, everything is in the move and we want to show that people can enjoy all kinds of transport.

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Summary: The article deals with modern marketing trends as for example Guerilla Marketing, Viral Marketing or Ambient Marketing are and shows how to use it in the transport area. Such marketing campaign can be cheap, funny, memorable and very successful for all participating.

BASIC PRINCIPLES AND PROPOSALS FOR THE IMPROVEMENT OF SUSTAINABLE DEVELOPMENT CAPABILITIES IN THE POSTAL SYSTEMS

Dragan Lazarević[1], Momčilo Dobrodolac[2], Libor Švadlenka[3]

Abstract: The postal systems include an integrated network of public and private postal operators which are characterized by a strong infrastructure and appropriate human, technical and technological resources. The activities of these companies have a negative impact on the environment, which represents one of the most delicate problems of sustainable development. The negative impact is especially present through the emission of greenhouse gases which cause a climate change. The aim of the continuous efforts of the Universal Postal Union (UPU), through specific regulations and initiatives, is creating a system whose basic characteristics is a social responsibility and economic and environmental efficiency. This paper presents the basic principles and proposals for the improvement of sustainable development capabilities in the postal systems, through the sub-systems performance and adequate assortment of postal services.

Key words: postal system, sustainable development, global trends.

1 Introduction

Postal system includes a highly developed distributive network, whose basic characteristics are the great number of postal items, plenty of business and customers' subjects and developed infrastructure. The functioning of such a system has an important effect on the environment.

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Universal Postal Union (UPU), which enacts some regulations, decisions and strategies in functioning of postal activity, has the key role in the business of postal companies at a global level. UPU initiated the Program of environmental protection in 1994, founding the Working group for environmental issues. At the same time, the Project group for sustainable development was founded (the Sustainable Development Project Group) with the aim to enable support to the operators in their efforts to integrate sustainable development into their business [7]. Three main dimensions of sustainable development are the following:

- Economic,
- Ecological and
- Social

In order to achieve the goal of sustainability, it is necessary to act through all of these three dimensions. Postal operators should satisfy the needs of the population, their needs through the economic profit, but also to accomplish the principles of environmental protection.

In October 2012, on the 25th UPU Congress in Doha, Postal Strategy was adopted for the period 2013- 2016, which defines as one of the four aims the promotion of sustainable development of the postal sector [14]. Based on this strategy and the earlier efforts, many postal operators started to apply the global mission of sustainable development through various tendencies and sustainability policy.

A complexity of the system implies the strategic activity in all the sub-systems separately. Every postal company includes two large sub-systems:

- The sub-system of postal services providing and
- The sub-system of postal services assortment.

The infrastructure is necessary for the postal service providing, which can be considered as the “green” infrastructure in a sustainable development.

2 Global trends of sustainability in the postal system under authority of Universal Postal Union

In the past period, a large number of various factors had an effect on the role of postal sector in the communications market. The effects of competition, privatization, liberalization, demand of customers for better and more reliable services, as well as the new technologies have caused that the postal operators must change their operative and financial strategy in order to stay competitive. Postal systems don’t function separately, but some social and economic factors influence them. Despite different development of some operators and systems, a trend applied for all, refers to the approach to the concept of sustainable development.

Under authority of Universal Postal Union and according to the strategy from Doha, that has been adopted, postal operators are concentrated to this concept step by step. Economic dimension of sustainable development has been distinguished as alarming dimension.

2.1 Economic dimension of sustainable development in global postal market

More than 600 000 posts in the world form a postal system, which becomes the largest global and distributive network on the planet. More than 1 500 000 vehicles, a large number of motorcycles and airplanes are being used daily to accomplish postal service. Production, technical and technological systems and employees require the energy consumption and other kind of energy every day such as water, paper etc., which have a negative impact on ecology. To reduce this negative impact, it is necessary all the actors to take part in it. Also, it is essential that all companies and organizations accomplish their aims and business policy according to the environmental protection and negative emissions reduction [12].

In 2008, the postal operators received the first questionnaire from Universal Postal Union for greenhouse gas emissions. The goal of this questionnaire, which consists of three parts is to determine the fuel consumption on an annual basis, as well as the number of passed kilometres for each vehicles and the amount of fuel and electric energy for lighting, heating, microclimate maintenance and other daily consumption. Considering the low level of replies in the first year (mainly because it's not impossible to gather data), the questionnaire was carried out again in 2009. Its purpose was to create regional card of emissions for postal sector until the end of the year.

The standard protocol, that refers to the emissions reduction and environmental protection, is based on the internationally accepted resources in this field, such as GHG (Greenhouse Gas) protocol WRI/WBCSD (World Resources Institute and World Business Council for Sustainable Development), International Energy Agency, Global Reporting Initiative (GRI) and ISO 14000 standard. The purpose of that document is all emissions resources are being identified, that come from the postal activities.

ISO standard 14001 refers to the environmental management and has appeared as reaction to the irresponsible behaviour of many companies and organizations. Aforementioned standard determines which of the business processes in a company can pollute the environment, then realistic goals are set and required steps are taken in order to accomplish these goals. Universal Postal Union must take into account different development levels of member countries. UPU has created the implement, that counts emissions from raw database and after data are entered, checkout, consolidation and conversion are conducted. Simplified version and standard protocol are complementary to one another [13].

Advantages of ISO 14001 are:

- Reduction of negative impacts on the environment ecological,
- Environmental disaster risk reduction,
- Ability increase of rapid and efficient intervention,
- Better reputation and building trust with community,
- Competitive advantage,
- Legal certainty due to the Law of Environmental Protection,
- Easier way to get permits and licenses,
- Improvement of your own and client's reputation with whom you cooperate,
- Better energy efficiency and source water protection,
- Careful selection of waste materials and controlled waste recycling,
- Costs reduction and improvement of competitiveness,
- Financial reduction,
- Quality improvement of workplaces,
- New employment opportunities in the markets where ecological production is very important [12].

2.2 The use of renewable energy resources

Renewable energy resources come from natural resources such as: sunlight, wind, rain, tides, geothermal heat, etc. These resources are cleaner in comparison to the conventional so that they have less negative impact on the environment. The most important advantage of these energy sources is the renewability, but the conventional energy resources are limited.

In 2008, of the total energy amount, 19 percent was the energy from renewable resources that appeared using traditional biomass, hydroelectric power station and new renewable resources such as small power station, modern biomass, wind, solar and geothermal energy, biofuel etc. In this 19%, traditional biomass participates with 13%, hydropower with 3,2%, and the other renewable resources participate with 2,6% [12].

3 Sustainable development in the sub-systems of postal services providing

The postal system enables an organized letter and parcel shipment, ensuring in this way the availability of postal service on the whole business area. Modern conditions require the investment continuity and company development, firstly in technical and technological aspect of traffic and infrastructure capacities. Besides, it is essential to invest in the development of new commercial services, also in services of computers (computerized or electronic services), as well as network extension of sales capacity [10].

Postal service accomplishing means the reception of items and their sorting, transport and delivery to the recipient. These are basic parts of sub-systems in the postal service providing. In the complex process of distribution where a customer is the main actor, from reception to the delivery, it is necessary to manage the items, information and people’s flow at the same time, requiring on this way operator has new equipment and organization [2]. Developed infrastructure, mechanization, as well as a high level of automation and information technology are important for postal service providing.

3.1 Reception of postal items

Reception of postal items is being accomplished in the units of postal network via postal clerks on the terrain via couriers or via postal mail boxes. The units of postal network enable the possibility of postal items reception on their post office counters. The reception is carried out by postal clerk, using the necessary equipment.

Reception of items via couriers refers mainly to the express services. These are services where the shortest guaranteed time limits of shipping items is enabled in domestic traffic and expected time limits of delivery in international traffic [17].

The reception via postal mail boxes may seem, at first sight, as has the best positive parameters values of sustainable development. On the other hand, it is necessary to empty mail boxes, they occupy the part of certain space, mainly on attractive locations. In this case some changes can be introduced, and they will mark the improvement of sustainable development parameters as result.

3.1.1 Reception of postal items in the units of postal network

Post office counters in the units of postal network are workplaces, which contain certain equipment, necessary for the clerk’s work. Equipment means computer terminal, precise electronic scales, franking machines and the other extra equipment. The present condition of equipment in The Post of Serbia and in the most of remaining operators on domestic market, qualify the presence of unnecessary and powerful computer configuration or, on the other hand, outdated configuration with low efficiency level, which means the shortage of remaining equipment. The need for larger feed quantity is obvious, which has an important impact on the economic and ecological parameters.

Tab. 1: Sustainable development on the reception of postal items

Impacts	The way of acting	Aim
Unused powerful computer configuration	Introduction of new technologies, e.g. hardware and software virtualization	Increase of system's use, reduction of required resources and systems for their feed, development of green IT
Outdated, energy ineffective computer configuration	Modernization and introduction of new technologies	Increase of energy efficiency and thus the reduction of feed quantity
Outdated systems for franking	Purchase of new efficient franking machines	Increase of energy efficiency, noisy reduction, increase of efficiency of counter's place
Outdated and unreliable scales	Introduction of new more qualified electronic scales and their better physical positioning in work environment	Efficiency increase and reduction of energy consumption
Long waiting in line	Tracking of clients flow and redesign counters capacities	Reduction of waiting time in line, increase of productivity and service quality

Due to reduction of energy consumption and other resources, virtualization technology is classified in field Green IT, i.e. in the technologies, which contribute to the environmental protection. There are shown the results of Green calculator of company WMware, that determines approximate cost savings and the impact on the environment for certain number of physicals and virtualized servers (Fig 1.).

When we talk about extra equipment, such as franking machines and electronic scales, it is recommended to follow the trends, and the energy efficiency shall be the main parameter of equipment selection. Also, it is necessary to pay attention to the machines positioning in work area in order to reduce the number of them.

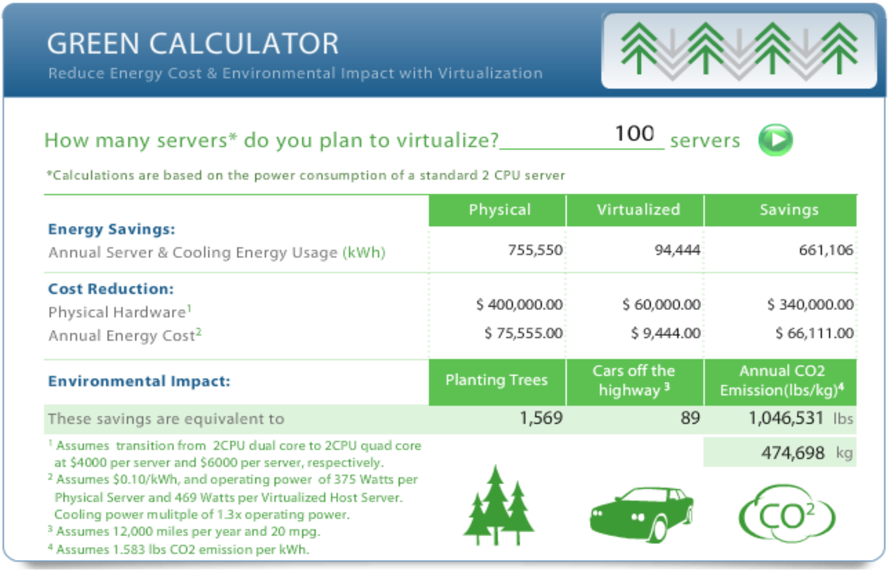

Fig. 1: Results of Green calculator of company WMware

The quality of postal service accomplishing depends, to a large extent, on the approaches possibility of clients to counters, i.e. on the waiting time in line. The important contribution in this sense is made using the approach of singular waiting line for all kind of services. It remains to follow the clients' flow because of eventual streamlining of counters capacities.

3.1.2 Reception of postal items via courier

When we talk about the reception of items via courier, this means a sender will contact the call center, then this application will be forwarded to the courier, that goes to the address and accomplishes the reception of postal items. It is essential to pay attention to the processes, which are on the border with economic profitability and affect the environment. Driving to the reception address and later transport of postal items are basic influential factors. Considering that the transport of items represents one of the most basic factors with impact on the sustainable development of postal activity, it will be particularly shown in this paper. It is necessary to pay attention to the routing quality, as well as the territory that is covered by service. Because of that, there is a need for constant tracking and analysis of customers' requirements in order to reserve and efficiently use the business resources (people, transport means, electronic devices on the reception etc.).

3.1.3 Reception of postal items via postal mail boxes

Postal mail boxes are set on certain locations in certain areas, manly of narrow city districts. The organization of visiting these locations and collection of items by a postal employee is not enough developed, i.e. the emptying of mail boxes is not often. This kind of reception of postal items is not enough developed in the real system. In ideal case, the presence of mail box increases significantly availability to the postal system. There's no need for clients to use transport means to the mail box, because the locations are various. Therefore it contributes notably to the costs reduction and environmental protection. Postal employee visits locations in a certain time and collects items. In the next period, it is necessary to track the demands of market and put the mail boxes on new locations. On the other hand, it is also necessary to pay attention to the route quality of postal employee, who visits the mentioned locations. According to the modern business, it is important to follow the new trends and technologies so the network of ATM postomats became clear need as replacement of mail boxes. A modern postomat provides the possibility for customers to send or collect their postal items and, at the same time, the services of payments are carried out. They require the feed, but on the other hand, they provide plenty of services and increase the availability of system (24/7), therefore the quality of service is improved and the economic profit of company is increased.

3.2 Sorting of postal items

Sorting of postal items represents the process of items classification based on the addresses, by destination. The classification is the complex logistic process. To achieve the appointed goals, in a short time of delivery, reliability and safety, with acceptable price, the rapid classification and accomplishing of reloading tasks are necessary. Different technical solutions can be found for these needs on the market.

Postal companies own extended infrastructure, where each object requires certain energy quantity to function normally. The systems for items sorting are situated in postal-processing centers. These objects, because of the service provision and the own maintenance require the huge energy quantity, which has important economic and ecological impact. Regarding the objects, electric energy is used to a large extent for their heating and supplying of required devices with energy, directly or indirectly. The quality of objects building and its possibility of adaptation to the use of renewable energy resources have a great importance.

Overload mechanization and systems for items classification have the biggest potential for improvement according to the sustainable development in this part of postal service providing.

3.2.1 Overload mechanization in processing center

Mechanization such as different types of forklifts, cranes and conveyors uses certain type of energy for its functioning. Some operations are energetically very demanding, so according to that and based on the principles of sustainable development, is necessary to find compromise in form of energy that is being used.

Forklifts, which are used for reloading manipulations, use mainly diesel and liquefied petroleum gas for fuel operation. Coefficient emission of KCO2 represents the mass of emitted carbon dioxide in atmosphere, reduced to the energy unit. For mentioned kind of fuel, it is 77.4 kgCO2/GJ and 63.1 kgCO2/GJ, respectively [18]. Because of less emission of harmful gases, and less noisy level (70db), the advantage is given to the forklifts on gas engine for domestic transport. Besides these advantages, TNG is cheaper in comparison to diesel and engine operates longer.

When we take the next step, following the trend of energy operation development, according to the level increase of environmental protection, we conclude that application of forklifts on electric engine is more suitable for sustainable development. The selection of remaining overload means should base on energy efficiency, environmental protection and less costs of maintenance.

3.2.2 Systems for classification of postal items

All postal items in system are observed as a main transport flow for different locations. Sorting means accomplish the items separation, i.e., diverting of items from main transport flow according to their destination. Most often are used: crossover with sliding bumpers, rotary carrying platforms or slats, horizontal band like platforms and diverting plates along the horizontal slats [4].

All mentioned means, as well as mean of movement of main transport flow, that can be the kind of transporter (e.g.) require important energy quantity (most often electric) for its functioning. The obsolescence of these systems in many cases means lower energy efficiency. It is necessary to take into consideration the self-sustaining systems, which had been used massively in the past. However, these systems are repressed by development of mechanization and automation, e.g. gravity transporters and systems for classification.

Tab. 2: Sustainable development for postal items classification

Impacts	**The way of acting**	**Aim**
System of main transport flow	Use of the most modern means, low energy consumers, tracking flow of items and its analysis	Use of energy efficient and economically profitable systems and system of increased productivity according to the right dimensioning
Means for classification	Use of modern means, low energy consumers, that is characterized by use of modern technologies for perception of its activation	Reduction of energy consumption and noisy level, increase of punctuality, i.e. reduced mistakes in classification
Outdated systems	Tracking and efficiency analysis of outdated systems, delay in the use of self-sustaining systems, such as gravity means and ejection from the use of ineffective	Reduction of energy consumption and negative impact on the environment with the delay level of system efficiency
Capacity dimensioning	Tracking of the items transfer and analysis of their flow	Right dimensioning of system for classification

3.3 Transport of postal items

For purposes of postal items transport, the means of road traffic, air traffic and ship transport are being used. Various factors have an impact on sustainable development of this sector: different characteristics of transportation mode, regulatory and legislative bodies, providers of services, financial systems, technologies of land use and behavior of people, which take part on all levels and all segments of system. The result of transport can be positive and negative, the both of them refer to the sustainability of system [8]. We will keep on the items transport by road.

According to the Intergovernmental panel on climate change (IPCC), globally, transport (including road, air traffic and ship transport), broadcasts 13,1% of the total emission quantity CO2 in 2004. For postal sector, vehicles are one of the basic sources of greenhouse gas emissions. According to the UNEP (United Nations Environment Programme), road traffic is responsible for the greatest part of harmful gas emissions in transport, and also represents more than 70% of total emission. Between 1987 and 2004, the emission in road traffic is increased for 46,5% [12].

Satisfaction of the sustainable development in road traffic can be achieved on many ways. Two ways that are often applied are the following: combined ground transportation and the use of alternative fuels in road traffic.

3.3.1 Combined ground transportation

Combined ground transportation is being used in the postal traffic, which includes road and railway traffic. The Government of Serbia enacted strategy of traffic development in Serbia for period 2008- 2015, which includes road and railway traffic [3,6].

Transport is in rapid growth, and accordingly to that, it represents the sector with the fastest growth of environment pollution [8]. Road transport is one of the greatest pollutants of air, water and ground, noisy etc. Its diverse affect manifests through many ways, across the air pollution, water, ground and noisy pollution etc…There are numerous traffic accidents. Pollutions are mostly the affects of released harmful gases – carbon monoxide, nitrogen oxide, sulfur dioxide, alkaline compounds, dust, plumb etc…Researches show that, for the same extent of transport, noisy level of road transport is twice larger than noisy level of railway transport.

Traffic congestion causes negative economic, ecological and social impact. They withdraw more fuel consumption and therefore higher pollution level. Also, they cause many problems in supply chains, being late to work etc. In railway traffic, the congestions are minimized in comparison with congestions in road traffic.

The basic advantage of road traffic, relative to the railway traffic is visible in development of network infrastructure, speed, higher mobility and comfort. On the other hand, railway traffic is significantly and ecologically cleaner and cheaper.

The conducted researches show that railway traffic is notably cheaper also it takes up less space. The space, that is taken up by roads, in comparison with railways is three times bigger in the same extent of transport.

Besides the speed and reduced probability manipulation and adaptability, the great deficiency of railway traffic represents the under development of railway infrastructure in our country. Based on these facts, we come to a conclusion that combined transport is the solution that has all advantages of transport modes, which take part in it. On the other hand, there is a need all deficiencies should be minimized. Also, sometimes, because of the geographical limits, it is not possible to accomplish direct transport, but the combined transport is being used [4].

Tab. 3: Sustainable development of combined transport

Impacts	**The way of acting**	**Aim**
Harmful emissions	Combination of road and railway traffic, wherever it is possible and deadlines permits	Positive impact of railway traffic influence the reduction of harmful emissions
Energy efficiency	Combination of road and railway traffic, wherever it is possible and deadlines permits	Railway traffic is more energetically more efficient, with its role it increases the total energy efficiency of system.
Mobility	Combination of road and railway traffic, wherever it is possible and deadlines permits	Road traffic has notably better mobility, with its role, it increases the total system mobility
Costs	Combination of road and railway traffic, wherever it is possible and deadlines permits	Including the savings of both systems, total costs are being reduced
Comfort and safety	Combination of road and railway traffic, wherever it is possible and deadlines permits	Increase of total comfort and safety

3.3.2 The use of alternative fuels in the road traffic

The greatest power of road traffic is in its capability to transfer goods nationwide, as well as internationally, with expressed flexibility. This sector cannot be replaced, but its economic and ecological impact is not on good level. The basic cause, for mentioned bad impacts, is the fact that is expensive and “dirty” fuel that is used.

Transport systems, sustainable from environmental aspect are in the following:

- The use of renewable resources to the level of their regeneration
- The use of non-renewable resources to the level of possibility of renewable substitute development

In road transport of postal items, diesel and petrol are mostly being used as fuel. The coefficient of carbon dioxide emission KCO2 represents the mass of emitted carbon dioxide in atmosphere, reduced to the energy unit. For mentioned kind of fuels it is 77.4 kg CO2/GJ and 71.5 kg CO2/GJ, respectively. This kind of emissions has an important negative impact on environment. The use of alternative fuels is necessary and it reduces that impact [8].

Such as alternative fuels there are the following:

- Liquefied propane gas LPG
- Compressed natural gas CNG
- Methanol
- Fuel cells
- Chemically stored electricity (batteries)
    - Batteries rechargeable in during driving
    - Batteries that charge on base
    - Replaceable batteries
- Hybrid vehicle
    - Energy and petrol
    - Energy and diesel
    - Energy and LPG
    - Energy and CNG

There are numerous researches, which take into consideration the following as criteria in selection of alternative fuels: impact on the environment, energy efficiency, costs of maintenance, technology development etc. Work of Multi-criteria analysis of alternative-fuel buses for public transportation base on researches of alternative fuels [11]. With methods of multi-criteria analysis, TOPSIS and VIKOR, expected results are achieved. Diesel, methanol and fuel cells are the fuel with worst characteristics according to mentioned criteria. The greatest shortage of diesel fuels represents the negative impact on the environment and consumption. The engines on methanol and fuel cells require high means for implementation and maintenance. The best alternative fuels are: Hybrid vehicle, Energy end petrol, Electric engine – Replaceable batteries, Electric engine-batteries rechargeable during driving [11].

Ecologically acceptable system is essential, but not enough condition for that system to be sustainable. For example, the strategy of emission harmful gases reduction cannot be optimal if it is caused by some high costs [1]. Implementing the transport means with hybrid vehicle (Energy-petrol), feedback between conventional and electric vehicles would be made, considering the principles of sustainable development.

The basic principles of sustainable development in part of postal items delivery, we can consolidate through the perception of sustainable development parameters of some activities in segment of items reception and transport.

4 Sustainable development in the sub-system of postal services assortment

It is necessary to implement and develop new services, which satisfy the needs of customers, ecological and economic aspect. On the other hand, it is also necessary to analyze unprofitable services, which cause negative ecological impact, and thereby are not services, which are in interest of customers.

The number of postal services, globally, as well as in the many countries, has negative trend in the recent years. The most of postal operators chose service diversification. On the other hand, postal sector is in very good strategic position, bearing in mind that global connection of sectors, as well as the approach to the Internet, opened new possibilities. In this way, favourable climate is present for development of new services and modernization of current services. The most of postal operators face to many problems in this process, and period between two congresses (Geneva-Doha) showed that postal operators, which developed three dimensions network (physical, financial and electronic/digital) are in better position than the others. It is necessary to take these activities:

- Project and studies working with goal of new postal services development

- Experience taking of the best practical work of the member state of European Union relative to the modern postal technologies and analysis of application possibility in Republic of Serbia
- Studies working on implementation of new postal services [15]

Very important role for sustainability of postal services provision has the application of telecommunication technology, such as SMS information service for items delivery or any other kind of connection maintenance, that enable information of customer attendance at address. In this way, the possibility of items non-delivery is being cancelled, i.e. empty walk to address, for which is necessary reservation capacity, fuel consumption etc.

4.1 Hybrid post

The right example of service, which is in accordance with the principles of sustainable development is the service of hybrid post. Hybrid post provides complete graphic services, from modern design to the product finalization and delivery to the customer. Printing is being performed on the most modern sheet-fed offset presses and rotary machines of world manufacturer. Product assortment includes the production and distribution of the following things: envelopes, flyers and posters, books and magazines, personal prints, catalogues and publications, booklets, various types of forms, other marketing and advertising materials [16].

Hybrid post is combination of traditional postal service and electronic mail. The basic idea is that customer-company, institution or physical person send information to the postal operator (e.g. accounts, advertising message etc.) in electronic mail. Then post should processes, prints and packs that information in envelope and, in the shortest period, it should be forwarded to the target group, to which company, institution or physical person is being referred. In this way, transport network is reduced, for transport lines to the item delivery on the entrance, i.e. demand for service because it is accomplished by electronic mail. It contributes notably to the reduction of negative transport impacts on the environment. Standard accomplishing is simplified because the service is centralized. Also, some machines of the latest technology are used (printers, converting machines...), which are more efficient with low noisy level and high quality level of quality production. "Production" of service is cheap, which enables economic profitability for postal operator and acceptable price for final customer [5].

In order this impact can be alleviated, there is a need of propagation. The hybrid post uses a large amount of paper so the use of recycled paper can achieve positive ecological impact. Some postal services use paper, that contains 80% of total recycled paper, which regardless to that, has enough strong whiteness. Extra problem for the environment is the colour, which prints paper. The colours, which are often used cannot biodegrade so easy. It is necessary to use alternatives, with natural basis, e.g. on the basis of soya bean.

4.2 Direct post of Royal mail

British Royal post initiated service of Sustainable mail (SM) in 2009, as good example of sustainable service with a goal to reduce the impact of direct post on the environment with increased use of ecological resources and to reduce the amount of wastes at the same time. SM service of Royal post is harmonized with PAS 2020 standard, which was developed by DMA (Direct Marketing Association), starting from real conditions in direct marketing, together with numerous other organisations, including DEFRA (Department for Environment, Food and Rural Affairs), in BSI - British Institute of standards. Standard establishes set of ecological goals, characteristics levels and indicators. Combining the application of PAS 2012 and SM service, important saving in standard costs is achieved. In December 2010, TNT POST becomes the first distributor of direct post, to which Level 3 of certificate PAS 2020 is assigned-ecological standard from BSI for direct marketing and sector of direct post. The certificate for direct post, assigned to the TNT POST is the result of cooperation with DMA and two organisations have obligation to give attention to work on promotion of the best way for environmental protection in sector of direct post [9].

4.3 Virtual post

Modern business and way of life are determined by time limits. Virtual post represents the Internet portal of a certain postal company through which different postal services can be accomplished. In this way, customers achieve time saving and costs for service offerer are less. Positive and ecological factors are realized, because of moving reduction and other characteristics of online business. It is clear that development and implementation of virtual posts represent real row of business activities which contribute to the sustainable development.

5 Green infrastructure objects

There are over 660 000 postal units worldwide. Besides, operators dispose other places such as logistic centres, seats, directorates, main offices so the emission reduction from postal objects is very important. According to the IPCC (Intergovernmental Panet on Climate Change), objects emitted 7,9% of total emission CO2 worldwide in 2004. There are many countries which adopted common politics or legitimate frameworks, directed to giving attention to the environmental protection through objects' building and renovation, and there are different examples of green objects, which are the result of mentioned politics [12]. "Green objects", i.e. "green" infrastructure is one of the most important factors of sustainable development in postal traffic.

This type of buildings means application of energy efficiency concept from fundament to objects roof. The use of modern technologies, the most efficient insulating materials and materials with expressed capability of micro climate protection are meant, as well as innovative thermal systems.

In 2009, on conference UN in Copenhagen, as well as on the IPCC, it is pointed out that there's a need to react urgently in reduction of harmful gases emission. It is also necessary business and housing objects have essential potential in this area.

The best way for moving to the concept of green buildings is in use of certain solutions, although there are standard objects. As one of many solutions, the implementation of solar collectors on the roof is imposed. In this way, the level of renewable energy resources use is increased using the solar energy. The energy we got can be used in various purposes.

The systems for micro climate maintenance of "green objects" use the technology of geothermal systems. The land absorbs the certain amount of solar energy at a large extent, and keeps its temperature by some internal processes. Geothermal systems use mentioned temperature for their functioning. They are universal so can be used for heating and cooling. In heating system, transfer of heat and earth is accomplished, i.e., the object that is heated. In cooling system, by reversed process, transfer of heat from cooled object to the earth is accomplished, which is the steady and thermically isolated source. It can keep the temperature from 8C to 18C on depth of 2 meters. Energy from earth is free so the saving is obvious.

6 Conclusion

Global mission of sustainable development represents the group of activities which are conducted with the aim of ecological, economic and social stability, of present and future generations. The important influential factor in this area is the postal traffic with the including activities.

The impact of postal operators on the parameters of sustainable development is reflected through the sub-systems of postal service providing and postal service assortment. Besides, the crucial impact is the postal network infrastructure.

In the sub-systems of postal service providing, an improvement of sustainable development is expressed through segments of items reception/delivery, sorting and transport. Tendencies mean the application of combined transport, use of alternative fuels, implementation of modern technical and technological systems which basic characteristics are energy efficiency and negative emission reduction.

Postal service assortment needs to be analysed in details and in this way it is necessary to move unprofitable services from offers, which cause negative ecological impacts, and which are not interested to customers at the same time. Also, it is necessary to implement the new services, which satisfy the needs of customers, ecological and economic aspect.

Precondition of modern business is in following, development and application of technical and technological trends according to the basic principles of sustainable development.

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FILTERING OF THE ELECTROMAGNETIC INTERFERENCE AT USING PULSE WIDTH MODULATION TECHNIQUES BY THE FINITE IMPULSE RESPONSE FILTER

Tomáš Lelek[1]

Abstract: The PWM technique, which is used for voltage inverters of traction drives is analysed. To decrease the higher harmonics level, various finite-impulse response (FIR) filters are considered. Obviously, that changes the efficiency of output signals. Therefore the electromagnetic interferences and efficiencies are examined using numerical simulations.

Key words: finite impulse response filter, simulation, windowing technics, pulse width modulation.

1 Introduction

In power semiconductor voltage converters, semiconductor elements are used mainly in switching mode because of decreasing power loses. Today, a pulse-width modulation (PWM) is mainly used. This is switching voltage with very sharp edges, so production of higher harmonic frequencies is a result [[1]] – [6]. The PWM signal creating sinusoidal waveform is shown in Fig. 1.

In traction drives with high power, today mainly with induction motors or with permanent magnet synchronous motors, they are fed from voltage inverters. It is not possible to use another mode of semiconductor elements operation, so it is necessary to be engaged in research of those devices from the point of view of electromagnetic compatibility and from the point of view of decreasing electronic distortion. In power semiconductor voltage converters, semiconductor elements are used mainly in switching mode because of decreasing power loses.

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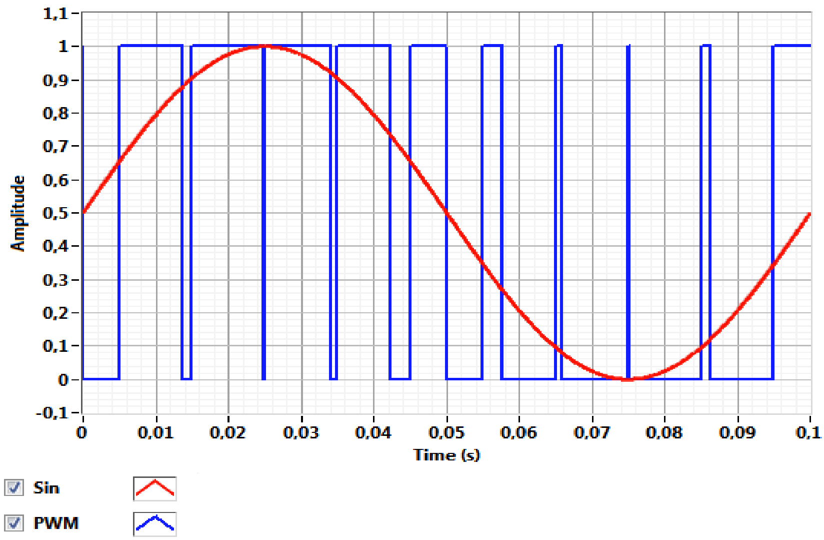

Fig. 1: PWM signal

The paper analyses the PWM techniques, which are used for voltage inverters of traction drives. To decrease the higher harmonics level, various finite-impulse response (FIR) filters are considered. Obviously, that changes the efficiency of output signals. Therefore electromagnetic interferences and efficiencies should be examined. The electromagnetic interferences and efficiencies are examined using numerical simulations.

2 Electromagnetic interferences and efficiencies

It is well known that windowing is one of the earliest techniques for designing the FIR filters [7]. The filter coefficients can be obtained in closed form without the need for solving complex optimization problems as in some other sophisticated FIR design techniques. Therefore, the design time is very short and the technique remains an attractive tool for FIR filter design. For a rectangular window, the maximum sidelobe amplitude is equal to approximately –13 dB relative to the maximum value, i.e. the sharp transition in the ideal response is converted into a gradual transition. To reduce the oscillations, i.e. higher harmonics, other window functions having spectra exhibiting smaller sidelobes should be used. The sidelobes of the rectangular window represent the high-frequency components and are due to the sharp transitions from one to zero at the edges of the window. Therefore, the amplitudes of these sidelobes can be reduced by replacing the sharp transitions by more gradual ones. The design of various low-pass FIR filters has been done using several windows. The rectangular (with -13 dB sidelobes), triangular (with –25 dB), Hanning (with –31 dB), Hamming (with –41 dB) and Blackman (with -57 dB) windows have been used. Their responses are shown in Fig. 2 and 3. They allows substantially decrease the electromagnetic interference. However, the design of FIR filters should be optimized considering several parameters such as sampling frequencies, cutoff frequencies and the order of the filter. The PWM signal shown in Fig. 1 was used as input of FIR filters as is shown in Fig. 4 - 8.

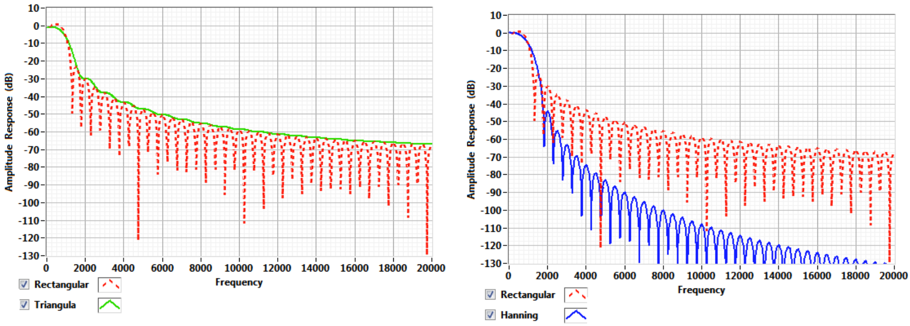

Fig. 2: Comparison of FIR low-pass filters for a) rectangular and triangular, also known as Bartlett, and b) rectangular and Hanning windows.

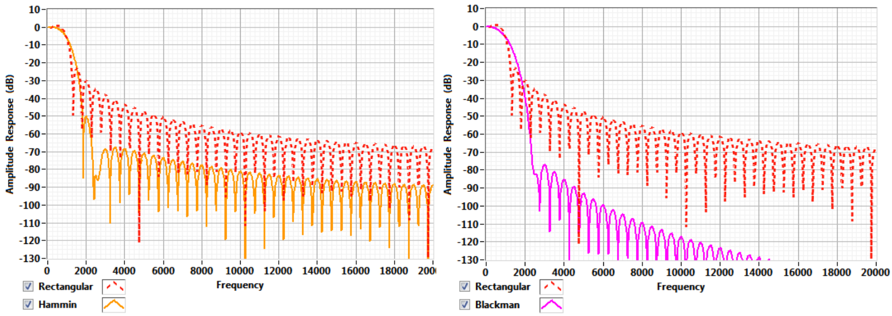

Fig. 3: Comparison of FIR low-pass filters for a) rectangular and Hamming and b) rectangular and Blackman windows.

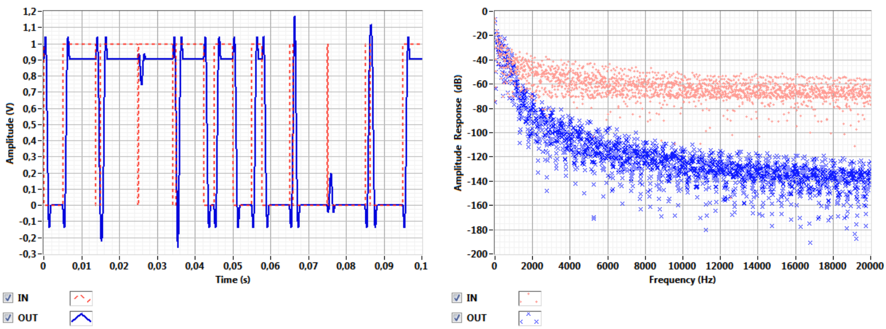

Fig. 4: Comparison of input and output of FIR low-pass filter for rectangular window. a) time domain, b) frequency domain.

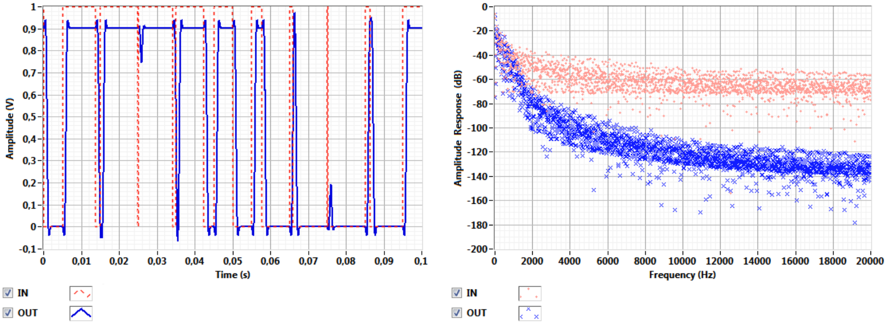

Fig. 5: Comparison of input and output of FIR low-pass filter for triangular, also known as Bartlett, window. a) time domain, b) frequency domain.

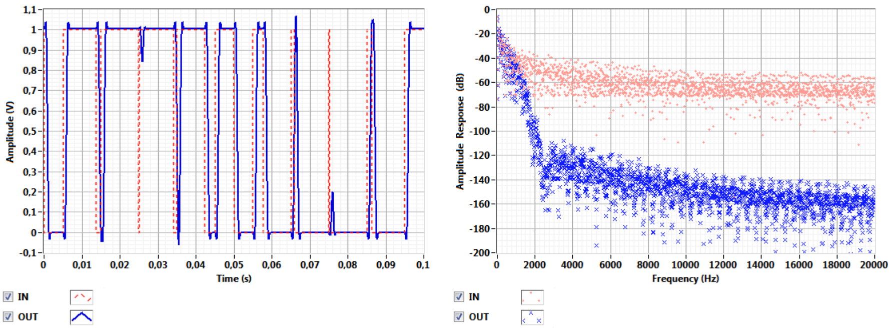

Fig. 6: Comparison of input and output of FIR low-pass filter for Hanning window. a) time domain, b) frequency domain.

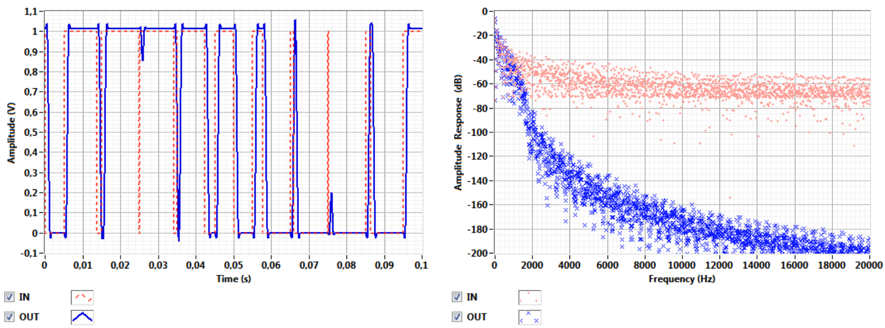

Fig. 7: Comparison of input and output of FIR low-pass filter for Hamming window. a) time domain, b) frequency domain.

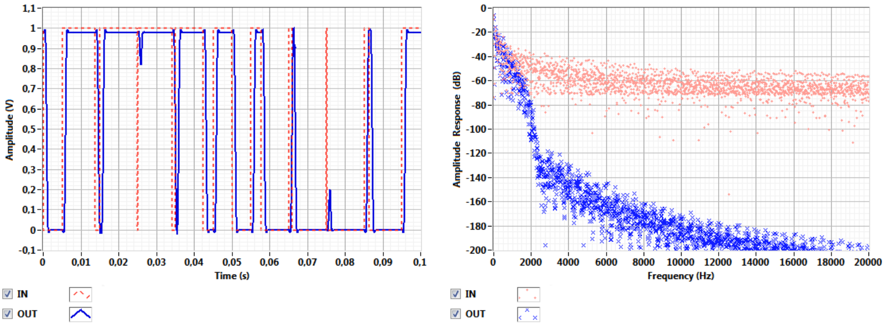

Fig. 8: Comparison of input and output of FIR low-pass filter for Blackman window. a) time domain, b) frequency domain.

To demonstrate the efficiency of various low-pass filters, shows the comparison of RMS for FIR low-pass filter based on various windows.

Tab. 1 shows the comparison of RMS for FIR low-pass filter based on various windows.

Tab. 1: RMS for FIR low-pass filter based on various windows.

Window	Rectangular	Triangular	Hanning	Hamming	Blackman
RMS	0,64371	0,63102	0,70557	0,70051	0,68106

3 Conclusion

The paper analyses the PWM technique, which is used for voltage inverters of traction drives. To decrease the higher harmonics level, various finite-impulse response (FIR) filters are considered. Obviously, that changes the efficiency of output signals. Therefore electromagnetic interferences and efficiencies are examined. The electromagnetic interferences and efficiencies are analysed using numerical simulations.

The comparison of input and output of FIR low-pass filters both for time and frequency domain clearly shows that frequency spectra could be substantially decreased using suitable designed FIR low-pass filters. Moreover, the output waveforms could be reasonable and efficiencies considering RMS are not substantially changed.

Acknowledgement

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TRAFFIC SAFETY ASSESSMENT BY USING MICRO-SIMULATION MODELLING AND TRAFFIC CONFLICTS AT LARGE ROUNDABOUTS

Pavel Lopour[1]

Abstract: Recent research has shown that traffic conflicts provide useful insight into the failure mechanism that leads to road collision between vehicles while being more frequent than accidents and without social cost. This paper provides proactive quantitative evaluation of traffic safety on three design layouts of large roundabouts by using microscopic traffic simulation approach. Combination of VISSIM and Surrogate Safety Assessment Model (SSAM) were used to model variant roundabouts with atypical layouts and assess traffic safety. The roundabouts were assessed by two approaches: (1) surrogate safety indicators - Time to Collision (TTC) and Post encroachment time (PET) and (2) safety assessment methods (reflecting severity of conflicts and potential collisions). Based on comparison of the results achieved by both methods and generally accepted safety principles were submitted proposals and recommendations for practical use of the proactive traffic safety assessment methods with surrogate safety indicators.

Key words: traffic conflicts, safety, roundabouts, surrogate safety indicators, SSAM, VISSIM

1 Introduction

The current trend of road safety development is uniform at national and international level and aims to minimize the occurrence of road accidents i.e. zero fatalities or serious injuries on the roads.

The road designers and planners are choosing safety measures and design layouts based mainly on general principles of safe road design, experiences and own intuition. The choice of intersection design according to the principles of safe intersection design could be define as “maximum road safety for all users of road

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traffic and also maximum fluency of the traffic flow (capacity and traffic level quality). The research and developing of useful methods/tools is needed.

2 Current state of art

Road safety assessment can be divided into traditional methods of analyzing traffic accidents records or traffic accidents deep analysis (reactive methods) and methods based on surrogate safety measures investigation by the theory of conflict situations (proactive methods).

2.1 Traffic Conflict Technique (TCT)

The concept of traffic conflicts was first proposed by Perkins and Harris who defined a traffic conflict as any potential accident situation leading to the occurrence of evasive actions such as braking or swerving. This definition was further modified and an internationally accepted definition is now "an observable situation in which two or more rad users approach each other in space and time for such an extent that there is a risk of collision if their movements remain unchanged".

The TCT model of traffic safety could be expressed by the traffic safety continuum, which shows two extremes in traffic flow (undisturbed passages and accidents). [1]

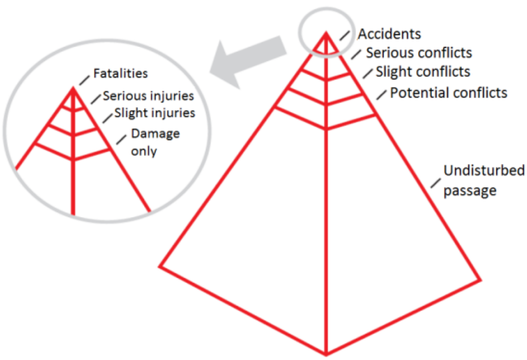

Fig. 1: The traffic safety continuum (The pyramid of safety)

Several studies have demonstrated the feasibility of collecting conflict data using: field observers, simulation models and videocamera. Each of these approaches has its own pros/cons. Field observers are most practical solutions, but are too expensive and the variability of observers make results repeatability and consistency very difficult. On the other hand the adjusting of simulation models can account for this limitation even on new design layouts. However, models don´t account with diverse and less predictable driver behavior in real traffic. Automated video camera analysis is useful for both ways (observers and simulations), but is applicable only on real layouts.[2]

The main quantitative surrogate safety indicators are Time to Collision (TTC) and Post-encroachment time (PET). TTC is defined as the time difference between the complete leaving of the collision point / area by followed vehicle and entering to the theoretical conflict point (no evasive maneuver).[3]

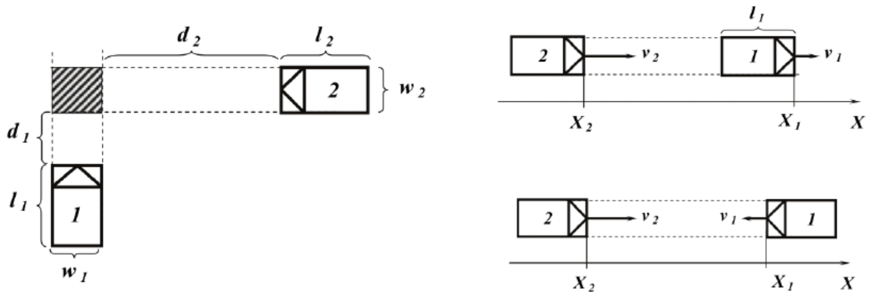

Fig. 2: TTC definition for three possible collisions (crossing, rear-end, lane change)

PET is defined as the time difference between the complete leaving of the collision point / area and the actual passing through the theoretical conflict point.

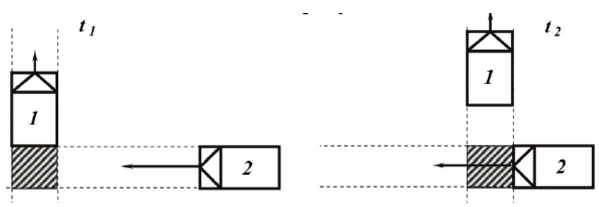

Fig. 3: PET definition

2.2 Safety assessment methods

It was the use selected methods for determining the safety of using TCT reflecting the severity of conflicts and potential collisions large roundabouts. Among the selected methods belong:

- USZ (Uniform Severity Zone) by Hydén

This method evaluates the severity of the conflict using the time to collision (TTC) and severity of the collision using the maximum speed of the vehicle when determining the collision (MaxSpeed). [4]

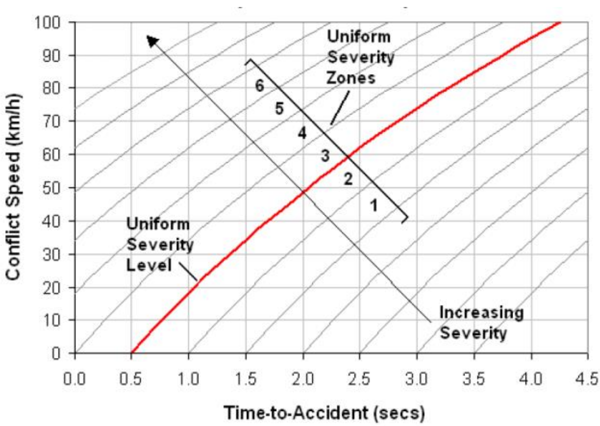

Fig. 4: Uniform severity level and severity zones developer by Hydén

TCS Score (Total conflict severity score) - method evaluates the severity of the conflict using the time to collision (TTC) and severity of the collision using the maximum difference of the speed of vehicles after the theoretical collision (MaxDeltaV).[5]

TTC and ROC Score	TTC (sec)	ROC
1 (Potential)	$1.5 < TTC \leq 2.0$	Low Risk
2 (Slight)	$1.0 \leq TTC \leq 1.5$	Moderate Risk
3 (Serious)	< 1.0 second	High Risk

Fig. 5: TCS Score method by Sayed

3 Methodology

3.1 Traffic microscopic simulator - PTV VISSIM

This case study use technique of microscopic traffic simulation in VISSIM version 5.4. This simulation software is a discrete, stochastic, time step based, microscopic model with driver-vehicle-units as single entities. It works on sub-models of psycho-physical car-following logic and rule-based lane-changing logic to determine the longitudinal and lateral vehicle movements.[6]

3.2 Surrogate safety assessment model – SSAM

The Surrogate Safety Assessment Model (SSAM) is a software application designed to perform statistical analysis of vehicle trajectory data output from microscopic traffic simulation models. The software computes a number of surrogate measures of safety for each conflict that is identified in the trajectory data and then computes summaries of each surrogate measure. [7]

3.3 Description of the simulated roundabouts

The chosen urban large roundabout is located on the road III/32224 near shopping center Globus in Pardubice. The findings were obtained on three design layouts of real roundabout (changed through the lifetime of selected intersection): roundabout with one circular lane, with two circular lanes and atypical spiral arrangement of lanes. The case study of variant roundabout design was performed to verify the findings about traffic safety assessment with use of proximal surrogate indicators.

Fig. 6: Roundabout with spiral arrangement of lanes in PTV VISSIM

The three roundabout designs including bypass were each modelled in VISSIM and examined with SSAM. Total traffic volume at roundabout was over 2300 veh/h. Driving characteristics were verified by experimental measurement with “fifth wheel cart”.

Each model was simulated 2 hours in VISSIM (first hour served as warm up and second hour was examined). Each alternative model was run 25 times with 25 different random seeds causing vary the arriving traffic and the results (stochastic variation of input flow arrival times).

3.4 Examination of the simulated roundabouts

To identify potential conflicts from simulated trajectories was used maximum TTC threshold 4,5 s and maximum PET threshold 6,3 s. These limits were chosen due higher speeds of vehicles (intersection is close to road I/37) and heavy goods traffic. TTC value 1,5 s was derived from previous research at urban low-speed intersections and representing uniform severity level between serious and non-serious conflict.

4 Results and discuss

4.1 Surrogate safety indicators TTC and PET

All results were filtered by simulated time and then examined. Table 1 summorizes summa of identified conflicts by SSAM during 25 simulated „second“ hours, average hourly conflict (AHC) and type of the conflict by conflict angle.

Tab. 1: Results of conflict frequency comparison for large roundabouts design alternatives identified by SSAM

	OK 1lane	AHC	OK 2lanes	AHC	OK s	AHC
Summa conflicts	***63856.0***	***2554.2***	***32567.0***	***1302.7***	***48464.0***	***1938.6***
rear-end	*58182.0*	***2327.3***	*25018.0*	*1000.7*	*43029.0*	*1721.2*
lane change	*5598.0*	***223.9***	*7341.0*	*293.6*	*5183.0*	*207.3*
crossing	*76.0*	***3.0***	*208.0*	*8.3*	*252.0*	*10.1*
rear-end	*91.11%*		*76.82%*		*88.79%*	
lane change	*8.77%*		*22.54%*		*10.69%*	
crossing	*0.12%*		*0.64%*		*0.52%*	

As is shown above the most conflicts were identified at 1 lane roundabout and the fewest at 2 lanes roundabout. As is shown below the most of the conflicts are rear-end (green) identified at the approach lanes (waiting queues). The lane change and crossing conflicts are mostly identified at the roundabout lanes. And according these types looks spiral roundabout as the safest and 2 lanes roundabout as the most danger.

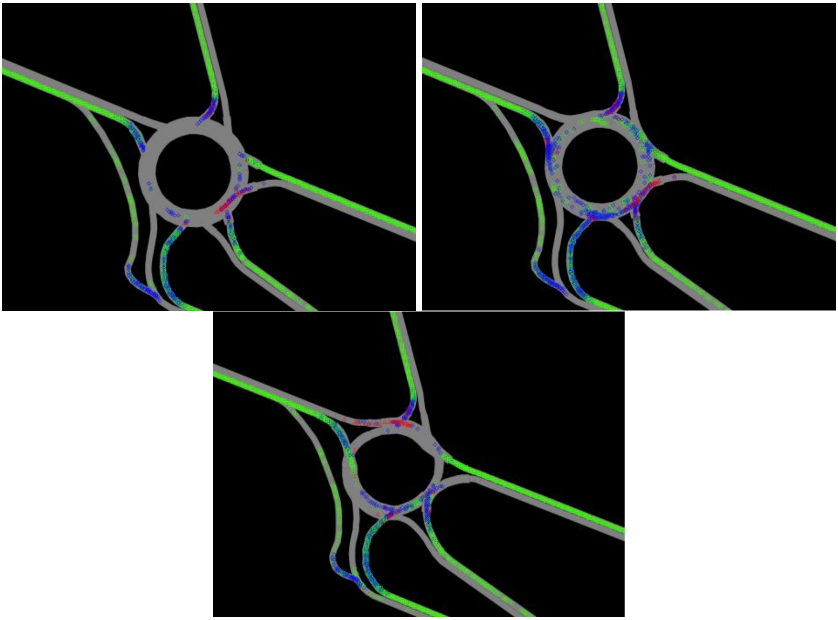

Fig. 7: Roundabouts design alternatives (1 lane, 2 lanes and spiral) with SSAM conflicts

Table 2 shows the main statistical characteristic of safety indicators TTC/PET (mean and median) are very similar for all three design alternatives, making it difficult to tell which alternative is the safest design. These results are not including important assessing parameter of conflict severity by TTC threshold.

Tab. 2: Statistical characteristic and frequency of TTC and PET

	OK 1lane	OK 2lanes	OK s
AHC	*2554*	*1303*	*1939*
TTC Mean [s]	***3.94***	***3.78***	***3.90***
TTC Median [s]	***4.20***	***4.10***	***4.20***
PET Mean [s]	***2.47***	***2.58***	***2.51***
PET Median [s]	***2.20***	***2.40***	***2.20***

Table 3 shows only serious conflict (TTC <= 1.5 s). The results are more objective and assess roundabout by conflict severity (the proximity to the accident). According this is the order from the safest to the most danger following: spiral roundabout, 1 lane roundabout and 2 lanes roundabout.

Tab. 3: Statistical characteristic and frequency of serious conflicts (TTC = 1.5 s)

TTC<=1.5 s	OK 1lane	OK 2lanes	OK s
Summa conflicts	*104*	*116*	*80*
AHC	***4.16***	***4.64***	***3.20***
%	*0.16%*	*0.36%*	*0.17%*
Mean [s]	***1.21***	***1.15***	***1.13***
Median [s]	***1.40***	***1.30***	***1.30***

4.2 Safety assessment methods

Uniform severity zones illustrated in Figure 8 were approximated by graphing MaxS (the maximum speed of either vehicle during the conflict event) versus min TTC. All conflicts were plotted and assessed by number (severity level) as shown below.

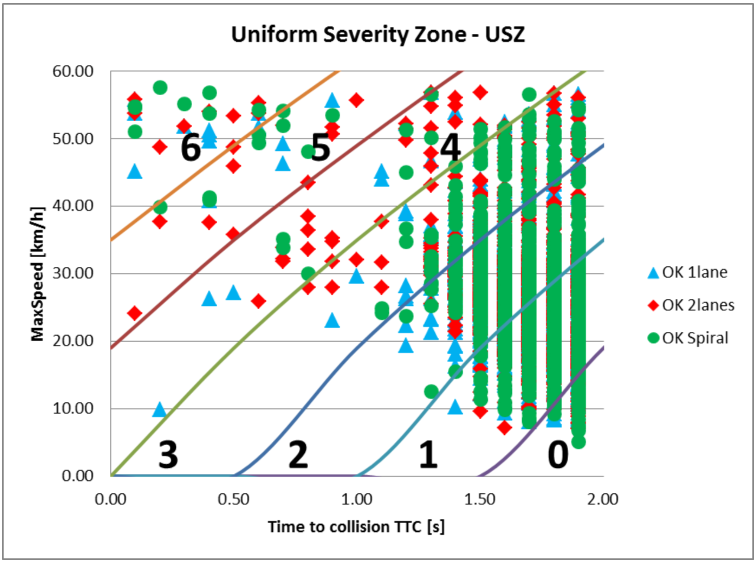

Fig. 8: Uniform severity zone for roundabout design alternatives

USZ 1+ is described as mean of conflicts with severity level at least 1. The order for safety assessment from the safest to most danger is: spiral roundabout, 1 lane roundabout and 2 lanes roundabout.

Tab. 4: Conflicts frequency according USZ and USZ 1+

	Uniform Severity Zone - USZ							
	0	1	2	3	4	5	6	USZ 1+
OK 1lane	62242	926	548	117	10	5	8	1.540
OK 2lanes	30661	1085	639	141	22	11	8	1.562
OK Spiral	46841	954	522	119	11	9	8	1.535

Second approach Total Conflict Severity Score (TCS Score) is the sum of TTC score and Risk of collision score and overall severity score need to be assigned to each conflict. Higher number means higher conflict severity.

The ROC is independent from the TTC score and assigned to each conflict based on its MaxΔV value (maximum delta velocity of the two vehicles in the conflict during hypothetical collision). The thresholds were selected as the 85th percentile of MaxΔV from all roundabout design alternatives. The 2 lanes roundabout shows higher values of MaxΔV than 1 lane and spiral design (both similar distribution).. The chosen threshold values are shown below in the Table 5.

Tab. 5: Assigned ROC score based on MaxΔV

ROC Score	MaxDV [km/h]	P injuries	P fatal	Sample size		Severity
1	<5	<0.0003	<0.0000	118453	81.76%	low
2	5≤maxDeltaV≤15	0.0003-0.0056	0.0000-0.0001	21168	14.61%	moderate
3	maxDeltaV>15	>0.0056	>0.0000	5266	3.63%	high

Table 6 summarized conflicts of assigned score (1 - 6). Average conflict score 1+ is described as mean of conflicts with TCS Score at least 1.

Tab. 6: TCS Score and ACS1+

	TCS Score (Total Conflict Severity Score)						
	1	*2*	*3*	*4*	*5*	*6*	ACS1 1+
OK 1 lane	*55887*	*5895*	*1774*	*269*	*28*	*3*	*1.163*
OK 2 lanes	*23023*	*6822*	*2379*	*288*	*45*	*10*	*1.389*
OK spiral	*39294*	*6470*	*2416*	*260*	*22*	*2*	*1.251*

The order for safety assessment by TCS Score from the safest to most danger is: 1 lane roundabout, spiral roundabout and 2 lanes roundabout.

Both methods have pros/cons. USZ is very simple to use, but does not count with severity of potential collisions (only with severity of conflict). TCS Score method count with severity of conflicts and potential collisions, but ROC score severity thresholds (MaxΔV) could be different for design alternatives and slightly affect results.

For right choice of design is needed to include both principles of safe road design: road safety and fluency of traffic flow (capacity with adequate level of traffic quality).

5 Conclusion

This report examined the use of SSAM and microsimulation models for performing a conflict analysis and safety assessment of roundabout design alternatives.

The safety assessment by surrogate safety indicators and safety assessment methods confirms general opinion about safer 1 lane roundabout than 2 lanes roundabout with equal traffic volume.

The spiral roundabout confirms partially better solution than both standard roundabout designs. The low severity of potential collisions (against 2 lanes roundabout) and higher capacity could be significant reason to be chosen by road designers.

The safety assessment using the Traffic Conflict Theory and safety analysis of the modeled surrogate indicators has great potential in these nowadays problem cases.

- Safety diagnosis of designs of existing intersections reconstruction. Especially in the case of under registration of accident records (accident reports may be unavailable, the information may be insufficient or unreliable).
- The evaluation of the impact of designed measures on traffic safety

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Summary: Application of traffic safety assessment at urban large roundabouts by micro-simulations (VISSIM) and Traffic Conflict Technique (TCT). The first approach use simply surrogate safety indicators from simulated trajectories (SSAM). The second approach use assessment methods with severity of conflicts and potential collisions. Both approaches of safety assessment were performed at three design roundabout alternatives (1 lane roundabout, 2 lanes roundabout and atypical spiral roundabout) and appropriate conclusions were summarized.

EUROPEAN RAILWAY RESEARCH FUNDING OPPORTUNITIES AND EXAMPLES OF SUCCESSFUL PROJECTS

Alena Loudová [1]

Abstrakt: The paper is focused on the financial instruments supporting railway research in Europe. Particularly European programmes Horizon 2020, SME Instrument and CEF are generally introduced, together with less familiar funding opportunities such as EUREKA or ERA-NET Transport. The paper will also bring an overview and the most updated information about the most challenging programme for railway research SHIFT²RAIL, the first European rail joint technology initiative to seek focused research and innovation and market-driven solutions by accelerating the integration of new and advanced technologies into innovative rail product solutions. The final part of this paper is dedicated to application of research and innovation approach in practice – a new Horizon 2020 project IT2Rail (Information Technologies for Shift2Rail). This project is a first step towards the long term IP4 – "IT Solutions for Attractive Railway Services", one of the SHIFT²RAIL Joint Undertaking's Innovation Programmes, which aims at providing a new seamless travel experience, giving access to a complete multimodal travel offer which connects the first and last mile to long distance journeys.

Keywords: financial instruments, European railway research, Horizon 2020, SME Instrument, Connecting Europe Facility, EUREKA, ERA-NET Transport, Shift2Rail Joint Undertaking, IT2Rail Project.

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1 Introduction

Rail is one of the most efficient and friendly form of transport. More than 8 billion passenger journeys are made by rail each year. But rail traffic is stagnating or declining in many EU Member States. Despite positive developments in a few markets, the modal share of passenger rail in EU transport has on average remained more or less constant since 2000, at around 6%, whereas the modal share of rail freight has decreased from 11.5% to 10.2%.

Rising traffic demand, congestion, security of energy supply and climate change are some of the major issues that the European Union and the wider world are facing. Tackling these challenges will require the railway sector taking on a larger share of transport demand in the next few decades.

EU research and innovation (R&I) must help rail play a new, broader role in global transport markets, both by addressing pressing short-term problems that drain rail business operations and resources, and by helping the sector to achieve a stronger market position, in particular by supporting the creation of a Single European Railway Area.

Yet, past rail R&I efforts at EU level have suffered from fragmentation and inefficiencies, and have not always been sufficiently targeted towards the broader policy goals of completing the Single European Railway Area and of increasing the competitiveness and attractiveness of the European rail sector and the rail manufacturing industry. Furthermore, the market uptake and impact of EU rail R&I projects under previous framework programmes has often been low and slow, although there are examples of EU-funded research and development (R&D) investments resulting in outputs that have been and are still being taken up by the market.

Over the past years, a great number of rail research projects have been funded by the European Commission, representing billions of Euros of investment. Yet the question remains as to how much of this research has actually been useful or relevant. It is clear that otherwise valuable research results are sometimes forgotten and some work is repetitive or redundant.

Under the Seventh Framework Programme (FP7), the Union contributed roughly €150 million to rail research projects. Over recent years the European Union and its Member States have taken important steps in response to the challenges raised by the economic and financial crisis.

The Multiannual Financial Framework translates the EU priorities into financial terms, laying down the maximum annual amounts that the EU may spend in different political fields over the next 7 years.

Multiannual Financial Framework must ensure that the European Union's budget is geared to lifting Europe out of the crisis. The European Union's budget must be a catalyst for growth and jobs across Europe, notably by leveraging productive and human capital investments.

2 Programmes for funding over period 2014 - 2020

2014-2020 EU funding programmes and the budgetary provisions of the Multiannual Financial Framework serve as the roadmap toward the renewal of a highly competitive social market economy in Europe and globally. The complex economic and social challenges the EU countries are tackling, make the Union resources useful tools to relaunch its economy, to deliver high levels of employment, productivity and social cohesion and to generate a smart, sustainable and inclusive growth.

The objectives of the funding Programmes for the period 2014-2020 follow the framework of EU's growth strategy for the coming decade. Europe 2020 stems from the necessity of taking charge of the EU future, tackling its structural weaknesses and facing the new societal long-term challenges: globalisation, pressure on resources, ageing.

The priorities of the Europe 2020 strategy mean to lead to a growth that is smart, through more effective investments for developing an economy based on knowledge and innovation; sustainable, thanks to a decisive move towards a more resource efficient, greener and a more competitive economy; and inclusive, fostering job creation and poverty reduction.

European Union funds

EU Competitive Programmes are programmes financed directly from the EU's budget in the form of grants and cover priorities. They are administrated by the European Commission and are competitive and transnational, thus participation of partners from more than one member states is often required in order to submit a proposal. These programmes are managed at central European level, without the intervention of the Institutions of the Member State. The proposals submitted compete with proposals from all Member states and successful proposals are selected after a comparative evaluation of all proposals submitted.

A strong emphasis has been put on expenditure aimed at boosting growth and creating jobs, in line with the political priorities of the EU. This category of expenses includes, among the others, funding opportunities for research and innovation, education and training, trans-European networks in energy, transport and telecommunications, social policy, development of enterprises. A pivotal role in Europe is played by the new programme for research and innovation Horizon 2020, which is equipped with a budget of almost €80 billion, around 30% more than in the 2007-2013 period. The Programme intends to boost to top-level research in Europe, strengthen industrial leadership in innovation, and promote investments in key technologies, greater access to capital and support for SMEs. The new COSME programme is another crucial instrument for competitiveness, it makes €2.3 billion available for SMEs to foster their competitiveness and boost growth and jobs in Europe. COSME is an EU programme targeted to SMEs, it aims at facilitating their access to markets inside and outside the EU and offers easier access to finance through loan guarantees and risk-capital.

Funds at national and regional level

On 6 October 2011, the European Commission published a package of six new regulations. Their final versions were approved on 17 December 2013. In the programming period 2014–2020, they form the legislative basis for aid from the European Structural and Investment Funds. The set of these regulations is to ensure uniform rules throughout the European Union as well as improving coordination among individual funds and also for programmes at the national level.

The **European Union's regional policy**, also called economic and social cohesion policy (ESC), reflects the principle of solidarity inside the European Union, where richer countries contribute to the development of poorer countries and regions to improve the quality of life of citizens of the entire European Union.

According to EU regulations, the ESC policy is to promote harmonious and sustainable development of economic activities, a high level of employment, and protection and improvement of the environment in the territory of the EU. The third pillar of the ESC is territorial cohesion, i.e. promoting territorial interdependence and cohesion of the Union. In this context, cross-border, transnational and interregional cooperation also plays an important role. Creating an open, flexible and coherent society with high employment is at centre stage together with emphasis on sustainable growth, innovation and competitiveness.

The **Structural and Investment Funds** (ESI) aim to improve the economic well-being of European regions and reduce regional disparities in terms of income, wealth and opportunities. The ESI funds are the financial tools set up to implement the EU 2014-2020 Regional Policy, also referred to as the EU Cohesion Policy.

The ESI funds include the **Structural Funds** (European Regional Development Fund – ERDF and the European Social Fund – ESF), the **Cohesion Fund** (CF), the European Agricultural Fund for Rural Development (EAFRD) and the European Maritime and Fisheries Fund (EMFF), and operate under the Common Strategic Framework (CSF). The Common Strategic Framework replaces the previous separate sets of strategic guidelines, strengthening the integration of EU policies and ensuring greater impact for citizens and businesses on the ground.

European Structural and Investment Funds (ESIF) include the financial tools for implementation of Cohesion Policy, aiming at promoting and supporting the overall harmonious development of its Member States and Regions.

Funding from European Union funds are spent through Operational Programmes (OP). The Operational Programme is a plan of targeted interventions designed to stimulate the development or expansion of one or more sectors. Breakdown of operational programs primarily reflects the main areas covered by the aid.

The European Union funds include a wide range of financial instruments. A wide range of Competitive Programmes are adopted providing to different types of beneficiaries financial support, in the fields related to the different EU policies. Programmes and tools which can be used for railway research and innovation are shortly describe in following chapters.

2.1 HORIZON 2020

One of the European funding programs for research and innovation is the framework program of the European Commission.

In 2011 the EU Heads of State and Government called on the European Commission to bring together all of the previous EU's research and innovation funding under a single common strategic framework. The Commission launched a wide-ranging consultation involving all key stakeholders which has led to Horizon 2020.

Horizon 2020 is the biggest EU Research and Innovation programme ever with nearly €80 billion of funding available over 7 years – in addition to the private investment that this money will attract.

It brings together into a single, coherent and flexible framework all research and innovation funding provided during the previous funding period 2007-2013 through the Framework Programme for Research and Technological Development, the Competitiveness and Innovation Framework Programme (CIP) and the European Institute of Innovation and Technology (EIT).

Horizon 2020 structure consists of three priorities or pillars, which are implemented through specific programmes and a dedicated financial contribution:

- Excellent science,
- Industrial leadership,
- Societal challenges.

The general objective shall be pursued through the specific objectives 'Spreading excellence and widening participation' and 'Science with and for society'. The Joint Research Centre shall contribute to the general objective and the H2020 priorities by providing scientific and technical support to Union policies in collaboration with relevant national and regional research stakeholders, where appropriate, for example on the development of smart specialisation strategies.

Horizon 2020 aims at promoting scientific excellence and the European research system; increasing and supporting competitiveness and European industrial leadership; responding to the major societal challenges Europe is facing by helping to bridge the gap between research and the market.

In particular, Excellent Science pillar aims at raising the level of excellence in Europe's science base and ensuring a steady stream of world-class research to secure Europe's long-term competitiveness. It supports the best ideas and the best talents by providing training and career development opportunities, developing future and emerging technologies and EU research infrastructures.

Supported actions:

- European Research Council (ERC) provides substantial grants to top-level individual researchers working in Europe,
- Future and emerging technologies (FET) opens up new fields of research and innovation,
- Marie Curie Actions develops research and innovation skills through the training, mobility and career development of researchers,
- Funding is also available for supporting access to, and networking of priority research infrastructures across Europe.

Industrial Leadership objective is to make Europe a more attractive location to invest in research and innovation by supporting major investments in key industrial technologies, facilitating access to risk finance for innovative companies and projects, and providing Union wide support for innovation in small and medium-sized enterprises.

Supported actions:

- Development of industrial capabilities in Key Enabling Technologies (KETs) which include (including ICT - Nanotechnologies - Advanced materials - Biotechnology - Advanced manufacturing and processing – Space),
- Access to risk finance (Debt facility, Equity facility and Specific implementation aspects),
- Innovation in SMEs (Mainstreaming SME support and Specific support).

Societal Challenges pillar addresses major concerns shared by citizens in Europe and elsewhere and covers activities from research to market with a new focus on innovation-related activities, such as piloting, demonstration, test-beds, and support for public procurement and market uptake.

Supported actions:

- Health, demographic change and wellbeing,
- Food security, sustainable agriculture, marine and maritime research, and the bioeconomy,
- Secure, clean and efficient energy,
- Smart, green and integrated transport,
- Inclusive, innovative and secure societies,
- Climate action, resource efficiency and raw materials.

Eligible countries cover 28 EU Member States; acceding countries, candidate countries and potential candidates, in accordance with the general principles and general terms and conditions for the participation. Third countries that fulfil certain criteria are also eligible (a good capacity in science, technology and innovation, a good track record of participation in Union research and innovation programmes, close economic and geographical links to the Union).

Independent researchers, public bodies/entities and private bodies/entities are eligible partners.

Overall budget is € 79.401 million, for Excellence Science € 24.441 million, for Industrial Leadership: € 17.015 million and for Societal Challenges: € 29.670 million.

The share of EU financial contribution for research and development projects can be up to 100% of the total eligible costs. EU financial contribution for innovation projects can be up to 70% of the costs, with the exception of non-profit legal entities which can also receive up to 100% in these actions. In all cases indirect costs will be covered by a flat rate of 25% of the direct costs.

2.2 SME Instrument

Small and Medium-sized Enterprises that are EU-based or established in a country associated to Horizon 2020 can now get EU funding and support for innovation projects that will help them grow and expand their activities into other countries – in Europe and beyond.

Horizon 2020 funds high-potential innovation through a dedicated SME instrument, which offers seamless business innovation support. With about € 3 billion in funding over the period 2014-2020, the SME Instrument helps high-potential SMEs to develop innovative ideas for products, services or processes that are ready to face global market competition.

The SME instrument consists of three separate phases and a coaching and mentoring service for beneficiaries. Participants can apply to phase 1 with a view to applying to phase 2 at a later date, or directly to phase 2.

In phase 1, a feasibility study shall be developed verifying the technological/practical as well as economic viability of an innovation idea/concept with considerable novelty to the industry sector in which it is presented (new products, processes, services and technologies or new market applications of existing technologies). The activities could, for example, comprise risk assessment, market study, user involvement, Intellectual Property management, innovation strategy development, partner search, feasibility of concept and the like to establish a solid high-potential innovation proposal aligned to the enterprise strategy and with a European dimension. Bottlenecks in the ability to increase profitability of the enterprise through innovation shall be detected and analysed during phase 1 and addressed during phase 2 to increase the return in investment in innovation activities.

The proposal should contain an initial business plan based on the proposed idea/concept. The proposal should give the specifications of the elaborated business plan, which is to be the outcome of the proposal and the criteria for success. Funding will be provided in the form of a lump sum of EUR 50.000 covering the 70% of total cost of the project as a general rule. Proposals should last around 6 months.

In phase 2, innovation projects will be supported that address the specific challenges identified and that demonstrate high potential in terms of company competitiveness and growth underpinned by a strategic business plan. Activities should focus on innovation activities such as demonstration, testing, prototyping, piloting, scaling-up, miniaturization, design, market replication and the like aiming to bring an innovation idea (product, process, service, etc.) to industrial readiness and maturity for market introduction close to deployment and market introduction, but may also include some research. For technological innovation a Technology Readiness Levels of 6 or above (or similar for non-technological innovations) are envisaged; please see part G of the General Annexes. Proposals shall be based on an elaborated business plan either developed through phase 1 or another means. Particular attention must be paid to IP protection and ownership; applicants will have to present convincing measures to ensure the possibility of commercial exploitation ('freedom to operate'). Proposals shall contain a specification for the outcome of the proposal, including a first commercialization plan, and criteria for success. The Commission considers that proposals requesting a contribution from the EU of between EUR 0.5 and 2.5 million would allow phase 2 to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts. Proposals should last between 1 to 2 years.

In addition, in **phase 3**, SMEs can benefit from indirect support measures and services as well as access to the financial facilities supported under Access to Risk Finance of this work program.

Successful beneficiaries will be offered **coaching and mentoring** support during phase 1 and phase 2. This service will be accessible via the Enterprise Europe Network and delivered by a dedicated coach through consultation and signposting to the beneficiaries.

Topics

- ICT – High risk ICT innovation
- MMP – Nanotech, or other advanced tech for manufacturing and materials
- SPACE – Space research and development
- PHC – Clinical research for the validation of diagnostics devices and biomarkers
- SFS – Sustainable food production and processing
- BG – Blue growth
- SIE – Low carbon energy systems

- IT – Greener and more integrated transport
- SC5 – Eco-innovation and sustainable raw material supply
- DRS – Urban critical infrastructure
- BIOTECH – Biotechnology-based industrial processes
- Mobile e-government applications (2015 only)
- SME business model innovation (2015 only)

2.3 Connecting Europe Facility

Connecting Europe Facility (CEF) is the new funding mechanism for infrastructure projects of common interest for trans-European transport, energy and telecoms networks. It is part of a new package for European infrastructure proposed by the Commission in October 2011.

CEF supports the development of high performing, sustainable and efficiently interconnected trans-European networks in the fields of transport, energy and digital services. CEF shall enable the preparation and implementation of projects of Common interest within the framework of the trans-European networks (TEN) policy in the sectors of energy, transport and telecommunications. In particular the Connecting Europe Facility shall support the implementation of projects aiming at the development and construction of new or upgrading of existing infrastructure in the field of transport, energy and telecommunications. The Connecting Europe Facility is specifically designed to promote growth, jobs and competitiveness through targeted infrastructure investment at European level.

The general objective is to contribute to smart, sustainable and inclusive growth by developing modern and high performing trans-European networks. The Programme aims to bring forward benefits for the entire European Union in terms of competitiveness and economic, social and territorial cohesion within the Single Market, by creating an environment more conducive to private and public investment through a combination of financial instruments, by offering direct support to the Union and exploiting synergies across the sectors.

In the field of transport, the Connecting Europe Facility supports projects of common interest pursuing the objectives set out below:

- removing bottlenecks and bridging missing links especially in cross-border connections,
- ensuring sustainable and efficient transport in the long run,
- optimising the integration and interconnection of transport modes and enhancing interoperability of transport services.

Proposals may be submitted by one or several Member States, international organisations, joint undertakings, or public or private undertakings or bodies established in Member States.

Where it is needed to achieve the objectives of a given project of common interest, third countries and entities established in third countries may participate in actions contributing to the projects of common interest.

€ 21.936,76 million is available from the EU's 2014-2020 budget to co-fund TEN-T projects in the EU Member States. Of this amount, €11.305 billion will be available only for projects in Member States eligible for the Cohesion Fund.

In the field of railway transport, following topics are supported:

- Freight transport service,
- ERTMS,
- Infrastructure works,
- Rail interoperability,
- Rail freight noise,
- Rail infrastructure,
- Cross border rail,
- Bottlenecks,
- Other project of common interest,
- Accessibility PRM (Persons with Reduced Mobility).

EU financial contribution

In the field of transport:

- with regard to grants for studies, the amount of Union financial aid shall not exceed 50% of the eligible costs;
- with regard to grants for works:
    - rail and inland waterways: the amount of Union financial aid shall not exceed 20% of the eligible cost; the funding rate may be increased to 30% for actions addressing bottlenecks; the funding rate may be increased to 40% for actions concerning cross-border sections;
    - inland transport connections to ports and airports, actions to reduce rail freight noise by retrofitting of existing rolling

stock, as well as development of ports and multi-modal platforms: the amount of Union financial aid shall not exceed 20% of the eligible cost.

- with regard to grants for traffic management systems and services:
  - the European Rail Traffic Management System (ERTMS): the amount of Union financial aid shall not exceed 50% of the eligible cost;
  - traffic management systems, freight transport services, secure parkings on the road core network, as well as actions to support the development of Motorways of the Seas: the amount of Union financial aid shall not exceed 20% of the eligible cost.

In Cohesion countries rail projects may also be financed through the Funding Objective 4, Cohesion Call with a co-financing rate up to 85%.

2.4 EUREKA

EUREKA is an intergovernmental organisation for market-driven industrial R&D. It is a decentralised network facilitating the coordination of national funding on innovation aiming to boost the productivity and competitiveness of European industries. The network integrates over 40 pan-European economies, but also includes Israel, South Korea, and Canada. Following a bottom-up approach with projects being in any technological area with a civilian purpose, EUREKA has been the driving force of innovation in Europe for over 30 years.

Following EUREKA's instruments can be applied:

- Clusters,
- Umbrellas,
- Eurostars,
- Network projects.

Clusters: Initiated by European industry, EUREKA Clusters are long-term and strategically significant initiatives that develop technologies of key importance for European competitiveness. Addressing the needs of both large companies and SMEs, they are the engine for industrial innovation and economic growth.

Clusters catalyse the generation of innovative, industry-driven, near to the market and pre-competitive R&D projects in their respective domains. Through their industrial representation, EUREKA Clusters have a prominent and active role to play in bringing innovation to the market.

The Cluster instrument reflects synergies where European industry's research and collaboration interests, innovation capacity - and national funding opportunities meet.

EUREKA **Umbrellas** are an association of at least five national thematic networks in a specific field of technology or service. Umbrellas are comprised of experts from science and industry as well as representatives of national funding institutions. They are set up to support and advice project consortia on developing project ideas through international partnerships in their given field of technology.

The **Eurostars Programme** is a joint programme between EUREKA and the European Commission and the first European funding and support programme to be specifically dedicated to research-performing SMEs.

The Eurostars Programme is a European Joint Programme dedicated to the R&D performing SMEs, and co-funded by the European Communities and 33 EUREKA member countries. Eurostars aims to stimulate these SMEs to lead international collaborative research and innovation projects by easing access to support and funding. It is fine-tuned to focus on the needs of SMEs, and specifically targets the development of new products, processes and services and the access to transnational and international markets. Through this joint Programme, based on Article 185 of the Lisbon Treaty, Eurostars aims to combine the best of two worlds with a bottom-up approach, a central submission and evaluation process, and synchronized national funding in 33 countries. Eurostars projects are collaborative, meaning they must involve at least two participants (legal entities) from two different Eurostars participating countries. In addition, the main participant must be a research-performing SME from one of these countries.

The role of the SME participants in the project should be significant. At least 50% of the project's core activity should be carried out by SMEs. This percentage can, however, include minor contracting. The consortium should be well balanced, which means that no participant or country will be required to invest more than 75% of the total project costs. Eurostars project should be market-driven: it must have a maximum duration of three years, and within two years of project completion, the product of the research should be ready for launch onto the market.

EUREKA Network Projects are transnational, market-driven innovative research and development projects. Projects supported by the public administrations and public funding agencies that representing EUREKA in each of its 40+ member countries.

The EUREKA "bottom-up" approach to project creation continues to be a characteristic which differentiates EUREKA from other similar initiatives. This approach allows the project consortia to define the nature of the technologies to be developed and how the project comes together. They agree upon the intellectual property rights and build partnerships, to share expertise and gain access to international markets with the results of their research.

EUREKA Network Projects aim to develop marketable products, services or processes. Participation in international cooperation projects through EUREKA offers businesses, research institutes and higher education institutions a range of advantages.

EUREKA Network Projects cover all technological areas with a civilian purpose. To set up a EUREKA Network Project there must be at least two partners from two different EUREKA countries. Partners can be of any type: SMEs, large companies, research institutions and universities.

2.5 Era-Net Transport

Era-net Transport (ENT) has evolved since 2004 into a service platform for Programme Owners and Managers, providing the required framework for initiating and implementing transnational research and innovation funding collaborations.

The Era-net Transport sees a need to encourage and enable less-experienced partners to participate in trans-national cooperation as well as in the European Framework Programme. ENT facilitates this target by supporting these partners in their development of appropriate structures, processes and transport research programmes.

Era-Net Transport has established a platform of transport research funding program owners and managers in Europe for coordinating transport related research funding activities in a transnational manner. National/regional transport research funds can be utilized more effectively by grouping and mobilising European research, innovation and technology competences in a way that promotes new and innovative solutions. Research should make use of complementary expertise and skills, create transnational innovation chains, and increase the competitiveness of Europe’s transport industry by exploiting synergies in utilization of national transport research funds through coordination.

The European landscape in the area of logistics and supply chain innovation is fragmented. R&D programming in logistics is now spread across programmes of different themes (e.g. in Transport, Information and Communication Technologies, Food or Security themes). Out of these programmes more than 60 R&D projects addressing relevant aspects of logistics and supply chain innovation have been funded between 2008 and 2011. Although quite a number of projects are carried out both at national and European levels, they are focussing too often at isolated aspects. As a result of this fragmentation, there has been a lack of paramount vision on the work done and important overarching logistics topics are not treated at all.

Based on the learnings of previous ENT stages Era-net Transport III is geared to establish large-scale cooperation actions (flagship initiatives) in order to bring research cooperation to the next level. Joint transnational collaborations in the frame of this Flagship Call are intended to connect research related to the formation of a freight network of Pan-European dimensions that will answer the needs of shippers, logistics service providers and carriers, in the light of the objectives of an internationally competitive and an environmentally sustainable transport sector.

Era-net Transport call is open for project proposals in five call domains:

- Cross-border freight transport corridors,
- Hub development,
- Urban / last mile logistics,
- Organisational innovations and new business models in logistics,
- Information infrastructure and services for logistics.

All five domains address R&D projects that mainly deal with transport logistics. Clearly, the first three domains are oriented towards key elements of logistics networks whereas the latter two concern overarching domains that have important implications for each sector in a supply chain network.

Fully 11 national/regional funding organisations in 10 countries are providing national/regional research funds totalling about €10 million for coordinated funding of projects.

2.6 Other programmes

Chapter 2.6 introduces some of the other funding opportunities that can be used for financial support of transport research; following list is not exhausting.

ALFA, GAMA, DELTA or OMEGA are few of the programmes managed by Technology Agency of the Czech Republic – TACR. In addition to these programmes, Operational Programme Transport (OPD), Operational Programme Enterprise and Innovations for Competitiveness (OPPIK), COSME and Fast Track Innovation Pilot (FTI) are also mentioned below. COSME and FTI are financed directly from the EU's budget and they are administrated by the European Commission. The others are managed at the national level.

ALFA Programme

The ALFA program aims to support applied research and experimental development especially in the field of advanced technologies, materials and systems, energy resources and the protection and creation of the environment and the sustainable development of transport.

GAMA Programme

The programme aims to support the verification of the results of applied research and experimental development in terms of their practical application and to prepare their subsequent commercial use. The main objective of the programme is to support and significantly streamline the transformation of R&D results achieved in research organizations and/or in collaboration between research organizations and enterprises into practical applications to enable their commercialization and support their implementation.

DELTA Programme

The DELTA programme is aimed at supporting collaboration in applied research and experimental development projects through joint projects of enterprises and research organizations supported by the TACR and major foreign technological and innovation agencies and other similar agencies with which TACR has/will have at the time of publication of the public tender in research, development and innovation established collaboration.

OMEGA Programme

The aim of the programme is to support projects of applied research and experimental development, the results of which have a high potential for application in many areas of Czech society (e.g. development of specialized software for modelling and simulation of economic and demographic trends, the impact of regulation and deregulation in various sectors, etc.).

Operational Programme Transport

The European Commission approved the Transport Operational Programme for 2014 - 2020 Czech Republic to draw on EU funds up to 4.7 billion euros for the development of road and rail infrastructure.

Investments from EU funds will now be directed to the modernization of the fleet of rail passenger transport, which significantly contribute to the greater comfort of passengers on Czech railways. The program also includes the development of transport telematics and intelligent transport systems (ITS).

The aim of OPD is further promoting multimodal freight transport, in particular the development of combined transport.

Operational Programme Enterprise and Innovations for Competitiveness

OPPIK follows the OP Entrepreneurship and Innovations in the programming period 2007 – 2013. Approximately €4.3 billion from the European Regional Development Fund for the projects within the OPPIK has been reserved.

COSME

COSME is the new Programme for the Competitiveness of Enterprises and Small and Medium-sized Enterprises. COSME builds on results and lessons learnt from the Entrepreneurship and Innovation Programme (EIP) and it largely the activities started under the Competitiveness and Innovation programme (CIP) COSME aims at supporting and encouraging the competitiveness, growth and sustainability of EU's enterprises, in particular SMEs, and promoting entrepreneurship.

To reach this goal, the programme eases SME's access to finance by providing loan guarantees and risk capital, facilitates access to new markets inside and outside the EU and improves the framework conditions for businesses, e.g. by reducing the administrative burden on SMEs, make it easier for entrepreneurs and small businesses to benefit.

Fast Track Innovation Pilot

The Fast Track to Innovation (FTI) pilot is a fully-bottom-up measure in Horizon 2020 to promote close-to-the-market innovation activities, and open to all types of participants. The FTI pilot provides funding for bottom-up proposals for close-to-market innovation activities in any area of technology or application. This thematic openness – combined with the possibility for all kinds of innovation actors to work together and deliver innovation onto the market and/or into society – should nurture trans-disciplinary and cross-sectoral cooperation. The aim is to:

- reduce time from idea to market,
- stimulate the participation of first-time applicants to EU research funding, and
- increase private sector investment in research and innovation.

The FTI Pilot will be implemented in 2015 and 2016 with a total budget of €200 million (€100 million per year) across the Horizon 2020 priority "Societal Challenges" and the specific objective "Leadership in Enabling and Industrial Technologies", without further topical restrictions. The pilot will be implemented through one common and continuously open call, meaning that proposals can be submitted at any time. Proposals will be evaluated and ranked and funding decisions taken after three cut-off dates each year.

3 SHIFT²RAIL

The Shift2Rail Joint Undertaking (S2R JU) is a new public-private partnership in the rail sector, established under Horizon 2020, to provide a platform for coordination of research activities with a view to driving innovation in the rail sector in the years to come. It was established on 7 July 2014, following the entry into force of Council Regulation (EU) No 642/2014 of 16 June 2014 establishing the Shift2Rail Joint Undertaking.

EU is more than tripling its financing for rail research and innovation to 450 million € (2014–2020) compared to €155 million that was available under the previous research framework programme (FP7), which ran from 2007 to 2013.

The S2R Joint Undertaking shall seek to develop, integrate, demonstrate, and validate innovative technologies and solutions that uphold the strictest safety standards and the value of which can be measured against, inter alia, the following key performance indicators

- a 100 % increase in the capacity of the railway transport system, to meet increased demand for passenger and freight railway services;
- a 50 % increase in the reliability and punctuality of rail services (measured as a 50 % decrease in unreliability and late arrivals);
- a 50 % reduction of the life-cycle cost of the railway transport system, through a reduction of the costs of developing, maintaining, operating and renewing infrastructure and rolling stock, as well as through increased energy efficiency.

The Shift2Rail JU will manage the entire budget for rail research under Horizon 2020. The Union financial contribution to the S2R JU will amount to a maximum of €450 million from the Horizon 2020 Framework Programme, of which EUR 52 million has already been earmarked under the Horizon 2020 Transport Work Programme 2014-2015.

To access this funding, the rail industry had to commit to a contribution of at least €470 million, so that the entire estimated budget of the S2R JU will be at least €920 million for the period 2014-2020.

In accordance with Article 17 of the S2R Statutes, the JU will carry out its work plan through two mechanisms:

- Up to 70% of the Union financial contribution to the S2R Joint Undertaking will be implemented though financial support to S2R members, through appropriate measures such as the award of grants following calls for proposals, of which
  - up to 40% of the Union financial contribution will be allocated to the founding members other than the Union and their affiliated entities;
  - up to 30% of the Union financial contribution will be allocated to the associated members and their affiliated entities;
- At least 30% of the Union contribution to the S2R JU budget will be implemented by outsourcing tasks through competitive calls for proposals and calls for tenders for non-JU members.

The work conducted within the S2R framework will be structured, first of all, around five asset-specific Innovation Programmes (IPs), covering all the different structural (technical) and functional (process) sub-systems of the rail system, namely:

- IP1 – Cost-Efficient and Reliable High Capacity Trains,
- IP2 – Advanced Traffic Management & Control Systems,
- IP3 – Cost-Efficient and Reliable High Capacity Infrastructure,
- IP4 – IT Solutions for Attractive Railway Services (Passenger),
- IP5 – Technologies for Sustainable & Attractive European Freight.

Within the S2R JU, all relevant stakeholders will be involved in the decision-making processes and share responsibilities. The main bodies of the S2R JU are the Governing Board, in charge of strategic decision-making, and the Executive Director, responsible for day-to-day management. The European Commission and the industrial JU members will have equal voting rights in the Governing Board. There are also be two advisory bodies: a Scientific Committee and a States' Representatives Group.

In addition, the S2R JU will establish a number of working groups to ensure the wide participation and close involvement of experts from all relevant stakeholders from the full rail value chain and from outside the traditional rail industry. In particular, "user requirements" and "implementation/deployment" working groups will be created in order to gather the expertise from actors that may not necessarily be members of the S2R JU such as the rail operating community and other rail private and public stakeholders, bodies representing customers (passengers and freight), and actors outside the traditional rail sector.

The official document Annual Activity Report 2014 was approved by the S2R Governing Board on 31 March 2015, in accordance with Article 20 of the Statutes of the S2R JU annexed to Council Regulation (EU) No 642/2014 and with Article 20 of the Financial Rules of the S2R JU.

On May 28, 2015 a vacancy for an Executive Director Shift2Rail in Brussels was announced. The Executive Director will be selected in November 2015. It is also expected that the first Open Call for Shift2Rail project will be launched in December 2015.

Call for Associated Members of the S2R JU

A crucial milestone in 2014 was the launch of the call for the selection of associated members to the S2R JU. Indeed, in accordance with Article 4 of Annex I of the Council Regulation establishing the S2R JU, the first call for associated members had to be launched at the latest three months after the establishment of the S2R JU. In agreement with the Governing Board of the S2R JU, the Commission successfully launched the call on 6 October 2014.

The call document listed the conditions and procedures for applications, as well as a detailed list of selection and evaluation criteria. The deadline for applications was 12 November 2014 and the Commission received 43 applications. These included 27 applications by single legal entities (SLEs) and 16 applications on behalf of consortia, so that a total of 127 entities applied. 7 applications were made by stakeholders from the rail operating community (ROC), i.e. railway undertakings (RU), infrastructure managers (IM) or urban operators (URBAN) either as SLEs or consortia. The research community (research centres or universities) was also rather well represented in applications either as SLEs or consortia. Finally, there were 4 applications from SMEs as single entities and a further 18 SMEs were involved in consortia.

Finally, all Innovation Programmes identified in the draft S2R Master Plan were covered by applicants, as were, to a lesser extent, the Cross-Cutting Activities (CCA).

Overall, the sum of proposed contributions on indirect actions (projects) reached €474 million, i.e. a more than three-time over-subscription compared to the expected overall contribution from associated members to the JU foreseen in the S2R Regulation (€150 million). Generally all IPs were largely "over-subscribed", in particular IP2, IP3 and IP5, almost three quarters of the applicants' proposed contributions were concentrated on IP1, IP2 or IP3.

The evaluation procedure of the first stage of the call was initiated in November 2014 and was completed in March 2015.

The Scientific Committee

The call for expressions of interest for the selection of members of the Scientific Committee of the S2R JU was launched on 22 October 2014 (Ref. S2R JU/SC/01/2014 – this document lists the eligibility conditions, evaluation and selection criteria and procedures for application). The ERRAC Technology Platform, the States Representatives Group of the S2R JU and the European Railway Agency were notified of the launch of the call for expressions of interest for the selection of Members of the Scientific Committee and were invited to make recommendations of possible candidates. The States Representatives Group of the S2R JU submitted 18 nominations. The ERRAC Technology Platform submitted 11 nominations. The European Railway Agency did not provide any nominations.

In response to the call, the S2R JU received 61 applications. One application was deemed ineligible (not meeting the deadline). One application was deemed inadmissible (application incomplete). The Governing Board appointed an evaluation panel which met on 11 February 2015 to evaluate the applications based on the selection criteria contained in the call document and to decide on the list of successful candidates, taking into account the nominations that were made by ERRAC and the S2R States Representatives Group, the profiles and the complementarity of expertise of the candidates, as well as potential conflict of interests. Twelve candidates were selected to constitute the Scientific Committee of the S2R JU and six candidates were selected to constitute the reserve list of the Scientific Committee of the S2R JU.

Example of successful projects - IT²RAIL

IT²RAIL is linked with SHIFT²RAIL IP4 and other Horizon 2020 Mobility for Growth projects, specifically IN²RAIL (call MG2.1) which is in close relation with SHIFT²RAIL IP2 (Advanced Traffic Management & Control Systems) and SHIFT²RAIL IP3 (Cost Efficient-High Capacity Infrastructure).

The works carried out under the MG2.2-2014 call will be used as a ramp-up towards SHIFT²RAIL IP4 full capabilities. SHIFT²RAIL IP4 works will later extend these capabilities to complete use cases.

The IT²RAIL - "Information Technologies for Shift to rail", first step towards the long term IP4 - "IT for an Attractive Railway" SHIFT²RAIL Innovation Programme, aims at providing a new seamless travel experience, giving access to a complete multimodal travel offer which connects the first and last mile to long distance journeys. This is achieved through the introduction of a ground breaking Technical Enabler based on two concepts:

- The traveller is placed at the heart of innovative solutions, accessing all multimodal travel services (shopping, ticketing and tracking) through its travel-companion.
- An open published framework is providing full interoperability whilst limiting impacts on existing systems, without prerequisites for centralized standardization.

This Technical Enabler will be completely settled in the context of the SHIFT²RAIL IP4, and IT²RAIL is proposing a reduced approach to the scale of a specified use case without weakening any of the key concepts of IP4, such as the usage of Semantic Web technologies, meta planning on distributed data, travel companion with a protected and secured personal wallet stored in the cloud and including the rights to travel.

The approach and methodology chosen for the Project will be centred on the introduction of a 'Technical Enabler' composed of:

Travel Companion application

Directly and personally interacting with the user, the Travel Companion is a protected and secured data store in the cloud accessible by the citizen through a preferred mobile device or a dedicated application. It introduces the major concept of a unique identifier used by an individual citizen to access and operate on the entire European Transportation System. As such, the Travel Companion is uniquely associated with a citizen and his/her secured ID, not with specific Travel Service Providers or retailers.

The cloud data store is organised in a set of secured compartments containing, among others, Customer preferences, preselected payment means and credentials, itineraries obtained from a Travel Shopper, and entitlements from Ticketing processes. The Travel Companion application is accessible via smartphone devices and is portable with respect to different travel retailers. Personal data shall be managed in accordance with the legally required protection of privacy and individual rights.

By customising his/her Travel Companion the Traveller can build a personal and dedicated virtual 'travel environment' where he/she can feel shielded from the complexity of the transportation system. Interaction with the Travel Companion can be customised according to personal choice, e.g. language and other 'local' properties, whilst indoor navigation and other capabilities as made available by local instrumentation may be discovered automatically by the interoperability framework.

Travel Shopper application

The Travel Shopper accesses distributed travel and transportation resources as a service of the interoperability framework as well as Customer preferences, stored in the Travel Companion. This provides the capability to build a set of integrated door-to-door, multi-modal itineraries in answer to a Traveller mobility query. The shopper has for ambition to become a seamless one-stop shop servicing all Traveller itinerary requests including the all-important first and last miles of the European journeys, as well as demonstrating how innovative and expert or 'niche' shopping related applications can be orchestrated at relatively low cost.

Ticketing application

The Ticketing component locates and interacts with multiple booking engines and/or payment processors distributed across the network to generate bookings and entitlements for one or more of the itineraries selected by the citizen on the Travel Shopper. Ticketing also coordinates payments as requested, and stores created objects (e.g. entitlement references/tokens) in the citizen's Travel Companion.

Multimodality and seamlessness are especially visible also through the Traveller being able to navigate throughout the heterogeneous urban transport environment (card centric systems, back office centric, electronic entitlement tokens or their physical embodiments, near field communication technologies etc.).

The capability to access older generation transport networks whilst offering an open and adaptive capability towards the latest progress of the transport industry (near field communication technologies, EMV payment etc.) is at the heart of this multimodal service.

Trip Tracker

Trip Tracker monitors relevant events available on the 'web of transportation things' that could affect the Traveller's journey. Matching those events with the preferences and door-to-door itineraries, stored in the Travel Companion, Trip Tracker aims to provide the user with a shield against travel disruptions by enabling seamless re-arrangement. To this end, Trip Tracker may automatically invoke Travel Shopper and Ticketing to create alternate itineraries, and, through the Travel Companion display alerts, offer alternative routings and trigger re-accommodation where applicable or desired.

IT²RAIL approach aims to give the Traveller full control of the door-to-door travel experience across transport modes and services, its engineering approach is naturally articulated around human behaviour.

The conventional approach of designing systems based on the Operator's operational capabilities and 'Customer needs' abstracted as mere system transactions will be replaced by modelling human behavioural patterns in relation with transportation on different modes, at interchanges, and in different gender sensitive and cultural settings. A full set of 'personae' will be modelled around which the design of components, interactions and human-machine interfaces will be conducted.

Seamlessness will be extended to encompass the full range of interactions between Citizens, their digitalised work and leisure environment, devices including vehicles, smart cities and intelligent transportation systems, and the Transportation Network, all considered as an open-ended, self-sustained world of networked resources and services. Building on open semantic web standards and big data technologies, IT²RAIL aims to provide interoperability with existing available resources automatically discovered over the network, but also to allow Providers to design and offer enriched and smart travel services.

The IT²RAIL consortium is composed of 27 partners originating from 9 European countries (Belgium, Czech Republic, Estonia, France, Germany, Italy, Netherlands, Spain and United Kingdom) with a broad spectrum of capabilities.

Results of IT²RAIL project will provide Travellers with the tools to construct a digital, customised, integrated and operable representation of the seamless transportation environment with which he/she interacts. It will mask differences in local protocols, procedures, customs or physical facilities and devices which currently make the overall transportation system hard to understand, trust or use, particularly for Citizens in an unfamiliar environment or with specific cultural, sensorial or mobility constraints.

4 Conclusion

Research and innovation is a key factor for organisations to be competitive in the market. Every dynamic sector needs to innovate and reinvent its practices. Rail sector faces significant economic and environmental challenges therefore it has to move quickly to meet them. Rail needs to innovate and bring new technology, processes and business models. This includes innovation that comes from research and development activities but also innovation that results from other activities, such as finding new uses or combinations of existing technologies or developing new business models or new ways of interacting with users.

Of course, without the necessary financing, no investment to innovations will take place. Both public and private resources are mobilised for this purpose over the current programming period. Although plenty of information is available on the different EU funding sources, potential beneficiaries are often still confused, in particular when it comes to deciding which source of funding is most appropriate for a given activity.

The paper summarise selected information about the implementation of the most important programmes for researchers, public and private sector entities. It brings quick and accurate information on funding opportunities available through the EU and national programmes suitable for the rail sector. It provides the key information to those with an interest in funding for the period 2014-2020.

Horizon 2020, the EU’s eighth Framework Programme for funding research and innovation plays a major role. In addition, there are many other funding opportunities outside the Framework Programme that support transnational collaboration in a wide range of activities including research and innovation. Horizon 2020 is open to everyone, with a simple structure that reduces red tape and time so participants can focus on what is really important. A key objective of Horizon 2020 is to improve the efficiency of EU funding and better address societal challenges by pooling together existing R&I efforts and expertise, namely through Public-Private Partnerships in the form of Joint Undertakings. Therefore, it is important to follow the new public private partnership SHIFT²RAIL Joint

Undertaking which will double railway capacity, cut the life-cycle cost of railway transport, increase reliability and punctuality.

The CEF will focus on projects that have high added-value for the EU, and will support the funding and development of the Trans-European Transport Networks. It will also make Europe's economy greener by promoting cleaner transport modes, high speed broadband connections and facilitating the use of renewable energy in line with the Europe 2020 Strategy.

There are also national and regional funds which represent a considerable part of the budget of the European Union, whose management is shared between the EU and the Member States.

SMEs are increasingly at the heart of EU industrial and R&D policies. SMEs will be encouraged to participate across the programme period 2014-2020. There are new instrument opened to highly innovative SMEs showing a strong ambition to develop and grow. Moreover, billions of Euros will be awarded by the European Union to SMEs during the next few years through Shift2Rail, the Structural Funds, the new H2020 SME Instrument or the new Programme for the Competitiveness of SMEs COSME.

Research and innovation have been placed at the centre of the Europe 2020 strategy. There are funding opportunities available that can help us implement our plans. Participation is open to a wide range of research entities both as organisations or individuals. Universities, research centres, multinational corporations, SMEs, public administrations, funding bodies, even individuals – all have the opportunity to participate. Either we want to build up or enhance the research capacity of our organisation or we are interested in innovation and wish to develop new or improved products and services, EU or national funds are there for us.

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LIST OF ACRONYMS

CCA	Cross-Cutting Activities
CEF	Connecting Europe Facility
CF	Cohesion Fund
CIP	Competitiveness and Innovation Framework Programme
CIP	Competitiveness and Innovation programme
COSME	Competitiveness of Enterprises and Small and Medium-sized Enterprises
CSF	Common Strategic Framework
EAFRD	European Agricultural Fund for Rural Development
EC	European Commission
EIP	Entrepreneurship and Innovation Programme
EIT	European Institute of Innovation and Technology
EMFF	European Maritime and Fisheries Fund
ENT	Era-net Transport
ERA	European Railway Agency
ERC	European Research Council
ERDF	European Regional Development Fund
ERRAC	European Rail Research Advisory Council
ERTMS	European Rail Traffic Management System
ESC	Economic and Social Cohesion policy (European Union's regional policy)
ESF	European Social Fund
ESI	Structural and Investment Funds
ESIF	European Structural and Investment Funds
EU	European Union
FET	Future and emerging technologies
FP7	Seventh Framework Programme
FTI	Fast Track Innovation Pilot
GB S2R	Governing Board of the S2R JU
ICT	Information and Communication Technologies
IM	Infrastructure Managers
IP	Innovation Programme (Shift2Rail)
IT	Information Technology

IT2Rail	Information Technologies for Shift2Rail
ITS	Intelligent Transport Systems
KET	Key Enabling Technology
OP	Operational Programme
OPD	Operational Programme Transport
OPPIK	Operational Programme Enterprise and Innovations for Competitiveness
PRM	Persons with Reduced Mobility
R&D	Research and Development
R&I	Research and Innovation
ROC	Rail Operating Community
RU	Railway Undertakings
S2R JU	Shift2Rail Joint Undertaking
SC S2R	Scientific Committee of the S2R JU
SERA	Single European Railway Area
SLE	Single Legal Entity
SME	Small and Medium-sized Enterprise
SRG S2R	States Representatives Group of the S2R JU
TACR	Technology Agency of the Czech Republic
TEN-T	Trans-European Transport Network

HYDROSTATIC TRANSMISSION CONTROL OF M27 RAILCAR

Zdeněk Mašek[1]

Abstract: The paper describes functions of control system for hydrostatic transmission for reconstructed railcar M27 which is used for transport of passengers on narrow gauge railway near Jindřichův Hradec, Czech republic. Software for this control system was developed at University of Pardubice.

Keywords: rail vehicle, control system, hydrostatic transmission, tractive effort, JHMD, M27, MUV 74.1.

1 Introduction

Jindřichohradecké místní dráhy a.s. (JHMD) company provides regular railway service on narrow gauge railway between Jindřichův Hradec and Obrataň in the Czech republic. During the year 2012 JHMD decided to start reconstruction of four railcars of type M27 (805.9). Originally M27 was manufactured in Romania in the middle of 80's. Tab. **1** summarizes technical parameters of original railcar M27 (805.9).

Tab. 1: Parameters of M27 railcar before reconstruction

Gauge	750 mm
Length	15 920 mm
Weight	24,5 t
Wheelset arrangement	B' 2'
Maximum towing capacity	57 kN
Engine type	Raba-MAN D2156HM6U
Engine output	141 kW
Transmission	Hydrodynamic
Maximum speed	60 km/h

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Reconstructed railcar M27 has completely new design, engine, new hydrostatic transmission, wheelset arrangement, control system, interior, air conditioning, lights etc. Main frame and bogies are almost the same as on original M27.

Fig. 1 Reconstructed railcar M27

Hydrostatic transmission is used instead of original hydrodynamic transmission. Control system for hydrostatic transmission used in reconstructed vehicle was developed at Univerzita Pardubice/DFJP-KEEZ and at first it has been succesfully used on special rail vehicles MUV 74.1 by CZ Loko company during the years 2012 and 2013.

Tab. 2: Parameters of M27 railcar after reconstruction

Gauge	750 mm
Length	15 920 mm
Weight	24,5 t
Wheelset arrangement	B' B'
Maximum towing capacity	24 kN
Engine type	Tedom 242R6VHTA26
Engine output	242 kW
Transmission	Hydrostatic (Parker) 2x hydraulic pump PV270 2x hydraulic motor F12-250
Maximum speed	60 km/h

2 Wheelset arrangement

There are two bogies and two independent hydraulic circuits, one for each bogie. It allows to continue driving if one circuit fails. Each circuit consists of axial piston pump with variable displacement (Fig. **2**, pos. 3) and hydraulic motor with constant displacement (Fig. **2**, pos. 4 and 5). Cardan shaft is used to couple wheels with hydromotor. Both hydraulic pumps are connected directly to engine output shaft.

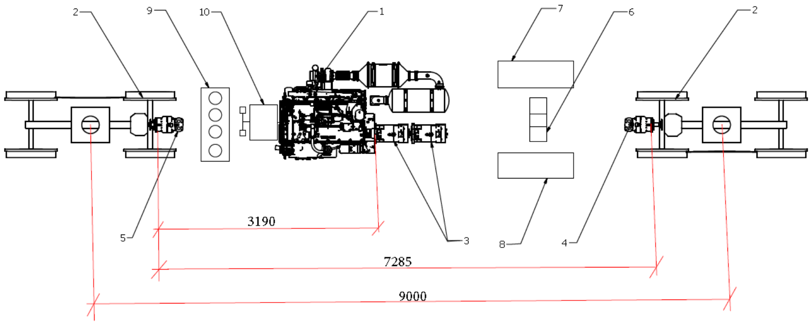

Fig. 2: Wheelset arrangement

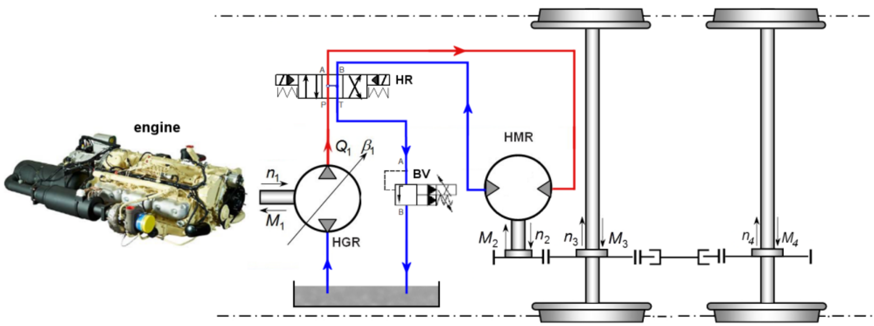

Fig. 3: Scheme of one hydraulic circuit

3 Hydrostatic transmission

3.1 Overview

Hydrostatic transmission is commonly used in off-highway vehicles. In locomotion applications is commonly used for propelling of auxiliary devices such as fans. Due to its benefits is also succesfully used in traction drives especially on low power shunting locomotives and special maintenance vehicles like tampers.

Benefits of hydrostatic transmission are high power density (easy installation to vehicle where only a small room is available) and continuous transfer ratio that allows to achieve prescribed speed-tractive-effort curve and utilizes of engine power well. Disadvantages are possible oil leaks, sensitivity to oil cleanness and increased demands and costs for maintenance compared to modern electric drives.

Basic structure of one hydraulic circuit (one bogie) of M27 vehicle can be seen in Fig. **3Chyba! Nenalezen zdroj odkazů.**.

Open hydraulic circuit consists of axial piston pump (HGR) Parker PV270 acting as a source of oil flow, hydraulic motor (HMR) Parker F12-250 with constant displacement, directional control valve (HR) and proportional brake valve (BV). Bypass valve is connected parallel to brake valve (not shown in Fig. **3**) for lowering pressure losses of brake valve if it is open.

Tractive effort depends on oil pressure on the output of pump. Therefore oil pressure is main controlled variable. Oil flow rate and vehicle speed are dependent variables. Oil pressure is controlled by pump displacement, which is represented by unitless quantity β, according to control law.

$$\beta = \frac{V_g}{V_{g\max}} \tag{1}$$

Where $V_{g\max}$ is nominal displacement (cm^3) and V_g is actual displacement (cm^3).

Theoretic oil flow rate in (litres per minute):

$$Q = \frac{V_{g\max} \cdot n \cdot \beta}{1000} \tag{2}$$

Where n (rpm) is speed of pump or motor.

Theoretic torque (input in the case of pump or output in the case of motor):

$$M = \frac{V_{g\max} \cdot p \cdot \beta}{20\pi} \tag{3}$$

Where p (bar) is differential pressure across pump or motor.

Theoretic power (kW) (input in the case of pump or output in the case of motor):

$$P = \frac{M \cdot \pi \cdot n}{30000} = \frac{Q \cdot p}{600} \tag{4}$$

All above mentioned equations are theoretic, i.e. efficiency is not included. Maximal pressure used on M27 is 330 bar, oil flow rate for maximal velocity 60 km/h is 367 litres per minute.

In the first proposals the proportional brake valve should have been used for hydraulic braking but in final version hydraulic braking is not implemented. Instead of it brake valve with its bypass valve are fully open during normal operation to avoid pressure losses. If driving direction is not set (direction control valve is disengaged and is in central position) brake valve is activated and its bypass valve deactivated to ensure minimal pressure for proper operation of pump. This minimal pressure is approx. 20 bar.

3.2 Control law

Hydrostatic transmission is controlled according to ideal tractive effort curve of vehicle.

In Fig. 4 you can see fundamental control characteristic of hydrostatic transmission equipped with pump and motor, both with variable displacement.

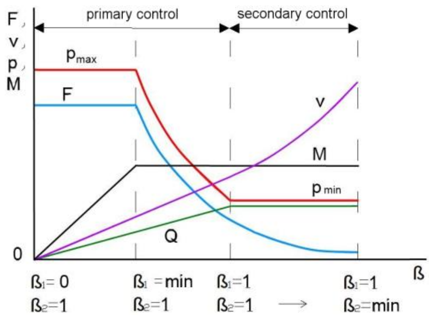

Fig. 4: Control characteristic of HS transmission

Motors used on M27 have constant displacement ($\beta_2 = 1$) therefore part named “secondary control” in Fig. 4 does not exist, control range is restricted to pump operation only (primary control).

In the region of constant power (from β_1 = min to β_1 = 1) engine load torque M is kept constant (5).

$$M_{1T} = \frac{V_{\mathrm{gmaxHG}}}{20\pi} \cdot p_{\min} = \frac{V_{\mathrm{gmaxHG}}}{20\pi} \cdot p_{\max} \cdot \beta_{1\min} = \\ = \frac{V_{\mathrm{gmaxHG}}}{20\pi} \cdot p \cdot \beta_1 = const. \quad (5)$$

Pump is commanded with desired pressure p according to desired tractive effort. Quantities β_1 flow Q and vehicle speed v result from actual situation (running resistance). Engine speed (not shown in Fig. 4) is commanded according to desired tractive power. Speed for desired power is compromise between engine manufacturer requirements and minimum brake specific consumption.

In the region of constant tractive effort, pressure is set according to desired tractive effort (330 bar maximum), engine load is proportional to actual pump displacement.

Vehicle velocity is directly proportional to actual pump displacement (β_1). Transmission ratio is continuously changing (6).

$$i_T = \frac{n_{2T}}{n_1} = \frac{V_{g\max HG}}{V_{g\max HM}} \times \frac{\beta_1}{\beta_2} \quad (6)$$

Where subscript T stands for "theoretic", i.e. efficiencies are not included, n_1 is pump (engine) speed and n_{2t} is motor speed (theoretic).

In Fig. 5 you can see tractive effort curve of reconstructed railcar M27 including grade resistance curves.

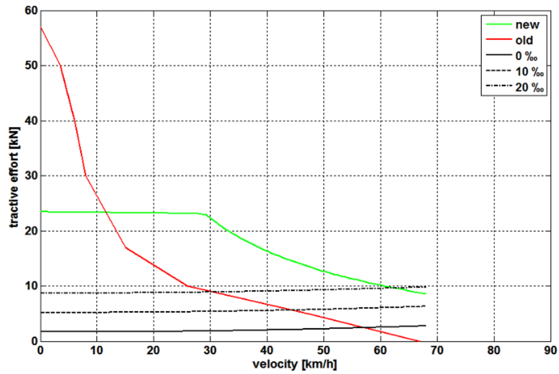

Fig. 5: Tractive effort curve of M27 after reconstruction (new) compared to tractive M27 before reconstruction (old)

Absence of motors with variable displacement reduces dynamic control range and shorten constant power region to lower velocities (see Fig. 6).

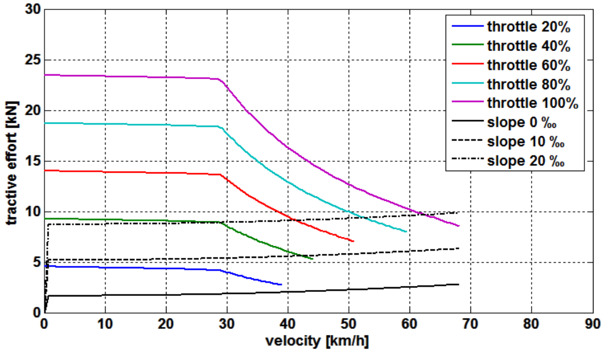

Fig. 6: Partial tractive effort curves of M27 after reconstruction

To achieve desired vehicle velocity while running resistance is low can be uneconomical because oil flow and therefore engine speed is high but engine load is low due to low running resistance (curves don’t intersect). Fortunately JHMD’s railway is situated to hilly country so aforementioned disadvantage can be avoided. Motors with variable displacement of used size and for reasonable price were not available for this vehicle.

3.3 Control structure

A simplified control structure is shown in Fig. 7.

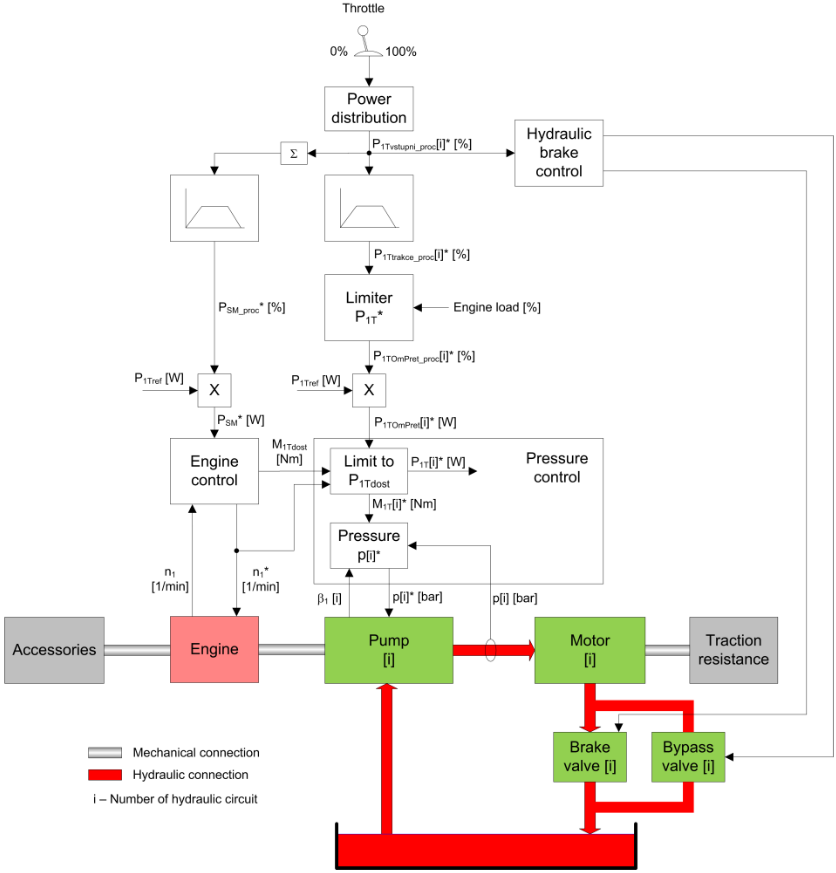

Fig. 7: Control structure

Driver sets desired tractive power. Desired power is evenly distributed across both hydraulic circuits (bogies). Traction control is not implemented. In the case of one circuit malfunction the broken circuit is commanded to zero desired power and circuit is disabled. Desired power is ramped and goes to tractive power limiter that limits desired tractive power in all circuits proportionally if engine load is above specified value. Actual engine load at current speed is received from engine ECU via CAN bus. Next a desired load torque $M_{1t}*$ is computed from desired tractive power and engine speed n_1*. $M_{1t}*$ is then converted to desired pressure $p*$ with the help of equation (5). Actual β_1 is sensed by LVDT sensor inside of pump. These computations are done for each hydraulic circuit. Desired speed of engine is computed according to desired tractive power including defined constant margin for accessory loads that can switch randomly on and off.

Due to used control principle available engine power at current speed is utilized only in the region of constant tractive power, not in region of constant tractive effort. This is due to fact that driver commands desired power not desired force, i.e. engine speed is set directly according to throttle position regardless of the fact if engine would be loaded with this power or not.

Brake valve and its bypass valve are fully open during normal drive to minimize power losses in system.

3.4 Coasting

If coasting is commanded by the driver or by external logic then direction control valves in both circuits are disengaged and oil can freely flows from output port to input port of both motors. Motors act in this situation as pumps. Desired power is set to zero but desired pressure is not zero, instead of it 20 bar is commanded. Minimal pressure 20 bar is needed for proper pump operation. Without this pressure it is not possible to close the pump to almost zero displacement. Almost no oil flow from pump is generated during coasting, engine is unloaded. Minimal pressure is maintained by actuation of brake valve, bypass valve is closed. Engine idles during coasting.

Special care must be taken during a return phase from coasting back to pulling while vehicle is moving. In the beginning of this phase pumps generate only small flow because desired power and therefore engine speed is low but motors generate flow that depends on vehicle speed. At maximum vehicle speed this flow could be twice as flow generated by pumps. To prevent big flow difference, that motor would have to suck via leakage line from tank, direction control valve in each circuit is not engaged immediately but after the flow difference decreases under defined threshold (50 litres per minute). Big flow difference should case negative pressure in leakage line of motor and cavitation could occur.

The same principle is used during “small” coasting while driver commands low power but vehicle still keeps its velocity. In this situation again flow difference between pump and motor exists. If this difference is greater then defined threshold

(150 litres per minute) then direction valves are disengaged to prevent negative pressure in leakage lines of motors. There are a few differences compared to “big” coasting. During “small” coasting the desired pressure stays at the level according to desired power, engine speed also, brake valves and bypass valves are fully open as during normal operation. Return from “small” coasting back to pulling is automatic and occurs if vehicle slows enough down causing reaching of flow rate difference threshold for engaging of direction valves.

4 Hardware components

Control system performs only functions closely related to hydrostatic transmission. All other functions like engine starting, lighting, information system, doors are controlled by their autonomous control systems. HW architecture is presented in Fig. 8.

The throttle is analog type (4-20 mA output) with latch in bottom position (coasting demand). External switching logic for blocking traction power is connected to the input named “coasting switch”. Reaction of hydraulic system on coasting demand is following. Power is set to zero and direction valves are disengaged. Oil can flow freely through the hydraulic motors, vehicle is coasting.

TEDOM engine is controlled in speed loop, communication runs over J1939 protocol. The state of engine is displayed on small color diagnostic display placed on driver’s desk. State of hydraulic drive would be also displayed on the same display in a future.

Ethernet port on RRCPU is used for debugging purposes and for firmware and application software download to RRCPU.

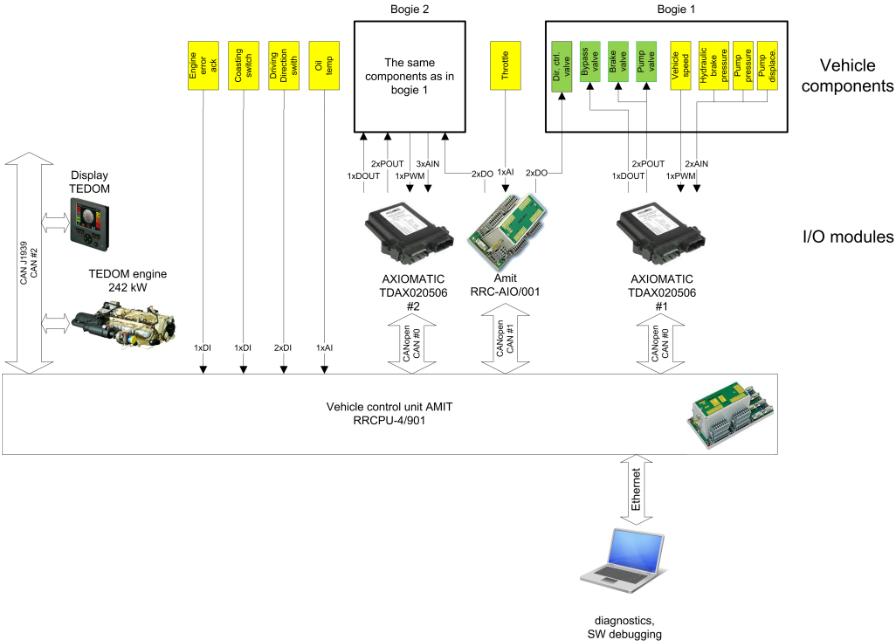

Fig. 8: HW architecture

5 Software development

The main functions of application SW are following:

- Control of hydrostatic transmission
- Control of engine speed
- On board diagnostic of components

Application software for vehicle control unit RRCPU is developed in compliance with legislative norm EN 50128 [2] and with MISRA coding standard. Vehicle computer firmware itself meets requirements for safety integrity level 0. Application SW is written in C++ language. Application SW uses TROL library by AMiT for access to CANopen buses, I/O and other functions in vehicle control unit RRCPU. Special applications TrolDatGen and TrolView developed by AMiT are used for setting up project and real-time application debugging including data logging, displaying data in charts, using alarms for detection mechanism of faults and so on. SAE J939 communication stack for communication with engine was developed on KEEZ department because this type of protocol was not supported by TROL library.

Safety functions are secured outside of application SW using HW relay logic. It sends signal to "coasting switch" input on RRCPU if it is needed and also mechanically interrupts digital outputs of RRC-AIO module for disengaging of direction valves in all hydraulic circuits. The result is disengaging of power and vehicle switches to coasting.

Safety relay circuit guards following:

- Air pressure in brake system (drop in pressure results in disengaging of power).
- If vehicle doors are closed.
- Actual position of hydraulic direction control valves (has to be same as commanded position).
- Oil temperature and oil level in tank.

Integration testing on the first and second vehicle takes place in these days. After completion a final validation tests will be performed. Vehicle will then be prepared for approval procedure.

6 Measurements

In Fig. 9 are shown main quantities of hydrostatic propulsion that were acquired during vehicle acceleration from zero velocity at 100 % throttle. Measurements were taken on real vehicle M27.002.

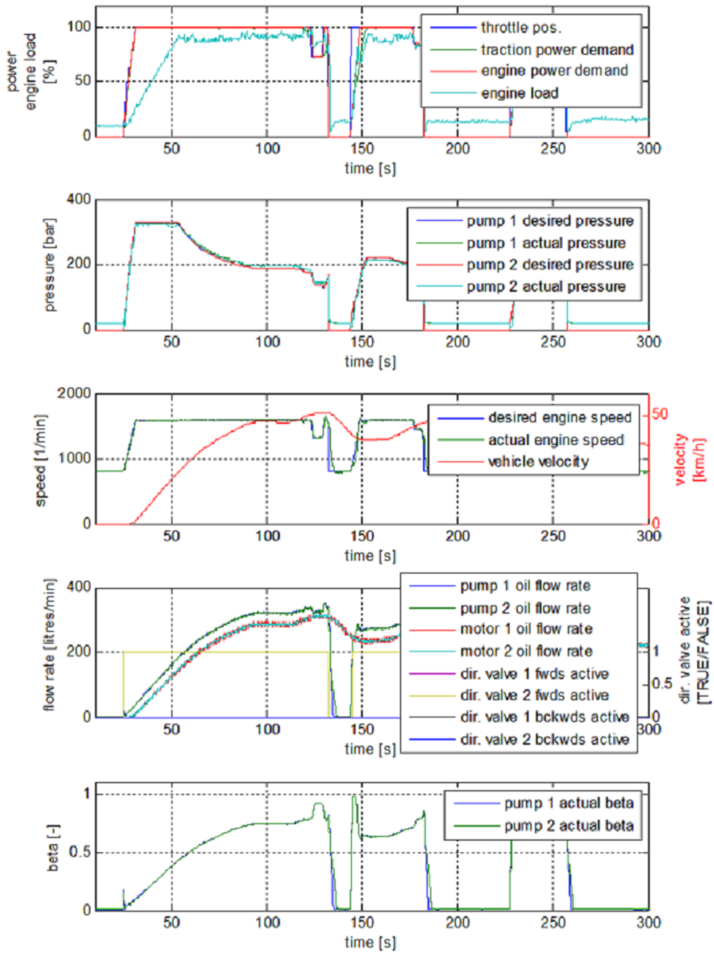

Fig. 9: Vehicle acceleration at 100 % throttle

At the beginning vehicle stays at zero velocity, engines idles at 800 rpm, direction valves are disengaged (outputs of both pumps are connected with oil tank through the brake valves), brake valves are activated and create approx. 20 bar pressure (pump 1 and 2 actual pressures are approx. 20 bar in Fig. 9) in order to close both pumps (beta of both pumps is approx. zero in Fig. 9).

Driver sets 100 % throttle at the 25th second, i.e. maximum tractive effort. Signal from throttle is ramped. Direction valves for switching forward direction are activated, oil can flow from pumps to motors from now on. Pressure ramps up to maximum value 330 bar. Vehicle begins to move. Pump's displacements and flow rates increase which results in vehicle velocity increase. Pressure is still held on maximum value. Engine load increases as well. Engine load represents engine torque at current engine speed. This part of figure corresponds to constant tractive effort region in tractive effort curve. Engine speed is set to value corresponding to 100 % power demand even if actual power taken from engine in constant tractive effort region is just increasing with vehicle velocity and commanded engine speed does not correspond to 100 % power demand (engine speed is set according to throttle position, not according to real power needed from engine).

At the 54th second velocity reaches approx. 24 km/h. This is the point where region of constant power begins. It corresponds with theoretic tractive effort curves shown in Fig. 4 or Fig. 5 quite well. From this point further engine works with optimal load at optimal speed, i.e. engine speed is optimal for demanded power. Pressure demand is computed according to (5) in order to keep engine load at constant value approx. 95 %. As vehicle velocity increases, pressure and tractive effort decreases to keep engine load constant.

At the 133th second the driver commands coasting. Traction power is set to zero, i.e. pressure demands are zero, engine goes to idle, direction valves are disengaged, outputs and inputs of motors are connected through the direction control valves. It enables free oil flow through motors. Pumps are closed because brake valves are activated. Vehicle is coasting.

At the 143th second driver commands full throttle again while vehicle is moving. Drive goes from coasting to pulling in the same way as at the beginning. The only difference is later activation of direction valves. Valves are engaged at the moment when difference between pump flow rate and motor flow rate in each circuit reduces below defined threshold (50 litres per minute). It enables fluent transition without oscillation.

7 Conclusion

Main functions of control system for hydrostatic transmission of railcar M27 were described in the paper. In these days all four vehicles are on duty. After the first tests a transition to coasting had to be modified in order to build enough pressure on brake valve to set hydrauling pump to closed position and algorithm for overcoming turbo boost lag of combustion engine had to be developed in order to prevent overloading of combustion engine during turbo boost lag interval.

Acknowledgment

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A SURVEY OF OPTIMIZATION APPROACHES FOR RAIL FREIGHT CAR FLEET MANAGEMENT

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Abstract: Rail freight cars are expensive capital items and rail freight car fleet management represents an important issue for both researchers and rail freight transport service providers. Many models for fleet management have been proposed in the literature. The aim of this paper is to present a survey of recent optimization approaches for the rail freight car fleet management. We propose a classification of models and describe their important characteristics by focusing on model structure and algorithmic aspects. The emphasis is given on recent approaches, but several older most important contributions are also cited.

Key words: rail freight cars, scheduling, demand estimation, sizing.

1 Introduction

In past, when the production of bulk cargo have dominated in world economy, the concept of providing low quality cheap services was enough to enable a high profitability of railway companies. However, changes in economy oriented to incorporating more eficient inventory policies (like just-in-time is for example), have led to unsuitability of policy making based only on adjusting business processes with demand increasing. Consequently, with the aim of maintaining profitability and concurrency, railway companies reinvest in advanced technology together with improvement of their management practicies.

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Railway transport system as well as other transport systems is characterized by an imbalance of commodity flows. That means that the difference between ingoing and outgoing freight flows is positive in some regions while it is negative in some other regions of a railway network. This leads to a spatial and time imbalance of supply and demand for empty rail freght cars. Complexity of the problem is additionaly weighted by the existence of a number of rail freight car types. Therefore, for transport demand fullfiling it is neccessary to establish a balance and therefore to alocate empty cars with minimal transport costs. Based on previous, it is clear that an efficient rail freight car management system represents an imperative for all rail transport operators. This system, besides the need to maximize fullfilment of transport requests, in a great extent influences on total number of needed cars in system, as well as on the way how these cars are used for transport requests satisfying. Consequently, large rail freight car fleet has higher investments, costs of maintenance and inventories than it is neccessary, whereas a shortage of rail freight cars resulting in lower service quality will be present in contrary. Therefore, there are two main research directions in the field of rail freight car fleet management. The first one is dedicated to rail freight car scheduling. This task considers determining the neccessary rail freight car flows. The second task is aimed to optimal rail freight car fleet sizing. Empty rail freight car scheduling process is composed from two phases. The first one is a planning phase whereas the second phase represents its physical alocation with minimum costs and demand satisfaction. Empty freight car transport has a large share in total transport on a railway and therefore an efficient and effective distribution process represents an imperative for capital and operational costs decreasing. The size of rail freight car fleet is in rail freight car allocation researches treated as an input parameter, although numerous academic discussions and practical experiences have shown that there is a strong relationship between potential benefits from investments in rail freight car fleet and operational cost decreasing. Determining an investment level in rail freight car fleet is based on establishing a balance between costs aimed to provide sufficient capacities and potential costs of unmet demand. For a long time, models dedicated to this problem have actually solved the task of determining the optimal fleet size for demand satisfying and most frequently with respect to a total cost minimization criteria. Lately, among the researchers appears a common consensus about the need for involving the costs of empty freight car allocation in the problem of rail freight car fleet sizing. The aim of these tendencies should be minimization of a sum of constant capital costs and variable allocation costs [52].

This paper provides a review of recent solution approaches for efficient and effective rail freight car fleet management. All three levels of planning are covered.

Considering the large size and complexity of approaches, paper contains only textual description of approaches. Recent approaches are covered as well as the most important older works. Review is focused on railway transport, even though a lot of approaches made in the field of road and container transportation is certainly important to the context of rail freight car fleet management. This work is also based on previous reviews, so we refer readers to papers [23], [25] and [44].

Paper is organized as follows. Classification of the approaches for rail freight car fleet management is given in Section 2. Section 3. contains review of operational models, whereas tactical and strategic approaches are given in Section 4. Concluding remarks are given in last section.

2 Classification of rail freight car fleet management models

Models for rail freight car fleet management can be classified in (Fig. 1):

- Operational models which cover problems of shorter time horizons such as rail freight car inventory problems, determining origin-destination flows for empty cars and routing of empty and loaded freight cars.
- Tactical and strategic models for railway related planning problems which cover middle and long time period. These models include service network design, rail freight car demand modelling and rail freight car fleet sizing.

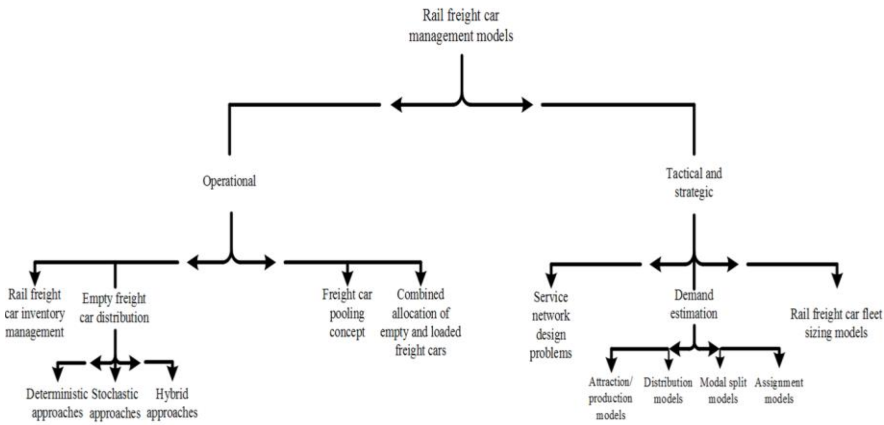

Fig. 1: Classification of models for freight car fleet management problems

3 Operational models for rail freight car fleet management

The essence of operational models is an efficient management of a given rail freight car fleet through minimizing empty freight car allocation costs and transport demand fulfilling [25]. These problems are usually defined on a network on which there are loaded and empty flows. In some nodes of a network, which represent yards and stations, supply and demand of empty freight cars is already known. Within the rail freight car fleet management, operational models consider freight car inventory problems and problems of empty freight car allocation.

3.1 Rail freight car inventory models

Every railway company has an inventory problem. There are uncertain demand and unreliable deliveries of empty cars in stations within the rail network. So, under the assumption that the railway company wants to provide all the cars that the shipper wants, there is a need for a buffer of freight cars in all stations. Since there are different demands in different stations and freight cars have limited capacities, a shortage or excess inventory may occur. The different demand rates will give varying replenishment periods and number of cars. Stations with higher consumption rates need a higher frequency of inventory replenishment or larger order sizes. Therefore, when a customer visits a station, his requests may not be met due to inappropriate replenishment policies including periods and quantities. Tab. 1. presents basic characteristics of selected models.

Tab. 1: Characteristics of rail freight car inventory models

Authors	Year	Type of model	Solution approach
Philip and Sussman	1977	Descrete event simulation	Simulation
Mendiratta and Turnquist	1982	Two-level decentralized optimization model	Dantzig-Wolfe decomposition
Joborn et al.	2004	Multicommodity network flow problem	Tabu search
Milenković et al.	2014	Fazi EOQ model	Differential calculus

First results of inventory control applied to empty car inventories are contained in [69]. Authors evaluate existing techniques in distributing empty rail cars on a rail network, and propose discrete event simulation model to account for variations in supply and demand. Proposed model can determine the optimum inventory level, for a single terminal area, as a function of a daily supply variations, daily demand variations, and cost of holding a car in a terminal awaiting loading compared to cost of having no car available to satisfy shipper demand.

Rail freight car inventory control has been treated also as a part of a general empty car inventory management model over an entire railroad network [60]. Namely, authors viewed the problem as a lack of coordination between decisions made centrally for the railroad as a whole and decisions made locally at individual terminals. Model incorporates interacting submodels, the network model and terminal model each representing the activities performed at the corresponding level in the railroad system: central decision making at corporate headquarters is concerned with movements over the total railroad network, while the inventory-sizing decisions are made at each individual railroad terminal. Decisions are made at each level (corporate and terminal), while the coordination between the two levels relies on a price mechanism. The objective of the system is to maximize profits for the railroad subject to the constraints imposed by available empty cars, shipper demands for empty cars, and institutional requirements. The objective of the network model is to determine internal transfer prices (dual variables) for empty cars that are then input to the terminal model. The terminal model uses these prices to determine orders of release the cars. Precise derivation of the form of the price schedules of the network model may be found in [59]. The model is formulated as a linear programming optimization model and solved by Dantzig-Wolfe decomposition. The terminal model is an inventory-control formulation that incorporates stochastic demand and lead times for the delivery of empty cars. It differs from previously described inventory control model only in details of the formulation. An important aspect of the model is that it functions even when there is an overall shortage of empty cars in the system. Inventory control system can be involved via a mixed integer optimization model for the operation of empty freight car distribution [46]. Presented optimization model is a capacitated network design model, where each capacity constraint limits the flow on several arcs. They described a tabu heuristic for solving the model and present computational results. Milenkovic and Bojovic [62] proposed an inventory control approach for the sizing the empty freight cars over the rail network. Rail transport demand and travel time are assumed as uncertain variables represented as triangular fuzzy numbers. Based on a fuzzy economic order quantity (EOQ) formula, a modified fuzzy EOQ model is set up and the optimal policy developed.

3.2 Empty freight car distribution models

Problem of empty freight car optimization has often been described as a classic transportation problem. Supply and demand locations are predefined.

A common practice is that costs of car assignment are proportional to distance travelled by a freight car between origin and destination station. For defined supply and demand nodes and correspondent costs, solution of given problem is performed by linear programming, network models or some other optimization methods. Empty freight car distribution process assumes that in any moment the states and location of freight cars on a network or part of the network are known. Status means availability of freight cars, if they are empty or loaded, or in correct state or in defect. Location assumes railway station in which the cars are in a given period. A number of approaches for empty freight car allocation is proposed in past. Detailed review of approaches is given by Dejax and Crainic [25] and Bojovic [10]. All approaches can be categorized on deterministic, stochastic and hybrid approaches.

Development of linear programming, network modelling and algorithmic techniques during the second half of last century initiated a number of researches that use these methods for freight car allocation problems. These optimization models are used for optimal empty freight car allocation in accordance to predefined rules and objectives of allocation. Next table contains some of the selected deterministic approaches for empty freight car allocation problem. We refer interested reader also to approaches made in [61, 64, 82, 56].

Tab. 2: Characteristics of deterministic empty freight car distirbution models

Authors	**Year**	**Type of model**	**Solution approach**
White and Bomberault	1969	Transhipment problem	Out-of-kilter algorithm
Joborn et al.	2004	Multicommodity network flow problem	Tabu heuristics
Narisetty et al.	2008	Linear Programming	Decomposition
Lawley et al.	2008	Mixed Integer Programming	Sequential heuristics

White and Bomberault [95] solved the problem of empty freight car distribution simultaneously considering time dimension through a state-space diagram that represents different routes which can be used for the aim of seeking target location and arrival time of empty cars. This structure is utilized for generation of a network through which the total cost of rail freight car distribution is minimized. Authors consider presence of freight cars of one type and supply and demand as already known. Modified version of out-of-kilter algorithm [32] is used for solving this transshipment problem. Introducing dynamic aspect represent important contribution served as a base for a number of later researches and development of models for general empty vehicle allocation problems. Joborn et al. [46] considered empty freight car problem in a scheduled railway system. Authors analyze cost structure of empty car prepositioning and conclude that distribution cost has an „economy of scale“ behavior. Besides the cost proportional to a number of rail freight car dispatched from an origin to destination, there is a cost of car handling in intermediate yards which depends on number of handled car groups. Authors propose an optimization model which explicitly considers the economy of scale effect. Resulting optimization model is a capacitated network on which capacity constraints limit the flow on links. Tabu heuristics is used for model solving. Narrisetty et al. [65] presented a demand based empty freight car scheduling model applied on Union Pacific Railway. Problem is formulated as a problem of optimal adjusting between available freight cars and customer demand. Model considers heterogeneous fleet so that the cars are different according to type and physical characteristics. Developed optimization model provides significant savings in transportation costs. Also, the number of crews needed for demand fulfilling process is reduced and that is resulted in 35% of returns on investment. Lawley et al. [55] proposed an approach for rail freight car distribution in case of bulk cargo (coal, steel) transportation. Authors used deterministic approach for problem solving considering that there is a relatively stable environment. Presented model involves demand information, railway network characteristics (topology, distances, time characteristics), loading capacities of shippers/producers, unloading capacities of receivers/users and freight car characteristics (number, availability). Model presents a time-space network, formulated as a mixed integer programming problem in which the physical network is replicated in every time epoch or planning period within a given planning horizon. Model explicitly treats train routings and operational times of railway yards in order to avoid congestions on railway network.

Unfortunately, rail freight car distribution models used in practice involve numerous approximations and frequently ignore the demands in future or they are based on deterministic forecasts. On real railway networks complex operations with many stochastic incentives are performed so there is an imperative of including the sources of stochasticity in distribution models. Demand for empty freight cars represents one of those noises, whereas they are not the most important source, considering that users usually place their orders a few days before. Second, many of big users are very predictive. Probably, the largest source of stochasticity for railways are travelling times, which can vary significantly between two nodes.

The second important source is the arrival of new empty cars. Besides other sources, freight cars can be dispatched also to some other network. These cars can be returned as empty but without any announcement. Consequently, rail freight cars arrive from another network on totally unpredictable way. There is also a problem of car failures or unsuitability from user's aspect (the reason is frequently that cars are not clean enough). Tab. 3. contains more details about the selected stochastic approaches for empty freight car scheduling.

Tab. 3: Characteristics of stochastic empty freight car distribution models

Authors	**Year**	**Type of model**	**Solution approach**
Jordan	1982	Nonlinear stochastic model	Frank-Wolfe algorithm
Jordan i Turnquist	1983	Nonlinear stochastic model	Frank-Wolfe algorithm
Turnquist	1986	Nonlinear stochastic model	Frank-Wolfe algorithm
Kraft	2002	Multicommodity network flow problem	Subgradient algorithm
Powell i Topaloglu	2002	Stochastic programming	Piecewise linear approximation

Turnquist and Jordan [47, 48] made one of the first attempts in solving the stochastic empty freight car scheduling problem. Their researches resulted in MOV-EM network optimization model for empty freight car scheduling [88]. Within the profit maximization objective authors explicitly treat and integrate few cost parameters: revenue from accomplished orders, yards car holding costs, costs of unmet demands and transit costs. Authors based their model on assumption about stochastic supply, demand and travelling times. Model uses time-space network whose nodes represent locations of stations in discrete time periods, whereas arcs represent flows of rail freight cars between stations and waiting in stations between consecutive time periods. Model maximizes expected profitability which is defined by known and forecasted supply and demand for empty cars, travelling times, revenues, freight car holding and shortage costs. Kraft [51] proposed a method for freight car scheduling process that involves a reservation system and capacity constraints. Proposed method is based on a special approach of price composing (bidding) for simultaneous analysis of freight service supply and freight car flows with the aim of profit maximization. Proposed methodology enables determining a target shipment delivery time considering the needs of customers as well as forecasted train capacities. The problem of shipment routings is decomposed on a deterministic process of dynamic scheduling of cars for already accepted shipments and a stochastic process of price determining for certain segments of train routes for predicting future demand for which the delivery times need to be defined. Both models are formulated as multicommodity network flow problems. Each shipment, composed from one or more freight cars, is treated as a separate commodity. Subgradient algorithm is used as a tool for problem solving. Powell and Topalogly [71] use stochastic optimization techniques as methods for solving two-level and multi-level empty freight car scheduling problems. They consider stochasticity in supply, demand and travelling times. Also, the emphasize some additional issues in empty freight car scheduling like time shifted informational process and the need for discrete solution. Authors considered a number of algorithms for two-level problems with network recourse. Basic problem characteristics (integer solution, size) eliminate scenario methods, stochastic linearization and Benders decomposition. As it is needed an integer solution, authors use piecewise linear approximation with break points that exist in integer values of supplies.

Railway companies also use simulation models for evaluation of a total influence of operational policies. In general, simulation models represent detailed interpretations of rail yard structures as well as network structures and transport operations, and therefore, they have large credibility in railway field. Baker [7] and Assad [3] among the others, gave a review of simulation models applied in railway domain. Ratclife, Vinod and Sparrow [72] proposed a combined simulation-optimization methodology for empty freight cars scheduling. Applied algorithm is based on linear programming (for solving car scheduling problems with known requests) and on stochastic linear programming (for allocation of empty cars toward the stations of orders expected in near future). Stochastic linear model uses the states of nature, which actually represent a station demand vector with a certain probability. As the supply and demand are statistically known, in simulation experiments they are determined on base of known probability distributions. Authors used SLAM programming language for simulation.

3.3 Rail freight car pooling concept

Traditional strategy of empty freight car prepositioning assumes return of unloaded cars in next loading station. This is a very simple and suitable approach by which the most of shipments is allocated from the area of one railway to the area of some other railway. For the sake of reducing the empty travelling costs a freight car pooling concept is introduced. Within the agreement about a joint use of freight cars among the railways, and in some cases users, cars unloaded in destination station may be dispatched into any of the next loading stations. Next table summarizes the main characteristics of the three most recent approaches. Important contributions within this domain are also made by [4, 37, 49].

Tab. 4: Characteristics of models for freight car pooling management

Authors	Year	Type of model	Solution approach
Adamidou et al.	1993	Nash equilibirum model	Gaus-Seidel algorithm
Sherali and Suharko	1998	Network flow model	Heuristic decomposition
Sherali and Lunday	2011	Marginal cost analysis	Game theory approach

Adamidou et al. [2] represented the problem of finding a global profit maximizing distribution strategy for railways that share the freight car fleet as a generalized Nash equilibrium problem. Their model involves pairing variables connecting multicommodity network flow subproblems of individual railways, and it is solved by a Gauss-Seidelov algorithm which iteratively process these subproblems. Sherali and Suharko [80] developed a tactical support model in a centralized management of distribution the freight cars which are used for shipping the automobiles. Problem covers a group of eight main automobile manufacturers which made a pool of freight cars in order to improve the utilization and reduce empty miles of freight cars. Authors developed and tested two model formulations for empty freight car scheduling on tactical level. First model is in essence a network flow transport model which takes into account practical issues involving uncertainties in travelling times, priorities with respect to time and location of demand, numerous objectives relating to a minimization of different levels of late delivery and policies of shipment groupings. In the second model the policy of shipment groupings is considered by introducing a set of binary variables which limit maximum number of car blocks made in each origin during every day. Sherali and Lunday [82] analyzed the problem of equal distribution of a given freight car fleet which is used by a consortium of automobile manufacturers and railways involved in a pooling agreement. Proposed approach improves actual practice by recognizing its disadvantageous with respect to equal distribution of freight cars. Four improved alternative schemes are proposed for freight car allocation which are based on involving waiting times in transit for calculation proportionality factors for loaded car-days, than on two different techniques used for marginal costs analysis and on game theory approach which use allocations of Shapley values.

3.4 Combined allocation of empty and loaded freight cars

Rail freight car demand appears as a result of unbalanced loaded freight car flows. Therefore, it is logical that on operational level these two types of movements are integrated in one model for rail freight car allocation. Key features of models for combined allocation of empty and loaded freight cars are given in Tab. 5.

Tab. 5: Characteristics of models for combined allocation of emtpy and loaded freight cars

Authors	Year	Type of model	Solution approach
Gorenstein et al.	1971	Multicommodity network flow problem	Simplex algorithm
Shan	1985	Cost minimal network flow problem	Network simplex algorithm
Kornhauser and Adamidou	1986	Multicommodity network flow problem	Iterative heuristics
Haghani and Daskin	1986	Nonlinear mixed integer programming	Heuristical decomposition

Gorenstein et al. [39] proposed a real time approach for real freight car flow management which has objective to improve utilization of freight cars and user satisfaction. Scheduling system is composed from the model of empty freight car allocation and a complete traffic scheduling model that represents LP multicommodity network flow formulation defined by a yard policy and train timetable. Empty freight car problem considers homogeneous freight car fleet. Shan [78] developed two models for improved freight car utilization and as a tool of analysis for problems that result from a joint use of freight cars. First model treats the case of homogeneous freight car fleet as a transhipment problem on a time-space network. In second formulation, heterogeneous rail freight car fleet is considered and problem is formulated as a cost minimal capacitated network flow problem. Network simplex algorithms are used solution methods for both formulations. Kornhauser and Adamidou [50] analysed the problem of freight car management in case of USA railways as a non cooperative game of N persons formulated as a multicommodity network flow problem which represent control actions of each railway. Problem is solved by iterative heuristics that solves each problem separately until a balanced state for all pairing variables is reached. Haghani and Daskin [41] suggested a combined model for train routing and empty freight car allocation based on a state-space network which takes into account operations in railway yards as well as the train traffic between rail yards. Nonlinear mixed integer programming formulation is solved by a heuristic approach.

4 Tactical and strategic models for rail freight car fleet management

Empty freight car scheduling problems can not be fully considered only on operational level. Empty freight car flows represent an important component of tactical and strategic problems such as planning on national and regional level, service network design and rail freight car fleet sizing.

4.1 Service network design problems

Railway freight operators operate on complex networks composed from nodes (loading/unloading points and yards for freight flow classification) and physical links (railway lines) connecting these nodes. One of the main aspects of decision process is tactical planning of activities (service network design – routes and level of service, freight car flow processing policy in yards and routing of traffic on service network) which results in an efficient operational plan designing. A lot of approaches has been suggested in literature [16, 17, 20, 21, 22, 33, 42, 45, 54]. Selected approaches are given in more detail in next table.

Tab. 6: Characteristics of models for service network design

Authors	**Year**	**Type of model**	**Solution approach**
Kwon et al.	1998	Multicommodity network flow problem	Column generation
Campetella et al.	2006	Multicommodity network flow problem	Tabu search
Fukasawa et al.	2008	Multicommodity network flow problem	Branch & Bound
Caprara et al.	2011	Integer linear programming	Column generation

Kwon et al. [54] presented a set of different approaches for improving of current practices for freight car scheduling and a dynamic model for freight car routing and scheduling. Developed dynamic model includes heterogeneity, traffic variability and train capacity constraints so as to generate trip plans consistent with train length constraints and sensitive on user's service requirements. Problem is formulated as a multicommodity network flow problem on a time-space network for determining of combined routes and car flow schedules for a given planning period. The aim of the models is a searching for an optimal freight flow sequence on a time-space network and determining appropriate trip plans to minimize the total penalty costs (equivalent to maximizing of service standard fulfilling). Column generation algorithm is used as a solution method. Campetella et al. [16] presented a mathematical model for design of a service network which represents a set of origin-destination connections. Resulting model involves empty and loaded freight car flows, as well as costs of intermediate handling of freight cars. Model suggests a set of services which can be offered as well as the number of trains and number and types of freight cars which will operate on each connection. Approach leads to a multicommodity network design problem with concave cost functions of some network links. As a solution method, authors used tabu search that contains perturbation mechanisms for forcing the algorithm to search for a larger domain of feasible solutions. Results on real cases have shown a significant improvement with respect to the current practice. Fukasawa et al. [33] presented a method for determining the optimal flow of empty and loaded freight cars. The objective of the problem is maximization of profit, revenue or transported freight volume, for a given timetable of freight trains with its hauling capacities. Authors suggested an integer multicommodity network flow model for a problem whose linear relaxation leads to good upper bounds, but with a large number of variables and constraints. In order to be applicable in practice, authors added a pre-processing phase that decreases the size of the model two to three times. Caprara et al. [17] analyzed a problem of designing a set of profitable freight routes on a railway corridor, taking into account the level of service requested by each of commodities. Authors proposed an integer linear programming model and applied column generation technique as a solution method. Computational results for a real case of corridor passing through 11 European states have shown the possibility of obtaining near optimal solutions.

4.2 Demand estimation

Continuous growth of population and very intensive economic activity imply an increase of freight flows on transport network. Increasing the demand for freight transport on networks where there is a lack of mechanisms for capacity increasing leads to decreasing of passenger and freight mobility. Increasing of freight transport volume represents a motive for precise estimation of shipment flows as well as for forecasting of expected future freight flows. In railway context, researchers and practitioners agreed that a lack of appropriate and reliable information system for monitoring the availability of empty freight cars and user requests represents very important problem. Besides, the availability of this information is of key importance for proper allocation of transport as well as for the system design. Due to the lack of researches in railway field, in rest of this chapter the most important recent researches in freight demand modelling for all modes of transport will be reviewed. Many concepts of modelling used in freight transport modelling are firstly applied for passenger traffic. Most of the authors agreed that sequential structure of passenger traffic modeling composed from four steps can be applied in freight transport. However, there are important differences between passenger and freight transport market such as diversity of decision makers in freight transport, a number of different commodity types and limited data availability. Four basic steps of freight transport modeling system are [24]:

- Production and attraction.
- Distribution.
- Model split.
- Assignment.

Some of the recent approaches belonging to each of these four steps will be reviewed in remaining part of this chapter. Production and attraction step contains four basic types of models: Trend and time series models, system dynamic models, zone models of trip generation, input-output models. In trend models, historical trends are extrapolated in future. Data time series are used for developing of models of different complexity, beginning with simplest models of raise factor up to complex autoregressive integrated moving average models. Time series models with explaining variables, such as gross domestic product, employment, number of habitants and others, are also developed and applied in practice. Some of the most interesting approaches are described below. Kulshreshtha et al. [53] proposed a cointegrated VAR methodology to draw inferences about the responsiveness of freight transport demand for Indian Railways at an aggregate level. Authors estimated long run structural relationships between demand for freight transport and its influencing economic variables using annual time series data for the period 1960±1995. The analysis was done in a multivariate cointegrating VAR framework to avoid the shortcomings associated with single-equation approaches to cointegration. Shen et al. [79] applied six econometric time series models to modeling and forecasting the road plus rail freight demand in Great Britain, based on annual time series data for the period 1974-2006. These models comprise: the traditional OLS (Ordinary Least Squares) regression model, the PA (Partial Adjustment) model, the reADLM (reduced Autoregressive Distributed Lag Model), the unrestricted VAR (Vector Autoregressive) model, the TVP (Time-Varying Parameter) model and the STSM (Structural Time Series Model). The relative forecasting accuracy of alternative models has been evaluated based on MAPE in the context of freight demand. The estimation results show that industrial production generally offers a good explanation of road plus rail freight demand in GB. However, the sensitivity of road plus rail freight demand to the change in the industrial production varies across different commodity groups, as different commodities have different transport requirements and each estimate reflects particular circumstances for each commodity group. Babcock et al. [6] concluded that the economic process generating quarterly railroad grain car loadings is quite complex and very difficult to model with regression techniques. Therefore, the authors developed a time series model to make a short-run forecast of quarterly railroad grain car loadings. An AR(4) model was estimated using the Maximum Likelihood estimation procedure for the 1987:4±1997:4 period. The actual railroad grain car loadings for this period were compared to the forecast car loadings generated by the time series model. For 92% of the 37 quarters the percentage difference between the actual and forecast values was 10% or less. Of the 9 annual observations, the per cent difference between the actual and forecast value was less than 2.6% for 8 of the 9 years. Guo et al. [40] analyzed trend and seasonal fluctuation of China's monthly railway freight and applied ARIMA and Holt-Winters models to forecast freight flows. After comparison of forecasting results, a final freight result from January to December of 2010 is generated. After verification, the predict results of ARIMA model and Holt-Winters model, with errors lower than 4%, are preferable to be used of railway freight forecast. Wijeweera et al. [96] examined the impacts of exchange rate, freight rate and economic activities on the growth rate of non-bulk freight demand in Australia. The paper uses a simple but robust econometrics method to estimate the demand growth function and utilizes a relatively large annual data set encompassing over four decades (1970-2011). The findings provide convincing evidence that the volatility of the Australian dollar has a substantial impact on freight rail demand within Australia. Furthermore, the study finds that, although freight rate and macroeconomic activities exhibit the expected relationship with freight rail demand, the relationships are not strong enough to make valid statistical inferences.

In ASTRA (Assessment of Transport Strategies) model of system dynamics, timely changes in transported volumes and feedback to/from economy, land use and environment are explicitly modeled [5]. In macroeconomic module increasing of gross domestic product has been predicted. Output predictions are used in regional economy module which gives transport demand from the aspect of freight flows in tones for each origin-destination pairs of nodes. Zone trip rates for production and attraction are usually derived from cross-sectional data for transport volume to/from each zone in an area which is considered in a number of homogeneous zone types [24]. Input-output models represent macro-economic models based on input-output tables. One example of space input-output models in freight transport is REGARD model for Norway, with 28 sectors, that generates demand used in Norway freight transport model NEMO [30].

As in previous step, all distribution models are based on aggregated data. Freight flows between zones of origin and destination are determined based on measures of production and attraction and a measure of transport resistance which is expressed as transportation cost [24]. Most frequently used method is gravity model. Coutu [19] applied gravity model for prediction of empty freight car flows. In gravity model it is assumed that the flow between a pair of origin-destination stations is proportional to supply in origin and demand in destination. Proportionality factor depends on parameters such as distance and transportation cost between two points. Author describes steps which can be undertaken in order to apply these methodologies for prediction the flows of empty cars on Canadian national railways. Sivakumar and Bhat [83] suggested an approach that represents a distribution model with partial separation for interregional freight flows modeling. Approach uses a logit model for estimation of part of freight flows oriented to destination zone and originated in each of production zones. This idea is in line with the essence of freight flows, which is based on the idea that the freight flows are generated by the demand for freight in destination which is satisfied by the flows from one or more origin points. Users of transport service usually choose a preferred mode for transport of their shipments.

Models of modal split or assignment on different transport modes consider behavior of users of transport service during the choice of transport mode. Main criteria of choice are offered level of service and transportation costs of different transport modes. Abdelwahab and Sargious [1] suggested an approach for demand modeling in freight transport that is based on simultaneous decision about transport mode and shipment size. Process of mode selection is formulated as a binary probit model, whereas two linear regression equations are used for simulation of shipment size for railway and road transport. Developed model is applied for analysis of transport mode (railway with respect to road) and shipment size for each of considered transport modes. Garrido and Mahmassani [34] applied a multinomial probit model with stace and time correlated error structure for analysis of transport demand in road transportation. Resulting model has a number of alternatives and for that reason the estimation has been made by the use of Monte Carlo simulation for model likelihood estimation. Nijkamp et al. [66] compared two types of statistical estimation models for multimodal transport flows. Authors consider two models of discrete choice (logit and probit models) and a neural network model. Comparative analysis has been made on a large dataset for two categories of shipments – food and chemicals. Train and Wilson [88] presented a problem of estimation a discrete choice model which is based on a limiting access if shippers to transport markets.

The last phase of presented sequential process of forecasting in freight transport is dedicated to a selection of routes between pairs of areas by the transport mode and resulting flows. In this phase, trips by road, railway and inland waterways are allocated on routes composed from links of corresponding modal networks. A large number of models does not involve this assignment step, whereas some of them consider assignment only for road transport. Assignment on a road network is in some cases conducted with passenger transport, while freight transport has only a small part of total transport. For example, origin-destination matrices for road transport of Holland freight model TEM II [24] are combined with road passenger transport in Holland national model so the trips in passenger and freight transport are jointly assigned.

4.3 Rail freight car fleet sizing models

Vehicle fleet sizing represents an important problem for researchers as well as for transport companies due to a high capital value of vehicles. Vehicle fleet sizing relates to the whole service design [22] and there is a large number of researches considering this problem in road transport [28, 43, 68] and express shipments in air transport [8] which emphasize the existence of this relationship. In a general, vehicle fleet sizing can be defined as a sizing of a system of reusable resources.

In [9, 47, 48, 56, 70, 89, 90] a taxonomy has been suggested for this category of problems by differencing on deterministic and stochastic models, which are further divided depending on loading of vehicles (fully or partially loaded vehicles). As the literature for vehicle fleet sizing is not especially concerned only on rail freight car fleet sizing, the rest of this section also considers the most important general approaches. Some approaches are formulated as exact methods based on mathematical programming problems whereas the others use heuristics or metaheuristics. By the types, problems can be categorized on [44]:

- Vehicle fleet sizing problems where the fleet size is considered.
- Fleet composition problems where the objective is determining a fleet composition of different types of vehicles.
- Vehicle fleet sizing and allocation problems in which fleet size is combined with vehicle allocation.
- Routing problems of heterogeneous fleet of fixed size where there is a need to route a fixed size heterogeneous vehicle fleet.
- Fleet composition and allocation problem with time windows.
- Fleet composition and allocation in presence of multiple depots.
- Network optimization approaches for fleet composition.

Some of the models for fleet sizing and composition are given in next table.

Tab. 7: Characteristics of vehicle fleet sizing models

Authors	**Year**	**Solution approach**	**Problem**	**Modality**
Etezadi and Beasley	1983	Integer programming	Vehicle fleet composition	General
Bojović and Milenković	2008	Multicriteria decision making	Vehicle fleet mix	Railway sector
Bojović, Bosković, Milenković, Sunjić	2010	Multiobjective optimization	Vehicle fleet composition	Railway sector
Cheon, Furman, Shaffer	2012	Mixed integer programming	Vehicle fleet sizing	Railway sector
Bojović	2002	Optimal control theory	Vehicle fleet sizing and allocation	Railway sector
Sayarshad and Ghoseiri	2009	Simulated annealing	Vehicle fleet sizing and allocation	Railway sector
Yaghini and Khandaghabadi	2012	Genetic algorithms and simulated annealing	Vehicle fleet sizing and allocation	Railway sector
Milenković and	2013	Fuzzy optimal	Vehicle fleet sizing	Railway

Bojović		control	and allocation	sector
Milenković et al.	2015	Stochastic model predictive control	Vehicle fleet sizing and allocation	Railway sector
Tavakkoli-Moghaddam, Safaei, Kah and Rabbani	2007	Simulated annealing	Heterogeneous routing of a fixed size fleet, service splitting	General
Braysy, Dullaert, Hasle, Mester and Gendreau	2007	Deterministic annealing	Vehicle fleet sizing and allocation with time windows	General
Calvete, Gale, Oliveros and Sanchez-Valverde	2007	Constructive heuristics	Vehicle fleet sizing and allocation with time windows	General
Dondo and Cerda	2007	Constructive heuristics	Vehicle fleet sizing and allocation with multiple depots	General
Beaujon and Turnquist	1991	Integer programming	Vehicle fleet sizing	General
Sherali and Tuncbilek	1997	Decomposition approach	Vehicle fleet sizing	Railway sector

Etezadi and Beasley [29] simultaneously consider problem of optimal vehicle fleet composition and its optimal size. Authors presented a mixed integer programming formulation for problem solving. Bojovic and Milenkovic [12] proposed a solution approach for the problem of optimal rail freight car fleet mix determining. Solution is based on analytic hierarchy process (AHP) as one of the most popular multicriteria decision making methods. Bojovic et al. [13] considered optimal rail freight car fleet composition problem. Problem is decomposed on two subproblems, optimal mix and optimal size subproblems. The first one has been viewed as a multicriteria decision making problem and it is solved by fuzzy AHP. Solution of the first subproblem is an input to the second one which represents the problem of determining the optimal size of rail freight car fleet. Fuzzy multiobjective linear programming has been used for solving the second subproblem. Cheon et al. [18] considered heterogeneous rail freight car fleet sizing problem in chemical industry. Inventory policy has been covered by the model statement. Mixed integer programming approach is suggested for problem modelling and solving.

Vehicle fleet sizing and allocation problems differ from the allocation problems because they consider vehicle fleet sizing. Therefore, objective function is based on minimization of total cost function which includes fixed costs of vehicle management and variable routing costs. Bojović [11] considers a problem of optimization the rail freight car fleet size by the demand satisfaction within a minimal total cost. Author developed a mathematical model based on optimal control theory. Problem is formulated as a problem of determining an optimal regulator for a linear system which is under the influence of Gaussian white noise, with quadratic performance measure and random initial conditions. Sayarshad and Ghoseiri [75] proposed a formulation and a solution approach for homogeneous rail freight car fleet sizing and allocation problem where the demand and travelling times are assumed as deterministic. Unsatisfied demand becomes zero at the end of planning horizon. Authors propose simulated annealing algorithm as a solution approach. Based on this research a multiobjective [76] and stochastic approaches [77] are developed. Yaghini and Khandaghabadi [97] proposed dynamic and multiperiod model for rail freight car fleet sizing. The demand and travelling times are assumed as deterministic. Hybrid approach based on combination of genetic algorithms and simulated annealing is applied as a solution method. Milenković and Bojović [61] proposed a new formulation and a solution approach for rail freight car fleet sizing and allocation based on a fuzzy optimal control theory where fuzziness and randomness are treated simultaneously in an optimal control framework. Transport demand is modelled as a fuzzy stochastic whereas travelling times as a fuzzy parameter. Milenković et al. [63] developed a stochastic model predictive control approach for heterogeneous fleet sizing and allocation problem. Transport demand and travelling times are considered as stochastic variables. Station capacity constraints and partial substitutability among freight car types are included in model formulation. Proposed approach shows good computational performances. Interesting general approaches for vehicle fleet sizing and allocation are published in [36, 38, 57, 84].

In contrast to the fleet sizing problems, in problems of routing a heterogeneous consist of fixed size the main objective is to exploit a given fleet of cars on a cost minimizing or profit maximizing way. Some of the newest approaches are presented in [35, 86, 87]. Tavakkoli-Moghaddam et al. [87] considered a variant of deliver splitting for vehicle routing problem with a heterogeneous fleet of fixed size. Authors developed a hybrid algorithm of simulated annealing tested on a set of cases.

There are a lot of approaches that consider time windows that represent an interval in which satisfying the demand for transport service must begin [26, 31, 98]. Braysy et al. [14] represent a deterministic annealing metaheuristic for solving a vehicle fleet sizing and allocation problem with time windows. Calvete et al. [15] developed a mixed integer programming model for routing problem with hard and soft time windows, heterogeneous fleet and more than one objective. Two-phase solution approach has been used proposed. In first phase all feasible routes are determined and total penalty for deviation from objective by each route calculated. In the second phase the set partitioning problem is solved for obtaining the best set of feasible routes.

In case where there are a number of depots, problem becomes even more complex. The objective of the problem is determining the users that have to be served from different depots along with the searching for the optimal vehicle fleet composition and the best possible routes [73, 74]. Dondo and Cerda [27] consider above mentioned problem with time window. Authors suggest three phase solution approach. In first phase they identify cost effective clusters, in second phase these clusters are assigned to vehicles and then vehicles are sequenced on routes. Distribution of vehicle arrival times is conducted in third phase by a mixed integer programming model.

Network optimization models differs by their structure from classical vehicle routing problems. Instead of searching for an optimal set of routes covering each user only one, these problems treat a selection of arcs on a graph for the sake of flow requests satisfying and total system costs minimizing. Flow requests are expressed in form of commodities which should be transported from an origin to destination in a given time interval [93, 90]. Beaujon and Turnquist [9] formulated a model that involves interactions between the fleet size, loaded and empty flows. It is a stochastic optimization model (demand and travelling times are stochastic) on a dynamic network solved by a decomposition which simultaneously treats subproblems of vehicle inventories on a network and vehicle allocations. In each node a net number of cars is defined and modelled by a normal distribution. Assuming the deterministic travelling time problem is reformulated in a network problem with nonlinear costs on some arcs. Allocations of loaded and empty freight cars are simultaneously calculated on a small network. Network approximation have been shown to be useful for obtaining a good enough solution from the aspect of vehicle allocation and vehicle fleet sizing. Natural initial solution is obtained by solving a deterministic variant of the problem. This solution will certainly be under the optimal fleet value, but it gives a sufficiently correct set of car movements, needed for variance calculating. Authors compare static deterministic, dynamic deterministic and dynamic stochastic variant on a hypothetical network composed from five stations on a 6-day planning horizon. Sherali and Tuncbilek [81] suggested static and dynamic models for rail freight car fleet sizing for a case of freight car pooling concept. Static model is based on stationary data and therefore it tends to underestimate the required size of rail freight car fleet. Dynamic model is composed with respect to a time-space network which represents empty freight car movement between origins and destinations with the aim to minimize the required fleet size with total demand satisfaction in different time instances. Problem has been solved by decomposing the model on a sequence of smaller subproblems with shorter, overlapping time period.

5 Conclusion

In this paper we have presented a review of the most important contributions for rail freight car fleet management. According to the number of contributions we may conclude that this is a very popular research area. From the aspect of modelling and solution methodology, there is an upward trend from simplier to more complex techniques in all segments of freight car fleet management. Besides deterministic approaches, there is an increasing tendency to model uncertainty which is very present in everyday freight transport operations, through randomness, fuzzy or even fuzzy randomness. Recently, there is an initiative to developing more realistic nonlinear models in a dynamic environment that imply the need for developing more efficient solution approaches. Increasing power of computers enables this process. Of course, a gap between theory and practice still exists, and therefore there is a need for an additional effort to make the railway freight transportation benefit from these researches.

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RECUPERATION IN THE TRACTION SYSTEM 3kV DC AND FAULTS IN THE SUPPLY UNITS

Ladislav Mlynařík[1], Jaroslav Novák[2]

Abstract: The paper deals with the fault states of twelve-pulse rectifier in traction substation of 3 kV DC traction system used at railways in the Czech Republic. The situation at diode breakdown of rectifier and at the same time recuperative traction vehicles in power supply section. The vehicle with recuperation can increase stress of elements in power supply system under certain conditions during fault states of rectifier. The simulation computer model was created for analysis of current waveforms in trolley line at this situation. The all simulations were done by program PSpice. The main goal is to analyze the endanger elements of power supply system and bring the recommendation for increasing of reliability of this mentioned power supply system.

Keywords: Twelve-pulse rectifier; diode breakdown; recuperation; traction substation; transformer.

1 Introduction

The operation of electrified railway lines depends on the stability and reliability of the distributions of electric energy at the traction power supply system. Every fault in this traction system leads to a reduction of electrical transport with following significant decreasing of railway line capacity. These faults can be represented by a damage of the catenary due to weather conditions or defective co-operation between the pantograph and contact wire and also faults in the traction substation. The switch off overcurrent or undervoltage protections of the 3 kV DC traction substation is easily soluble by the remote control and the electrified railway lines can be operated in short time again. The bigger problem

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can occur at the faults of the power rectifier units located in the traction substation where the number of these units can be limited due to the previous faults. This situation can bring the effect to decreasing of railway line capacity or stopping of railway transport in the extreme case.

2 Vehicle with recuperation

The condition at the 3 kV DC traction system is that electric energy got by the recuperation must be consumed in the same time by other electric traction vehicle or vehicles in the feeding connected section of the traction system and it cannot be returned back through the traction substation to the main network [1-2]. A different situation can arise in the case of two diode breakdown with opposite polarity in one of the bridges (six-pulse rectifier). In this situation of the catenary short-circuit and thus also the short-circuit of vehicle with recuperation is created. This short-circuit represents the consumption for this vehicle. Figure 1 shows the example in such conditions. There has been the diode breakdown (D5 and D2) creating the short-circuit source, which is represented in the circuit DC link by capacitor C_V of vehicle with recuperation (the coming current is shown by red color). The current is reduced by the substation inductance L_S, the catenary resistance R_C and the catenary inductance L_C.

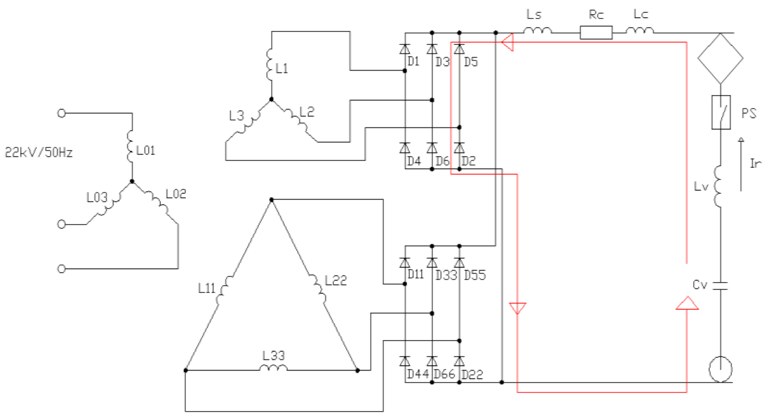

Fig. 1: The flow direction of recuperative current coming through the fault rectifier

3 Equivalent circuit

The equivalent circuit of the traction system has been derived for the necessary simulations. The simulations of the effect of vehicle with recuperation on the power rectifier with the diode breakdowns and the traction substation transformer were researched for the reason of the current situation at the Czech Railways at the 3 kV DC traction system.

3.1 Equivalent circuit for recuperation

The equivalent circuit for the recuperation allows the simulation of diode breakdowns in the traction rectifier and is in Fig. 2. The middle part of the equivalent circuit represents vehicle with recuperation by capacitor C_V in intermediate circuit. If the voltage of this capacitor overpasses the actual values of catenary voltage then vehicle current is coming to the catenary (recuperation). In the circuit this current with value P_{rek}/U_c [A] is supplied by the voltage dependent current source G. The Zener diode D_{zener} has set the value of zener voltage of 3 600 V and it represents the ability of vehicle to control voltage at the pantograph (just at this value). The left part of the equivalent circuit represents the model of the traction substation at fault. The first stage of the simulation of the left traction substation has the same function as the right traction substation in the circuit. The simulation of short-circuit of vehicle with recuperation at the diode breakdown is done by circuit switch S1 [3-6].

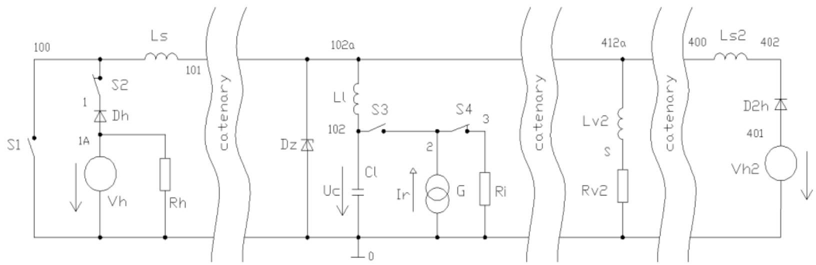

Fig. 2: The equivalent circuit for simulation of faults at recuperation

3.2 Model transformer

The three-phase transformer with two secondary windings and the nominal power of 5 000 VA was used for measurement of characteristics of DC current flowing through the secondary windings of the transformer. The primary winding has the Y-connection, transformer ratio is 1:1 and transformer phase angel corresponds to the real transformer with two secondary windings type RESIBLOC Yyn0d1. The same leakage inductances of two secondary windings of the transformer and also the same phase-to-phase voltages of output of both secondary windings are necessary conditions for transformer feeding the twelve-pulse power rectifier at 3 kV DC traction system. The same phase-to-phase voltages and a little bit different leakage inductances of both secondary windings of the transformer at no-load mode were found out by the experimental measurements.

4 Analysis of rations at fault rectifier at recuperation

The short-circuit of the rectifier happens due to the diode breakdown as it was mentioned at the situation in Fig. 1. At the situation when vehicle with recuperation is located in the feeding section of the catenary, this source will be short-circuited and its current increases the load of parts of traction system.

4.1 Estimation of current waveforms flowing back to traction substation

The waveforms of currents which can flow back to the traction substation, were analyzed by simulation used the equivalent circuit from Fig. 2. The example of the simulations is the situation with two passing vehicles in half of section between traction substations (20 km), Fig. 3. One vehicle is breaking (i.e. recuperation with power 6 MW) and the second vehicle is starting. At the first stage of the simulation the second vehicle is fed only by traction substations (each of the traction substation supplies the half current for the vehicle). The first vehicle starts to recuperative in time of 100 ms and the voltage of the catenary is getting the voltage value of 3600 V [7-8]. The recuperative current of first vehicle covers all other consumptions and therefore the current of the traction substations is zero.

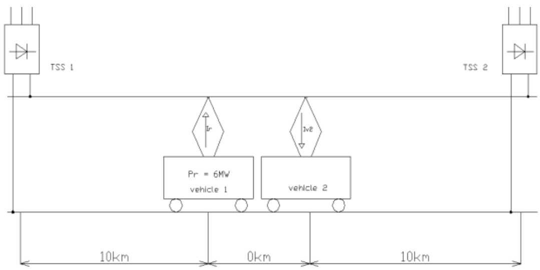

Fig. 3: The situation with two passing vehicles

The diode breakdown (D2 and D5) in the rectifier of the first traction substation is simulated at the time of 200 ms. The short-circuit causes a voltage drop on the vehicle pantograph. Because this voltage is lower than the voltage of the second traction substation, this traction substation begins together with vehicle with recuperation produce a current for the second vehicle and also for the short-circuit caused by the diode breakdown (D2 and D5). This stage will last until the turn off high-speed circuit breaker in the traction substation in which the fault occurred. The high-speed circuit breaker in the neighboring traction substation also switches off by using of the control coupling of these high-speed circuit breakers. If high-speed circuit breaker is set over the value of the steady short-circuit current, the stage of switching off will last until switch off disconnector which is located between the damage rectifier and DC bus. If the recuperative current flows through this disconnector during operating control it can be damaged.

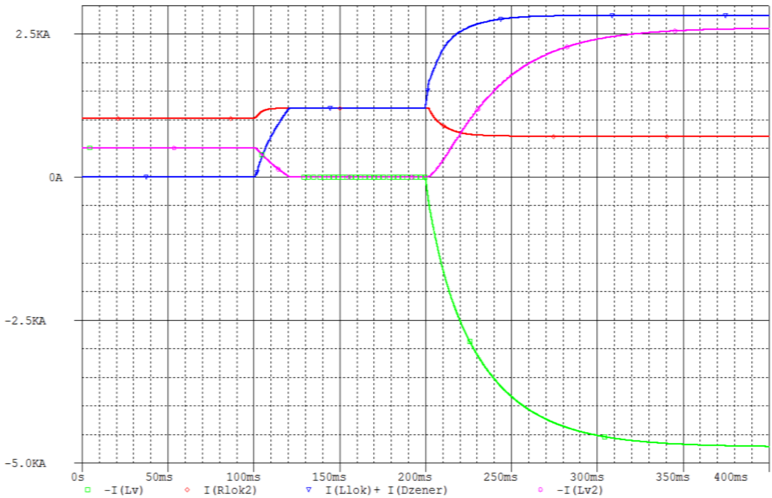

Fig.4: The theoretical current waveform flowing back to the traction substation

- The maximal theoretical current flowing back to the traction substation 4.70 kA (green color in Fig.4)
- The pantograph voltage of vehicle with recuperation 2.12 kV

5 Analysis of inductance of transformer

In the case that recuperative current flowing through the secondary windings of the transformer it is obvious that the inductance between two phases will slow down the rise of current to the traction substation with the faulty rectifier. The theoretical analysis of the relations between the inductances of each winding of the traction transformer was done to verify of waveforms of recuperative current flowing through the secondary winding of the transformer. The analysis of failure modes without detailed knowledge of the parameters of this transformer is not possible to complete. Therefore the passing of this recuperative current was analyzed experimentally in the laboratory. The speed of the rise of the short-circuit current and the value of inductance between two phases at the real traction transformer during the fault of rectifier and energy from vehicle with recuperation by the fault of rectifier is deduced from the results. The inductance of 5.27 H at the Y-connection winding and 5.79 H at the Δ-connection winding were found out by measurements at no-load mode. The measurements of the time response of the current flows through the pairs of the secondary windings of the transformer to the voltage jump was done to verification of the values of this inductance obtained from laboratory measurements. During the measurements was monitored the time (a period) when DC current reached 63 % of its steady value. This time was 0.5 s. In the case the first system order, it would be possible to evaluate the value of the inductance in the circuit on the basis of the L / R ratio. The similar measurements were done at the secondary winding at the Δ-connection and the obtained value was 0.7 s. The measurements of the time response of the current flows through the pairs of secondary windings of transformer to the voltage jump was determined the value of the inductance of 0.60 H at the Y-connection and 0.91 H at the Δ-connection.

6 The analysis of transformer current in the case of DC power supply

Theoretically it is possible to describe this situation by the equivalent circuit in Fig. 5.

This circuit describes the real transformer fed by DC voltage. The secondary circuit created by the elements L_2 and R_2 represents the magnetic losses of the transformer. The difference of values of inductances found out by AC measuring at no-load mode and by current response to the voltage jump comes out at the loaded transformer when the mutual magnetic coupling of the primary and the secondary circuit becomes evident. The derived equation for the current waveform was solved numerically by substitution of values corresponding to parameters of the laboratory transformer. For the circuit in Fig. 5, the magnetic coupling simulation of the primary and the secondary windings of the transformer (respectively the magnetic coupling between the primary winding and the fictive secondary winding simulated the influence of eddy currents in the magnetic circuit) is valid

$$U_1 = R_1 i_1 + L_1 \frac{di_1}{dt} + M \frac{di_2}{dt} \tag{1}$$

$$0 = R_2 i_2 + L_2 \frac{di_2}{dt} + M \frac{di_1}{dt}, \tag{2}$$

$$L_1 = L_h + L_{1\sigma}, \tag{3}$$

$$L_2 = L_h + L_{2\sigma}, \tag{4}$$

$$M = L_h. \tag{5}$$

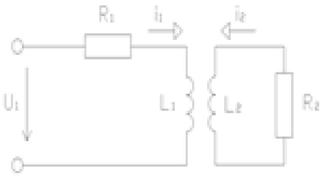

Fig. 5: The equivalent circuit for the theoretical derivation of the time response of the current to voltage jump U_1

After differentiation of equations 1 and 2 we get

$$0 = R_1 \frac{di_1}{dt} + L_1 \frac{d^2 i_1}{dt^2} + M \frac{d^2 i_2}{dt^2}, \tag{6}$$

$$0 = R_2 \frac{di_2}{dt} + L_2 \frac{d^2 i_2}{dt^2} + M \frac{d^2 i_1}{dt^2}. \tag{7}$$

The linear differential equations of the second order with constant coefficients has the form

$$U_1 = R_1 i_1 + \left(L_1 + \frac{L_2 R_1}{R_2} \right) \frac{di_1}{dt} + \left(\frac{L_1 L_2}{R_2} - \frac{M^2}{R_2} \right) \frac{d^2 i_1}{dt^2}. \tag{8}$$

we get for the laboratory transformer numerical values of solution of the characteristic equation λ_1 and λ_2. λ_1 = -0.095 and λ_2= -14.34. Supposing real different solutions of the characteristic equation we get a general solution of the differential equation in form

$$i_{1O} = K_1 e^{\lambda_1 t} + K_2 e^{\lambda_2 t}. \qquad (9)$$

After determining of the coefficients K_1 and K_2 we obtain the equation for current waveform

$$i_1(t) = -0{,}149 e^{-0{,}095 t} - 0{,}151 e^{-14{,}34 t} + 0{,}3. \qquad (10)$$

The time waveform of the current response to voltage jump is obtained by representation of solved equation 10, Fig. 6.

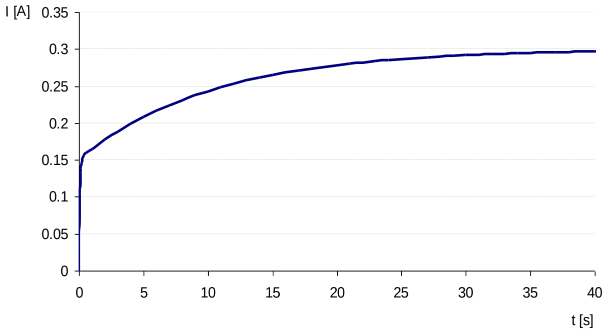

Fig.6: The theoretical waveform of the current

The dependence of this time response on the value of the resistor R_2 (in Fig. 5) is evident from the derived equations. This resistance represents at the real transformer at no-load mode the effect of losses, especially eddy currents in the magnetic circuit of the transformer. The above mentioned calculations were further verified by measuring of the time response of the current to the voltage jump on the laboratory transformer and by the simulation of the equivalent circuit using the connection in Fig. 5. The main inductance between two phases is not indicative exactly about the speed of the rise of DC short-circuits current in the secondary winding of the transformer as it was proved by previous calculations. They do not contain the losses in the magnetic circuit of the transformer. The speed of the rise of DC short-circuits current will be higher in the case of the recuperation. The waveform of rise of the short-circuit current at the time of the recuperation will rather correspond to the curve in Fig. 6, because the real transformer is loaded by the losses in the magnetic circuit (cos φ no-load mode is 0.73). At the first stage it will be a very quick process practically limited only by the leakage inductance of the transformer and the recuperative current will increase the current stress of the transformer in the traction substation.

7 Conclusion

In the first part of this paper, the values of short-circuit currents flowing through 3 kV DC traction system were numerically simulated. Independently the situation, when the short-circuit DC current flowing through the secondary winding of the transformer, was analyzed. The inductances of this transformer slow down the rise of DC short-circuit current. However, in the first stage of the rise of this DC short-circuit current, the leakage inductances of the transformer which allow a rapid rise of this current, become evident. The whole interval of rise of the short-circuit current at the real transformer is further reduced by the effect of oversaturation of the magnetic circuit at connection to the DC source. It is possible to conclude by the theory of the circuits that the worst situation is in the case of vehicle with recuperation very close to the traction substation when the short-circuit current is not limited by the resistors of the traction line. The simulations show, the voltage drop on the pantograph below 2 kV occurs by this close short-circuit. The vehicle has a good opportunity to recognize this non-standard situation and stop the recuperation. Potentially the most hazard situations can be considered, when vehicle with recuperation is close enough to pass through the catenary the high current, but far enough that the voltage on the pantograph does not fall below 2 kV. If the DC source in the contact line passes through the higher current to the traction substation than the set of high-speed circuit breaker, it will be turned off this circuit breaker. The current values by the effect of the inductances in the circuit reach their steady maximum. This situation is dangerous especially for the machine isolator (circuit breaker) located between 3 kV DC bus and the damaged rectifier. The circuit breaker starts to disconnect immediately after the switch off of the primary switch of the transformer (responding to diode breakdown in the rectifier).

Therefore, it is always appropriate to add the protection to the rectifier evaluating the direction of the DC current flow. This protection is already installed in some built traction substations. Usage of this protection makes sure disconnection of the damaged rectifier unit from the catenary. The only vehicles, that would recuperative even if very low value of voltage at the pantograph, could complicate this situation (i.e. the situation of recuperation close the traction substation when the current flowing back to the traction substation could be up to tens of milliseconds with very high values). The recuperation at the low catenary voltage is always suitable interrupt from viewpoint of protection of traction substation from dangerous current flow back to this traction substation.

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DESIGNING PRICES FOR THE USE OF RAILWAY INFRASTRUCTURE

Petr Novák[1]

Abstract: The current system of charging for railway infrastructure needs to be updated to reflect the current market situation and take account of the new transport strategy set by the European Union, and to reflect legislative changes in relation to the Directive on the creation of a single railway area. The final price will be calculated as a multiple of the length of the train travel, the basic price according to the category and the coefficients of the relevant product and other specific factors. The new pricing system will be based on adapted current and new specific factors entering into the calculation of the price. The expected benefit will be more efficient capacity utilization and equitable price differentiation for the use of railway infrastructure, compliance with European legislation, reflection of real demand and needs of railway operators and flexible pricing policy.

Keywords: railway infrastructure, product factor, specific factor

1 Introduction

The latest update of annual inland transport infrastructure investment across the 34 member states of the Organisation for Economic Co-operation and Development (OECD) shows that continued economic crisis has caused a decline to a record low 0.8% of GDP. However, the study by the International Transport Forum (ITF) also shows that despite the overall decline, the railway is now receiving a greater proportion of the funding being made available by governments. The share of investment in railways in total investment in inland transport increased from 17% to 26% between 1995 and 2013, a rise which has been driven primarily by developments in Japan, North America, and Europe.

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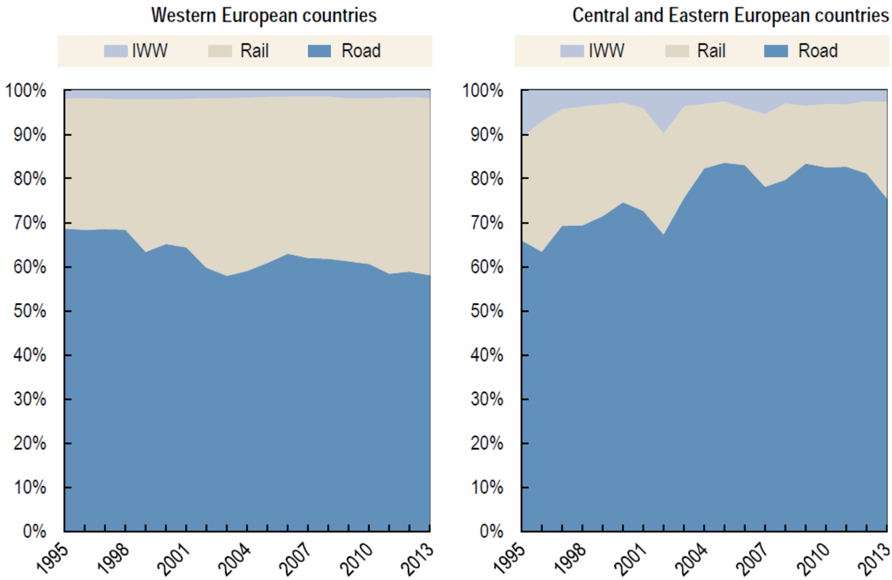

Fig. 1: Distribution of infrastructure investment between modes

Source: International Transport Forum

In western Europe, rail's share of transport investment increased from around 30% in 1995 to 40% in 2013. The ITF notes that the trend observed in this region reflects a political commitment to the development of railways, and recent data does not seem to indicate any change in policy. [1]

However, in central and eastern Europe investment is skewed heavily towards road, which saw its share of inland transport investment increase from 66% in 1995 to 84% in 2005. Nonetheless, the ITF identifies a potential break in this upward trend as road's share fell back to 76% by 2013. [1]

Economically developed countries are aware of the considerable potential values that railways can bring. Increasing line speeds up to 160 km/h, repairs particularly to transit corridors and a number of other activities will also increase the attractiveness and productivity of rail transport in the Czech Republic. This country gives the impression of having a dense railways network, but in reality, only about a fifth of the country’s network consists of full serviced track suitable for express, freight and local service trains which are competitive with road transport. The Pareto Principle, that 80% of the effects come from 20% of the causes, is quite valid here, as the greater part of the railway network experiences economic difficulties because transport revenues do not cover all costs. [2]

2 Design proposal of prices for the use of railway infrastructure

2.1 Overview of the factors used in the calculation

The resulting price for the use of railway infrastructure will be calculated as a multiple of the length of the train journey, the basic price according to track category and coefficients of the relevant product and other specific factors.

Track category

- Unit price according to track category – 5 new track categories (3 European and 2 domestic)

Product factor

- Passenger transport – bringing prices more in line with freight rates
- Regular freight – bringing prices more in line with passenger transport
- Combined freight – setting a plan of gradual approximation advantage
- Transport of individual wagon loads – a significant benefit only for the first and last mile
- Other product factors – no significant changes compared to the present

Specific factors

- Wear and tear on infrastructure from train operations – determined according to weight categories of the trains
- ETCS equipment – high advantage in the first phase; afterwards, its gradual decline
- Express trains – surcharge for trains with priority to run ahead of other trains
- Power sources for drive units – surcharge for non-ecological diesel vehicles on electrified lines
- Noise emissions – an advantage for “silent” trains with estimated implementation by 2020
- Track utilization rate – differentiation of prices rates according to seating periods and peaks on selected routes

- Minimum specific power of a train – penalizing trains with insufficient power for fast travel
- Consideration of major investment projects – options of surcharges on certain lines such as high speed lines

This proposal does not address any detailed tariff policy, for which it is necessary to further develop the application of direct costs and compile an extensive data model to simulate the impact of a tariff policy. This model may be compiled when the general data warehouse of the RIA is functioning.

2.2 Summary of key changes

The new pricing system will be based on current factors entering into the calculation of the price for the use of railway infrastructure. The method of setting these factors, however, will be regulated by a number of completely new specific factors.

Current factors entering into the calculation of the price for the use of railway infrastructure reflect the situation on the market in recent years, and although it makes sense to continue using them in the future, it is necessary to update the manner of their application with regard to market trends and legislative changes. The main changes are as follows:

- Convergence of the basic price of passenger and freight transport, with a view to harmonizing pricing with neighboring countries, required compliance with European legislation and the ability to reflect increased costs associated with freight transport (such as delays) through other elements of the pricing.
- Gradual reduction of benefits for combined transport against regular freight as a result of an expected reduction in prices of basic freight transport, the rapid development of combined transport in the Czech Republic and benefiting combined transport through other elements of pricing.
- Limiting the significant benefits of individual wagon loads only for domestic and regional routes, where sections of the first and last mile are most often implemented and rail transport is less competitive. Benefits for individual shipments on other lines should be lower.

The introduction of new specific factors is recommended in order to streamline the use of railway infrastructure, to take account of the differing quality of services provided by the different types of trains and to ensure compliance with new European legislation.

New factors will deliver the following key changes:

- Consideration of outfitting trains with an ETCS system which will need to be implemented with an overall neutral impact on revenues of the RIA and also to motivate carriers to outfit trains with this system. Setting the motivation of carriers will need to be coordinated with the Ministry of Transport and the European Union.
- The introduction of surcharges for express trains which have priority on the track before other trains. The quality of service provided to them is higher and also reduces the quality of services to other trains, which cannot always travel smoothly. This should be reflected in the price for the use of railway infrastructure.
- Differentiation of prices according to peak periods and seating on selected routes which allows the capacity utilization of the transport route to be optimized throughout the day. This factor will be applied only on congested routes, where freight traffic also constitutes a significant share of the total traffic.
- Penalizing trains with insufficient power in order to avoid blocking the railway infrastructure capacity with slowly moving trains. This factor will be applied only on selected routes where the probability of fitting trains with low-powered locomotives is high.

3 Product factors

3.1 Vision of unifying unit prices of passenger and freight transport

The base price of passenger and freight transport should gradually be brought closer together until they reach the same basic price. Other factors will ensure a fairer differentiation of prices than splitting it into passenger and freight transport.

The fairness of reflecting costs in the price for the use of railway infrastructure – the product factor passenger/freight transport allows the negative effects of transport to be only generally reflected.

Compliance with the concept of direct costs – limiting the averaging of costs as part of the product factor corresponds to the philosophy of direct costs promoted by the European Commission i.e., the carrier should pay only for what additional costs are brought to the infrastructure administration, the companies and possibly other carriers.

Harmonization of pricing conditions for the railway infrastructure with neighboring countries – a significantly higher basic unit price for freight is not applied in any of the neighboring countries or other European countries surveyed.

Fig. 2: Comparing prices of passenger transport (PT) and freight transport (FT)
Source: author

3.2 *Combined transport*

A separate product factor for combined transport is maintained in the new price concept for the use of railway infrastructure; within the tariff policy, however, a plan should be prepared for the gradual reduction of benefits for this type of transport.

The reason for maintaining this factor is that, compared to other freight, it is relatively less costly for the infrastructure administration and limits to a relatively lesser extent the quality of the railway infrastructure service usage to other carriers, while these assumptions are valid:

- High degree of regularity of traffic and train speeds.
- On average, less wear and tear on the infrastructure with regard to a lower degree of wagon axle loads.

3.3 *Individual wagon loads*

A separate product factor for individual wagon loads is maintained in the new price concept for the use of railway infrastructure. It can however be modified to more accurately reflect the areas in which this type of transport are uncompetitive.

The reason for maintaining the product factor is the strategic support single wagonload shipments at the national level, which reflects:

- Low competitiveness against road transport when transporting smaller volumes of cargo.
- Prevention of migration of a significant part of the railway infrastructure (on certain lines more than two-thirds of freight) to the roads, which would have a negative impact on the track loading and track revenues of the RIA and also on the environment in the Czech Republic.

3.4 Other product factors

The product factors Infrastructure Maintenance, Non-Standard Trains, "Nostalgia" Trains, Charitable Trains and new Shipments are in the minority in terms of the overall impact. They should however not be overlooked in the new price concept for the use of railway infrastructure. [3]

4 Specific factors

4.1 Wear and tear on the infrastructure

This is a key specific factor used for the allocation of costs associated with infrastructure wear and tear by individual trains, in accordance with European legislation.

Reasons for implementing this specific factor:

- Consideration of the different degree of wear and tear on the rail infrastructure by individual trains, which had until now been applied by means of a price item based on gross ton kilometers.
- Request of the European Commission to take into account the direct costs associated with train movements, which according to the current interpretation of European legislation in this area is primarily derived from the rate of wear and tear on the rail infrastructure.

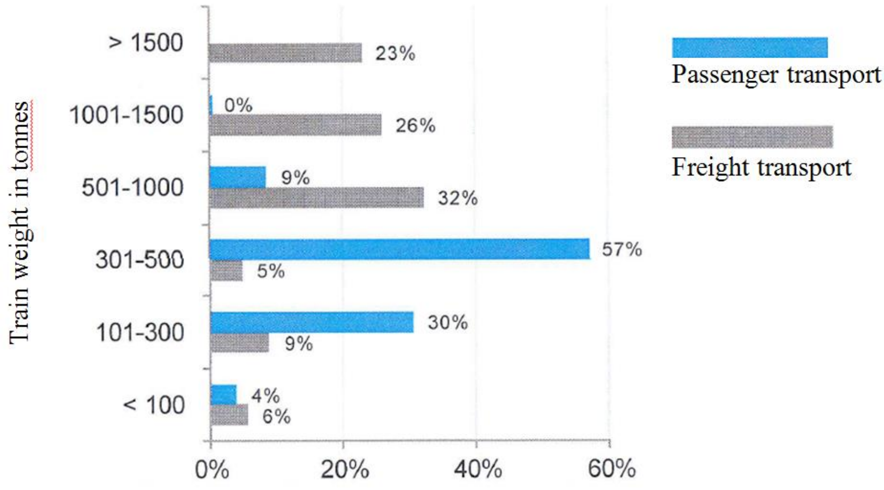

Fig. 3: Weight trains on tracks of category 3 – 5

Source: author

4.2 ETCS

Support for the introduction of ETCS is one of the main points of support of the interoperability of European railways, the attainment of which is a key objective of the transport strategy promoted by the European Commission.

The use of the ETCS increases traffic safety and full use of it on corridor lines may also increase the overall capacity of the railway infrastructure.

According to Directive 2012/34/EU on the creation of a single railway area, the pricing method for use of rail corridors should provide motivation for the outfitting of the ETCS. It should be effected with zero impact on the change of revenues for the infrastructure administration. [4]

4.3 Express trains

Express trains are given priority on the tracks at the expense of other trains. The difference in the quality of services of the use of the railway infrastructure is therefore appropriate to reflect the basic price with a surcharge, especially for passenger trains which are limited by the continuity and speed of travel.

4.4 Power sources of drive units and Noise emissions

Both of these specific factors are intended to take into account the public costs of transport and one of the key strategic objectives of the European Commission.

It is desirable to set these factors appropriately in relation to other transport modes as well as to encourage carriers to reduce government costs.

4.5 Track utilization rate

The price differentiation according to peak and seating periods allows the railway infrastructure capacity to be utilized while increasing the utilization of routes on which there is currently a significant excess of capacity.

The track load factor, however, is suitable only for certain lines, and must be adjusted individually, as some transport phenomena cannot be affected by blanket tools, as experiences from abroad have shown.

4.6 Minimum specific power of trains and Large investment projects

The minimum specific power of a train should be aimed at limiting excessive consumption and blocking railway infrastructure capacity caused by insufficient power of driving vehicles and subsequently low speeds of some trains.

The factor of Large Investment projects allows for specific parts of the rail network to apply an additional surcharge for the use of railway infrastructure in order to increase economic efficiency of the investments.

5 Conclusion

The new approaches given here in pricing for the use of railway infrastructure should not lead to further transfers of rail freight to road transport, as happened at the turn of the century, especially in the mid-nineties. It is important to bind the price tool for using the railway infrastructure to the determination of the technical parameters of both passenger and freight trains, such as their length. This indicator should prevent the capacity of the transport infrastructure from being used up with short trains, as is often done today.

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Abbreviations

ETCS – European Train Control System

GDP – Gross Domestic Product

ITF – International Transport Forum

OECD – Organisation for Economic Co-operation and Development

RIA – Railway Infrastructure Administration

ANALYSIS OF BASIC ACCOMODATION INFRASTRUCTURE ON ELBE BICYCLE TRAIL

Jiří Nožička[1]

Abstract: Long-distance cycling is currently on a rise across Europe. This is due to people's desire to combine healthy lifestyle and travel with effortless environmentally sustainable transport.

The river Elbe is one of the longest European rivers. Along this river there is already nearly completed continuous cycle route which has a length of more than 1200 kilometers. The first third of this trail is located in the Czech Republic and the rest lays in Germany. This paper elaborates analysis of basic accommodation infrastructure in different locations on the trail. It aims to identify bottlenecks of infrastructure on the Czech parts of the trail resulting from comparison to the German parts. Removal of these vulnerabilities would allow the creation of positive image of the Czech parts of the trail and encourage development of cycling in Czech regions.

Key words: contribution structure, template, contribution format.

1 Introduction

Cycling is one of sustainable modes of transport which also improves health and fitness of the inhabitants. Thanks to long-distance cycling people can explore the landscape and lifestyle in different areas without burning of fossil fuels. In addition this form of travel allows a deeper understanding of foreign landscapes than traveling by car or bus because the traveler is not separated from the environment by the mode of transport and has contact with the environment is so immediate. The intensity of tourism on long cycling routes is largely influenced by the density and variability of accommodation infrastructure.

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In 2016 it the construction of bicycle paths that passes along the river Elbe is likely to be completed. After completion we can expect increased traffic of cyclists along the river. The aim of this paper is to analyze basic accommodation infrastructure along the route Elbe bicycle trail in the Czech Republic and then the whole section of the trail in Germany. The results of the analysis will determine whether the concentration of camps on the trail is sufficient and allows cyclists to complete the entire route on a bicycle. Gaps and weaknesses in accommodation infrastructure will be also identified. The removal of these weaknesses would increase the attractiveness of the area and promote tourism.

2 Methodology

The article analyzes the accommodation infrastructure. Data for this analysis are obtained through the study of publicly available data and through interviews with experts in the field. Another data were collected by author on the Trail. The collected data are processed by basic statistical methods developed analysis.

3 Description of Elbe Bicycle trail

The length of the Elbe bicycle trail is 1270 km. Czech section begins at the source of the Elbe in the Giant Mountains and is 430 km long. Section passing through the territory of the former East Germany is 513 km long and finally section in the former West Germany is 327 km long. Bicycle trail ends in Cuxhaven on the North Sea coast. Trail is marked by signs (see picture 1).

Fig. 1: Logos of Elbe trail in Czech republic and in Germany

source: http://www.labska-stezka.cz/uvod.aspx
http://www.elberadweg.de/start.html

German sections are already completed. Development of the German part is coordinated by organization Elberadweg. The organization publishes an annual guide to the cycle trail which includes detailed cycling maps indicating tourist attractions and most accommodation options. All German cities on the Elbe trail have concluded an agreement on cooperation with this organization. Cyclists can often choose from two options. It is possible to complete the entire route along cycle paths excluding other modes of transportation. One is required to use several ferries however as the trail crosses from left to right bank and back several times. The second option is to travel along one bank and accepting the fact that some parts of the trail are passed on local roads instead of cycling route.

In the West German section (known as the northern part of the trail) there was no break in the continuity of a market economy and therefore in this section the highest density of accommodation infrastructure is expected. In the nineties central and southern parts of cycle path were built right after reunification of Germany. These parts are passing through the territory of the former East Germany. When building these segments Germans largely used road "Signal" which was used by border guards who served in East Germany and leads right along the banks of the Elbe River.

Restoring market economy on those sections were allowed to exploit the potential created by building bicycle paths. Along the trail there is lot of new camps.

In Germany the Elbe bicycle trail is a very popular destination in the summer. Most camps along the cycle trail are fully occupied. The Elbe cycling route is chosen annually by the most popular cycling route in Germany [1].

Czech part of the cycle paths began to emerge in the area Pardubice-Melnik already in the 80s of the last century [2]. As a continuous trail of modern style was created little by little. Currently only remain part to build is between Hradec Kralove and Pardubice. The current trail runs between the regional capitals on a very busy road. Width and condition of this road is unsuitable for simultaneous vehicular and bicycle traffic. Construction of this bicycle path after several years of preparation is beginning this year after several years of preparation and is planned to be completed in the year 2020 as a functional class D2 communication (path for pedestrians and cyclists with reduced or eliminated motorized transport). Construction of this section is complicated due to problematic buying of lands [3]. Development of the Czech part of the Elbe bicycle trail is coordinated by Foundation called Partnerstvi which deals with the promotion of cycling in the whole country. Since 2016 the foundation will cooperate with statutory towns of Pardubice and Usti nad Labem and thus will be involved in the cooperation with all statutory cities on the Elbe River.

4 Description requirements of basic accommodation infrastructure on Elbe Bicycle trail

Certification of catering and accommodation facilities on the Elbe bike trail provides Allgemeiner Deutscher Fahrrad-Club (ADFC) and Foundation Partnerstvi. In order to be mentioned in the guides facilities must meet certain criteria and must ask for the appropriate certification. If facilities meets the requirements for the equipment they will pay a registration fee and obtain a designation given in the paper guides and on website. This analysis deals only with camping therefore only campsite requirements are described.

4.1 Description requirements of basic accommodation infrastructure on Elbe Bicycle trail in Germany

The facilities are certified by the German Allgemeiner Deutscher Fahrrad-Club ADFC and are displayed in a virtual guide on the website www.elberadweg.de, which can be accessed in German, English and Czech. Smartphone version of the website is also available. The certificate is called bettundbike and all certified facilities use logo as a proof of certification (see picture 2).

Fig. 2: Logo of bett und bike

source: http://www.bettundbike.de/

For the successful certification the campsite must meet the 8 basic requirements relating to spots for tents. Next to there is a 9 optional requirements that a certified camp must choose at least two that meet [4].

4.2 Description requirements of basic accommodation infrastructure on Elbe Bicycle trail in Czech Republic

The facilities are certified by the Foundation Partnerstvi and are displayed on www.labska-stezka.cz. The website is available in Czech, German and English, but does not have a version for smartphones. The certificate is called Cykliste vitani (Cyclists welcome) and certified establishments use the following see picture 3.

Fig. 3: Cykliste vitani

source: http://www.cyklistevitani.cz

On the Czech certified camps the requirements are very similar to those in Germany. The campsite must meet 9 mandatory requirements and then must choose at least three of the 14 additional requirements [5].

5 Analysis

In this chapter the amount and concentration of camps analysis will be done. Number of camping sites is not a key characteristic. The author considers the maximum distance between the camps in the sector as a key characteristic as the distance determines what must be traveled in one day. If any of the cyclists in the group lacks sufficient condition to completion of the longest section then group must use either expensive accommodation in a guesthouse / hotel or more likely - will not use the bike trail. In a row for indicator “maximal distance between camps” a distance to the second closest campsite can be seen in the bracket. It is therefore a distance that would become critical in case of removal of the original weakness chain area. Concentration of camps is reported only as indicator of the development of tourism in the area.

Czech section is 430 km long and there are 18 camps located in it. From these camps just 15 benefited from free registration in the system seznam.cz and displayed to users on the website www.mapy.cz. Certification Cykliste vitani has only 6 campsites and displays to users on the labska-stezka.cz. One of the camps has paid certification Cykliste vitani, but does not use a free listing on mapy.cz. Monitored characteristics are listed in the following table Tab1.

Tab. 1: Characteristics of Czech part of the Elbe trail

Czech Republic	
length of this part (in km)	430
number of camps	18
average distance between camps (in km)	23,9
minimal distance between camps (in km)	1
maximal distance between camps (in km)	76 (62)
maximal distance between registered camps (in km)	115 (99)

sources: http://www.labska-stezka.cz/uvod.aspx
http://www.mapy.cz/
author

In Germany only one campsite was not registered. Selected characteristics are listed in the following tables Tab. 2 and Tab. 3.

Tab. 2: Characteristics of former East Germany part of the Elbe trail

former East Germany	
length of this part (in km)	513
number of camps	26
average distance between camps (in km)	19,7
minimal distance between camps (in km)	3
maximal distance between camps (in km)	76 (52)

source: http://www.elberadweg.de/start.html
author

Tab. 3: Characteristics of former West Germany part of the Elbe trail

former West Germany	
length of this part (in km)	327
number of camps	11
average distance between camps (in km)	29,7
minimal distance between camps (in km)	4
maximal distance between camps registered (in km)	74 (59)

source: http://www.elberadweg.de/start.html
author

From the tables above it is clear that if all camps located on the Czech part will ask and receive the registrations then there would be almost completely balanced position on all sections of the trail. Because the maximum distance between the camps will be 74 to 76 km. This is a distance that can be ridden by a child during one day. However if only registered Czech campsites are taken into account then the maximal distance between camps will be 115 km. This distance could be far too long for some groups.

The longest average distance between campsites can be found in the section of the former West Germany (29.7 km). Followed by the Czech section (25.3 km) and has the highest concentration is in the East section (19.7 km).

During field research it was found that the camps in Czech republic which are not registered are in tourist season filled with more than 80% of their capacity. It is therefore evident that tourists use different sources of information while searching for a campsite. However it is mostly tourists who are not travelling alongside the Elbe trail but rather stay at one place for several days. Such tourists are therefore not the same target group as the cyclists and may even have different criteria for the establishment. In the German part of the trail it is very obvious that cyclists travel along the river and every day sleep in another camp. For such tourists it is difficult to search for each camp separately. These wandering tourists would greatly appreciate if all camps are published in one place and moreover in a free printed guidebook. Campsites have however sufficient availability to ensure their economic existence already. Registration would increase their competitiveness but on the other side would create additional costs for investment registration and in some cases the cost of investments into infrastructure of the camps to meet the requirements for certified camps.

When analyzing the campsite facilities no significant differences between the quality and range of services provided to individual sections of the Elbe trail were seen and therefore not revealed any factor that would significantly decreased the quality of accommodation

6 Conclusion

From the analytical part it is obvious that the current number of camps in all sections of the Elbe trail is relatively comparable. On the Czech section of the trail weakness for cyclists which travel along the river is viewed. This weakness is in the low rate of registered camps which reduces the possibility of the development of sustainable tourism in the area.

The existing camps do not have sufficient incentive to participate in the registration system because they have enough customers already. The cities however have such motivation as registered camps would attract new tourists traveling along the trail thus increasing the attractiveness of the city. For example in the city of Decin an entirely new Cyklocamp designed for cyclists on the Elbe trail was founded in 2014. It was created on unused meadow in the city center and it is fully mobile in case of flooding and still has all the facilities including the washing machines and lockable storage for bicycles. Although in this particular section of the trail there are several camps this new on is occupied enough due to its focus on cyclists and also due to its registration to the Partnerstvi foundation. The potential for emergence of similar camps like in Decin are mainly in the cities of Pardubice and Kolin. These two cities are located in areas with the greatest distances between the camps and are also in areas where the surface of the trail will be considerably modernized in coming years. There is a low quality campsite in the city of Pardubice. This camp neither is nor registered neither use free publication on mapy.cz so it is complicated to be found for traveling cyclists. The city of Kolin has its the closest camp in city of Podebrady but this camp has a very weak advertising and does not even have its own website so it is again very difficult for cyclists to obtain information about it.

Further research in the field of sustainable tourism and sustainable transport should be given to the type of surface of the trail. German parts are at a high level and still being upgraded. In the Czech part there is currently lot of parts which are totally unsuitable for cycling and certainly not for long distance cycling. Potential research can be also done in marking of the trail in different parts which affects the tourist’s comfort as well.

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WHAT-IF ANALYSIS AS A TOOL USED IN THE DECISION MAKING AND RISK MANAGEMENT

Iveta Oborilová[1], Klára Lustigová[2], Ivo Drahotský[3], Vlastimil Melichar[4]

Abstract: Sustainable Transport Development, as a today's times often inflected term, is a main problematic issue of world. This is reason why Sustainable Transport Development is solved in top-strategic documents at European Union level (respectively at the national Czech Republic level). Inherently, one of the main objectives of Sustainable Transport Development is traffic safety. Transport Operation and Safety is defined as one of the priority of the Czech Republic top-strategic document - The Transport Policy of the Czech Republic for 2014–2020 with the Prospect of 2050. Within the traffic safety effort, creation of preventive measures to minimize damages arising from crisis situations has become more topical issues.

What-If Analysis is one of the tools of catastrophic scenarios creating with subsequent risks identification and preventive measures formation, which can be used by road infrastructure owners at all levels of state hierarchy.

This article aims to introduce this decision-making and risk management technique and demonstrate its implementation at particular case.

Key words: What-If Analysis, transport policy, risk management.

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1 Introduction

"*In integral sense, safety represents a set of measures and actions to ensure safe and sustainable development of all essential public interests protected in the state*" [8]. In the context of Transport Policy, Transport Operation and Safety is one of the important priorities, which set out specific targets and measures for achieving them. In terms of Transport Policy, importance of this priority is emphasized in the chapter 2.

Ministry of Transport and organizations responsible for transport infrastructure managing and developing are liable for the implementation of specific measures under this priority. They must ensure preventive measures that will help reduce damages caused by adverse operating conditions. What-If Analysis ("What happens if ..." Analysis) is tool that allows detecting relatively high numbers of risk factors affecting the formation and development of crisis situations quickly and effectively.

This article aims to familiarize readers with the What-If Analysis tool used in decision-making and risk management, and to present its application to the particular case.

What-If Analysis theoretical definition is practically demonstrated by What-If Analysis application in case of traffic accident on Pavel Wonka´s Bridge in Pardubice. This place is critical point in the transport network of Pardubice, because Pavel Wonka´s Bridge is one of three road bridges in Pardubice over Elbe River, and if it is necessary to close one of them, overload capacity problem arises on other bridges [2]. Amount of damages is another reason why traffic accidents should be dealt with in Pardubice. "*The average loss per accident reached CZK 50,949 in the Pardubice Region in 2014. The most frequent major accident causes are identical with accident causes reported in statistics for the Pardubice Region: bad driving (60.4 %) and excessive speed (21.9 %)*" [11].

2 Priority Transport Operation and Safety in Transport Policy Context

Priority Transport Operation and Safety is one of the priorities of The Transport Policy of the Czech Republic for 2014–2020 with the Prospect of 2050 in which measures leading to greater safety level are proposed in order to reduce losses caused by traffic accidents [5]. Ministry of Transport and organizations responsible for transport infrastructure managing and developing are accountable for specific targets execution. Within the traffic safety effort, creating of preventative measures to minimize damages arising from crisis situations is actual matter. Road infrastructure owners at all levels of government can use What-If Analysis for catastrophic scenarios creating and subsequently for risks identification and preventive measures formation.

3 What-If Analysis Theoretical Bases

What-If Analysis is a qualitative method based on expert knowledge and represented unsystematic risk identification methods [6].

What-If Analysis is based on a brainstorming of experts group in field of assessment. They answer to questions beginning with "*What happens if*". On results basis, possible catastrophic scenarios (revelation of undesirable operating situations and weaknesses) and risk factors causing these disasters are defined. Based on the identification and assessment of risk factors, measures that eliminate risk causes (in case of suggestible risks), respectively that reduce the risk impacts on a predetermined level (within non-suggestible risks case) can be determined after. The good discussion result is a list of events scenarios, their consequences and measures for risk reduction [10].

What-If Analysis can be used as part of a proactive (preventive) management and also of reactive management at the context of state, county or municipality. What-If Analysis within proactive management involves uncertainty and vagueness arising from longer time period on which the analysis is formed. In the event of crisis situation (depending on the identified risks which can turn into disaster), What-If Analysis is utilized in the reactive phase of management.

From the traffic accidents perspective, What-If Analysis can be carried out already in the design part of the project communication within proactive management. In terms of time consumption due to project documentation control, this method of preventing accidents is disregarded. What-If Analysis is therefore often used in the reactive management context according to accumulated accidents places (gained from statistical evaluation of bottlenecks in communications).

Identification of areas that may be affected by possible disaster is important element of What-If Analysis formation. Disaster impacts can be divided into general and specific impacts. General impacts concern general protected assets in the form of lives and health of people, property, and others. Specific impacts are affected by disaster place or by type of disaster. In terms of safety, the impacts of disasters are followed in several areas, which are [9]:

1.) possible impacts on lives and health of people,

2.) possible impacts on security of people,

3.) possible impacts on property,

4.) possible impacts on public welfare,
5.) possible impacts on environment,
6.) possible impacts on infrastructure and technology, which are further divided into:
   - possible impacts on energy supply system (electricity, heat, gas),
   - possible impacts on water supply system,
   - possible impacts on sewage system,
   - possible impacts on transportation network,
   - possible impacts on cybernetic infrastructure (communication and information networks),
   - possible impacts on banking and financial sector,
   - possible impacts on emergency services (police, fire fighters, paramedics),
   - possible impacts on basic services (food supply, waste disposal, social services, funeral services), industry and agriculture,
   - possible impacts on state and local governments.

Method is useful in cases where the greatest number of risk factors have to be found in a short time, but it is not suitable for comparative comparisons [4]. Because it does not provide quantified data, What-If Analysis is necessary to be complemented by other quantifiable methods of risk analysis (which allows to determine probability and impact of event defined in measurable units, such as death or personal injury expressed in monetary terms) [10]. After identification of risk factors probability and risks impact, the overall risk can be calculated and priority of scenarios can be determined according to significance.

4 What-If Analysis Application within Case Study

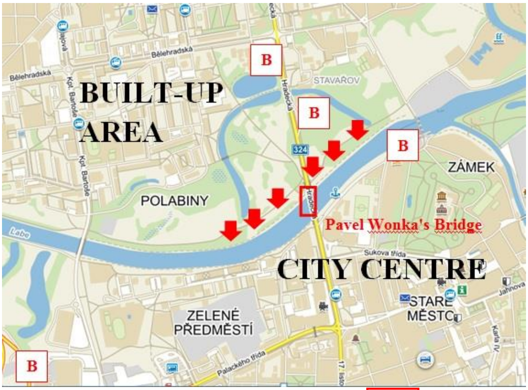
For specific example of What-If Analysis usage within the traffic accident, Pavel Wonka´s Bridge was chosen as one of sections in Pardubice centre. It is a busy section with high accident rates (see figure 1).

- Traffic accident without consequences on health, only with material damage
- Traffic accident with light effects on health
- Traffic accident with serious consequences on health
- Traffic accident with fatal injuries

Fig. 1: Traffic accidents on the Pavel Wonka´s Bridge (1.1.2007–31.12.2014)
Source [1]

In terms of Figure 1, accumulation of accidents is the strongest in peripheral parts of the bridge. Accidents without consequences on health (only with material damage) and accidents with light effects on health occur in the biggest amount.

In view of fact that the bridge connects the centre with other districts of Pardubice, several important protected assets are situated near the bridge. The bridge is an important traffic artery not only for individual passengers, but especially for public transport. Approximately 26,000 vehicles pass through Pavel Wonka´s Bridge daily [7]. Accident on the bridge would mean traffic collapse in the city. In the immediate vicinity of the bridge over the Elbe River, bike trail is located. Towards Hradec Kralove, wooded area and also the University of Pardubice within reach of 0.5 km and two gas stations are situated. Towards the centre of Pardubice, sports stadium, O2 phone operator building, CSOB Insurance Company building, Atrium Palace shopping centre, housing estates and other public places, where a large number of people may find at the time of disaster (see Figure 2).



Cycle track near wooded area B Gas station

Fig. 2: Protected assets within reach of Pavel Wonka´s Bridge in Pardubice
Source [3]

What-If Analysis evaluation in the event of traffic accident on the Pavel Wonka´s Bridge is shown in Table 1, in which major impacts on protected assets are indicated. Impacts can be further fleshed out through a timeline, which would organize impacts by time of their formation after disaster outbreak in next step, but given the extent of text this breakdown is not stated in the article.

Tab. 1: What-If Analysis in event of traffic accident on Pavel Wonka´s Bridge in Pardubice

Protected Interest	**Impact**
Lives and Health of people	Injuries and life losses of direct participants of traffic accidents, drivers or pedestrians and cyclists. Potential death while transporting injured due to delays in congestions. Potential injuries of people on cycle path in consequence of flying debris. Potential injuries of IRS members and other participating organization´s members during the rescue activities. Injuries of others people owing to the ongoing disaster (buildings in centre, University of Pardubice etc.). Hotlines Overload, IRS personnel overload and overload of other

	participating organizations. Injuries of people during clearing of debris.
Security and Welfare of people	Shock, stress, panic, uncertainty. Fear of evacuation (buildings, settlements etc.), worry about family and friends. Fear of unsuccessful solving of proceeding disaster. Increased demands on finding alternative transport. Extension of travel time due to occurrence of congestions and chaos. Lack of information.
Property	Violation of buildings and infrastructure. Damage or complete destruction of vehicles and things involved in the disaster. Injuries or death of animals involved in. Destruction of IRS property. Possible gas stations hitting. Possible property damage during removing debris. Possible damage of adjacent buildings affected by fire.
Environment	Fuel spill, possibly leakage of other hazardous substances into the air, soil, Elbe River and groundwater. Formation of toxic fumes from hazardous substances. Possible fire foundation of wooded areas in consequence of flying debris. Possible spread of fire from gas stations to other forested areas and to the University of Pardubice. Increased dust and noise due to the removal of debris. The possibility of the fish death in the river and further spreading disaster along the river.
Infrastructure and Technology	Infrastructure blocking. Routes diversion, public transport overload, congestions. Failure of transport information services. Transport collapse, unnatural distribution of passengers between the various transport modes. Possible damage of trolley lines. Secondarily, the loss of O2 phone operator signal caused by damage of transmitter in near building.

Source: Authors

On the basis What-If Analysis outputs (impacts from Table 1), it is necessary to deduce activities that can be implemented within individual scenarios. Further risk factors can be assessed in terms of their severity. Next, data can be used to creation of suitable procedure for dealing with the crisis (according to individual scenarios), and assigning of responsibility for its implementation.

Given the scope of the text, activities resulting from What-If Analysis of protected interests **Lives and Health of People** are outlined as examples via Table 2.

Tab. 2: Activities arising from What-If Analysis results in the selected field

Protected Interest	**Activity**
Lives and Health of people	Calling the IRS.
	Treatment and transport of wounded.
	Ensuring warning, evacuation and sheltering people from imminent danger.
	Carrying out rescue and relief work with the integrated rescue system, possibly in cooperation with volunteers.
	Material utilization of civil protection (e.g. in the event of dangerous chemicals).
	Ensuring quality of information transfer.

Source: Authors

Based on the knowledge of possible disaster spread resulting from the What-If Analysis in the event of traffic accident on the Pavel Wonka´s Bridge, severity of risk factors can be determined subsequently using other management methods.

Risks can be then assessed as unacceptable, acceptable and conditionally acceptable. Based on this risks categorization, preventive measures can be created to avert or mitigate of risks.

Example of measures is "*to provide documents and information needed to handle emergency plan of Pardubice or external emergency plan of Fire Rescue*".

5 Conclusion

What-If Analysis is qualitative method which is useful in cases where the greatest amount of risk factors identification has to be revealed in a short time. Because it does not provide quantified results, What-If Analysis should be complemented by other quantifiable methods of risk analysis (which allow defining probability of risk factors occurrence and the intensity of their impact on the resulting criteria).

Protected interest areas and impact in case of accident on Pavel Wonka´s Bridge in Pardubice were described in the What-If Analysis. From these findings, activities associated with resolving crisis were also necessary to draw. Ranking (importance) of activities is determined by evaluating of impact intensity and events likelihood in different areas of protected interest. For this, other management techniques are necessary to use to determine risks seriousness. Risks can then assess as unacceptable, acceptable and conditionally acceptable. Based on this categorization of risks, preventive measures can be taken to avert or mitigate of risks impacts.

It follows that risk management and security management are tools used by state at all levels of government to ensure sustainable development, in order to eliminate (or at least reduce) unacceptable risks by implementing various measures of Transport Policy.

Risk reduction competence is given by communications ownership rights.

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HOW MUCH NEW MODES OF ENERGY ARE POSSIBLE IN THE OLD MODES OF TRANSPORT?

Wojciech Paprocki[1]

Abstract: This paper presents a short description of a few most modern technical solutions of energy production as well as of its consumption which have been already implemented in the transport sector or can be implemented soon.

Key words: modal split, transport system, cargo traffic.

1 Introduction

The traditional modal split in the global transport system has not changed for decades. However, it is necessary to look closer to realize that the way of production and consumption of the energy develops dramatically almost every day. There are several reason why exactly in the last 20 years so many new solutions were implemented. The most important reason is international acknowledgement of the global climate changes. The Kyoto Protocol was adopted in 1997. Since then all governments and top managers in the world have known that there is not an alternative for the new global policy towards reduction of the greenhouse gas (GHG) emissions. The development and implementation of absolutely new and original solutions in field of producing and consumption of energy are supported by public sector. Simultaneously, several administration barriers are settled to avoid the utilization of the old technological solutions in the future. It might be expected that the new goals will be defined during the conference in Paris at the end of 2015 and they will refer to the Sustainable Development Goals prepared last August [1].

Nowadays we need to have more fantasy but we have be realistic too. This is an important competence to understand what kind of changes are possible in the transport system and to predict which economic effects may occur in the next years in regards to both macro and micro economy. This paper presents a short description of a few most modern technical solutions of energy production as well

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as of its consumption which have been already implemented in the transport sector or can be implemented soon.

2 The transport system in Europe is established

The most important changes in the structure of industrial production happened in Western Europe in the 70's and 80's of the last century whereas in Central Europe (in the former socialistic countries) they took place just in the last decade of the XX century. Road transport plays the most important role in the transport system of all European countries (Table 1). The reduction of road transport of goods, which is one of the most important goals of the transport policy by the European Union, generally has not brought the expected results. This might be spectacularly observed in Germany. Some but only very modest results were achieved in Austria and Switzerland, where the administrative barriers regarding road traffic in transit through the Alps and also in inland traffic are the strongest on the whole continent. Recently, there have been the first comments, also from Brussels, that the expectations defined by politicians in the last decades, e.g. in the White Book 2000 and 2011, were partly unrealistic. [2] Experts report, what is at least obvious, that it is basically impossible to shift any part of cargo flows from road to rail transport, as the structure of commodities changed in favour of 'small shipments' containing high value goods while the volume of raw materials purchased by the shrinking heavy industry was drastically reduced in the last four decades.

Tab. 1: Share of the road transport in the modal split in cargo traffic (based on tkm)

	2013	2000	Changes in %-points
Iceland	100,0	100,0	0,0
Cyprus	100,0	100,0	0,0
Malta	100,0	100,0	0,0
Ireland	98,9	96,2	2,7
Spain	95,4	92,8	2,6
Luxembourg	94,2	87,8	6,4
Portugal	94,1	92,4	1,7
Greece	90,8	97,9	-7,1
Italy	86,9	89,0	-2,1

	2013	2000	Changes in %-points
Denmark	86,8	92,1	-5,3
United Kongdom	86,7	90,0	-3,3
Norway	86,3	83,5	2,8
Poland	82,9	57,3	25,6
Slovenia	80,7	71,9	8,8
France	80,6	76,0	4,6
Chech Republik	79,7	68,0	11,7
Croatia	76,2	-	
Slovakia	76,0	53,0	23,0
Bulgaria	75,9	52,3	23,6
Hungary	75,5	68,1	7,4
Finland	71,8	75,8	-4,0
Lithuania	66,4	46,6	19,8
Belgium	64,5	77,4	-12,9
Germany	63,9	65,3	-1,4
Sweden	61,8	64,7	-2,9
Romania	57,5	42,9	14,6
Netherlands	56,2	63,4	-7,2
Estonia	55,9	37,2	18,7
Austria	52,8	64,8	-12,0
Switzerland	52,0	55,1	-3,1
Latvia	39,6	26,5	13,1

Source: author according http://ec.europa.eu/eurostat/web/transport/statistics-illustrated (read 19.08.2015).

A similar situation is observed in passenger traffic. Rail transport, including the high speed trains technology, is preferred by authorities in several countries. Mostly the passengers choose the mode of transport not in favour of the recommendations made by politicians and technocrats. For example, they have used buses in long distance travels much more often in recent years than in the past. The tendency presented in figure 1 is easy to follow in Germany, where when the road transport was liberalized in 2012 the number of passengers traveling by bus increased from 2 to 19 million in 5 years.

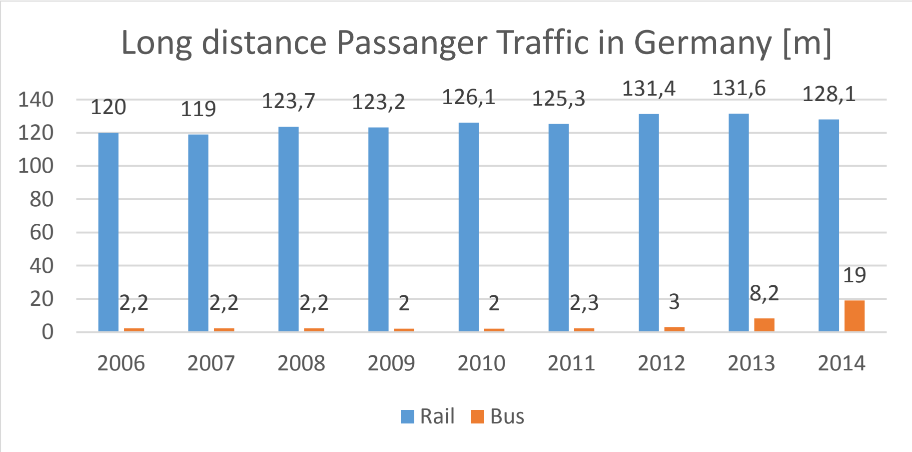

Fig. 1**:** Development of the passengers in the long distance traffic in Germany in 2006 – 2014 [16]

Concerning short distance transport in the big agglomerations it is observed that the share of public transport modes in total passenger traffic in the biggest towns in Germany has remained at the same level of about 14 per cent for last 10 years (Fig. 2). Besides, it is interesting that bicycle travel, unchanged, plays a very modest role, although this form of mobility is promoted very often in media.

The leading position of individual motorization remains unchanged in Western Europe. A similar level of individual motorization has been achieved in Central Europe during the past 25 years – e.g. in Poland there were 486 cars per 1,000 population in 2012 [3] and this already quite high level continues to increase.

The data mentioned herein lead to the clear conclusion that the transport system in Europe is established and currently there are no existing factors which would trigger significant changes of the modal split in both passenger and cargo transport.

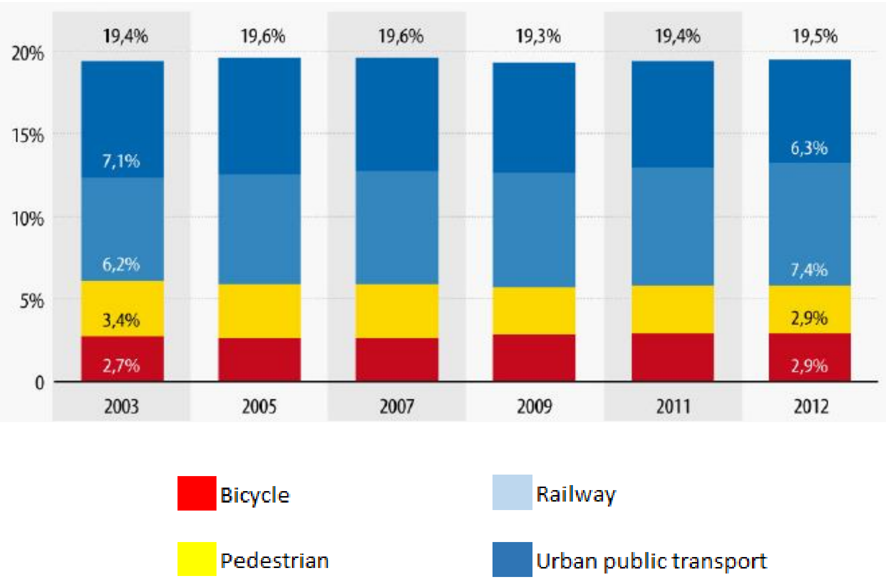

Fig. 2: Share of the environment-friendly modes of transport in the urban passenger traffic in Germany in 2003 – 2012 [17]

3 Conventional energy carriers used in the transport system

The steam railway and steam shipping are not existing because this technology is much less efficient than two others: motorization and electrification. The popularity of electrification in rail transport (as well as in underground and tram transport in the cities) is typical and obvious in Europe. This is not the fact on other continents, especially in North America where diesel traction is used almost everywhere in railway transport. The only small exception consists of local railway networks with electric traction around a few big cities and inside of them.

Motorization is the only solution used both in air and sea transport. The biggest question mark concerns road transport, though. Are there any other alternative energy drivers than fluid or gaseous fuels produced either from oil or gas or alcohol?

At the very beginning of the motorization in Europe there were more factories producing electro-cars than motor-cars. [4] At the same time also hybrid-cars [5] were produced. More than 100 years ago electro-cars did not find acceptance among drivers due to fact that the batteries allowed to travel no more than 50-80 kilometers. The same generation of batteries remain the most popular in cars until now. A new generation of batteries has capacity to power the car on a distance up to 440 kilometers. [6] But there are still several reasons why modern electro-cars are not popular. One of them and absolutely the most important is the high price of these cars as well as of the batteries which have to be exchanged every three to four years. [7] It is also important to note that car drivers still complain about the range anxiety today at the beginning of the XXI century in the same way as they did in the beginning of the XX century. Experts and politicians predicted in the 90's that the number of electric cars would increase rapidly. By 2010 they forecasted 1 million of them in Germany alone, both on the streets in towns as well as on roads in the regions. The real development has instead been very poor. In Europe in 2014 there were only about 30.000 electro-cars. In Germany only about 19,000 electro-cars were registered, while the total number of car-fleet in this country amounted to almost 50 million. [8]

4 What is new – hydrogen fuel cell, solar cells and once again bicycle

There are a few new solutions, which have already been implemented in the contemporary transport system or can be implemented soon. The first solution is the use of hydrogen fuel cells. After years of development works the first Toyota Mirai cars were sold in Japan in October 2014. In August 2015 the first of these cars arrived in Europe. [9] These are fuel cell cars with carbon-fibre fuel tanks in which hydrogen is stored. The front intake grills deliver the outside air to the fuel cell stack. Hydrogen travels from tanks to the fuel cell stack. There, it goes through a chemical reaction involving oxygen from the air, thus creating electricity. From this moment the car works like a standard electro-car. There are two differences between Mirai and standard electro-cars. Firstly, the delivery of the electricity power takes place from the stack and not only from (big) batteries. Secondly, the only by-product of creating electricity with hydrogen and oxygen in the fuel cell stack is water, which leaves the car through the tailpipe. [10] There is no emission of CO_2 at all.

A second solution is the installation of solar cells on the aircraft. The "Solar Impulse-2" is the only airplane of perpetual endurance equipped with 17,000 solar cells which supply four electric motors and charge batteries with renewable energy. [11] It can also fly during the night using the stored energy. The first journey around the world started in March 2015 from Abu Dabi. This journey had to be suspended on Hawaii on July 3rd, 2015 after the airplane suffered battery damage. The next section flight is not planned before spring 2016. [12]

We may renew the discussion, if humans shall be treated once again as source of power. The industrial revolution two hundred years ago brought new possibilities which allowed to stop using human-powered transport. Today there are some projects towards the re-implementation of humans as the source of power in transport. [13] As a bicycle rider everyone can move himself using his own power and as a cargo bicycle driver one may even start labor activity. [14] Walking and cycling are treated in such projects as important pillars of sustainable urban mobility. These two kinds of mobility create alternatives. But they cannot become the sole transport mean for the entire population of a large agglomeration, with today's urban sprawl compared to the past where small towns were walkable. [15] Cycling is possible in several regions only during a certain period of the year. Riding a bicycle is often impossible during the winter as snow or ice are on the streets. Due to these reasons cycling can become popular only in certain local communities. It should be considered that cycling has lost its leading position in the transport system in many Chinese towns ever since a significant part of the population has started to afford own cars.

It seems to be a strange coincidence that almost all new projects in the field of implementing new solutions regarding the consumption of energy concern only individuals, who have a choice to use new hydrogen techniques in their new cars or to restart using their old bicycles. The highest consumption of energy concerns cargo traffic, where the use of heavy commercial vehicles (HCV) remains the leading transport mode position, and high see vessels powered by motor engines. Modern HCV and vessels become friendlier for the environment but they consume not much less fluid or gaseous fuels than they used to do beforehand.

5 What can happen to make the transport system more sustainable?

The share of energy costs are different in particular modes of transport. A challenge for the future is the consumption of energy which production runs with marginal costs amounting to quasi zero. There is potential on the planet to produce electrical energy almost without limit using renewable energy technologies. The current situation on the electrical energy market in Europe shows that there are some hours during the day that the offered energy is very cheap because the spot price falls to a level of about 30 per cent of the average price. The real full cost of production of electrical energy and its consumption (reported as the purchasing price) can become extremely low if the consumption takes place in the same location as the production. This could be the case if the production of hydrogen is decentralized.

The production of hydrogen would be possible only in a limited period of the day when renewable energy can be produced at the lowest (full) cost. The storage and transport of hydrogen will become safe and effective soon. Then the supply of hydrogen will be possible and efficient every time. The construction of storage infrastructure as the network of fuel stations covering the network of roads would be a prerequisite to let the consumption of hydrogen become popular.

In road transport the exchange of motor-cars with new electro-cars equipped with hydrogen technique would be warmly welcomed in accordance with modern climate and environmental policies. Let us assume that electro-cars equipped with hydrogen technique will be offered for a price acceptable for the majority of drivers. A limitation for the popularization of these kind of cars is then the rate of reinvestment in the fleet of light vehicles (cars used by households). The average rate amounts currently to about 5 per cent. It means that the quasi total exchange of the fleet in the world takes a minimum of 20 years taking into consideration the purely hypothetic scenario that the automotive industry starts producing only electro-cars with hydrogen technique.

The scenario of the quasi total exchange of the existing light vehicle fleet is unrealistic for the next decades due to the fact that the automotive industry does not plan to terminate the production of traditional motor-cars. Falling oil prices since 2014 make each alternative for motor-cars unattractive. Climate policy can lead the governments in several countries to sharply increase the excise tax on fluid or gaseous fuels but such regulation will create several negative consequences for the economic growth and prosperity.

Cargo transport creates very huge GHG emissions. If the generation of electric energy used in the electric traction by railways will change the technology, this emission will be reduced. This question might be solved outside the transport system. There are no new ideas how to reduce the GHG emission in the cargo road transport.

The current transport system is well established in the global economy and it makes this system resistant for revolutionary changes, including any changes in the field of energy consumption. This means that a significant reduction of the consumption of fluid and gaseous fuels in the transport system should not be expected any time soon. The consequence is a very limited possibility to reduce GHG emissions in the transport industry, while a significant reduction will perhaps be achieved in mid-term first of all in the commercial production of electrical energy as well as in the traditional industries and municipal engineering.

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AIRPORT TRAFFIC – COMPARING CZECH REPUBLIC AND UK

Kateřina Pojkarová[1]

Abstract: The paper focuses on airport traffic, especially Václav Havel Airport Prague, London Heathrow and other important airports in United Kingdom such as London Gatwick, Manchester or London Stansted. There is comparison in their changes during a year for these airports. The economic crisis in 2008 has significant impact on airport traffic, but it manifest differently in these countries as is showed and described in the article. There are also differences in distribution of passenger among national airports and in seasonal deviations in these two countries. For testing and modelling seasonal deviations *F*-test, *p*-value and multiply model with moving averages are used.

Key words: airport traffic, seasonal indexes, models

1 Introduction

There are lots of opportunities for travelling by plane and more and more people use this opportunity for their business trips and also for their vacations. We can this trend in past years, before the economic crisis, when the increase was about 10 % each year in Czech Republic and about 5 % in UK. After the crisis the situation changed.

2 Airport traffic performance trends

Few years before 2008 – the year known for economic crisis – number of passengers in Czech Republic had been increasing. In this year the performance was highest (13 629 278 passenger) and from the next year till now there was decrease with small deviations. The level of passengers is now about the level in 2006.

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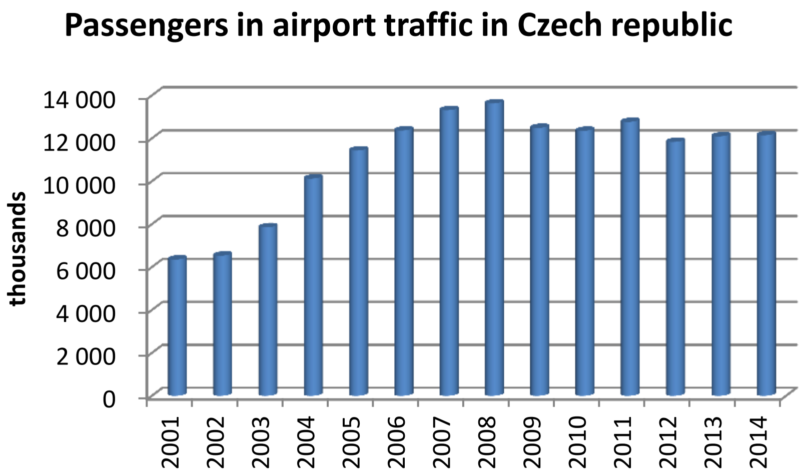
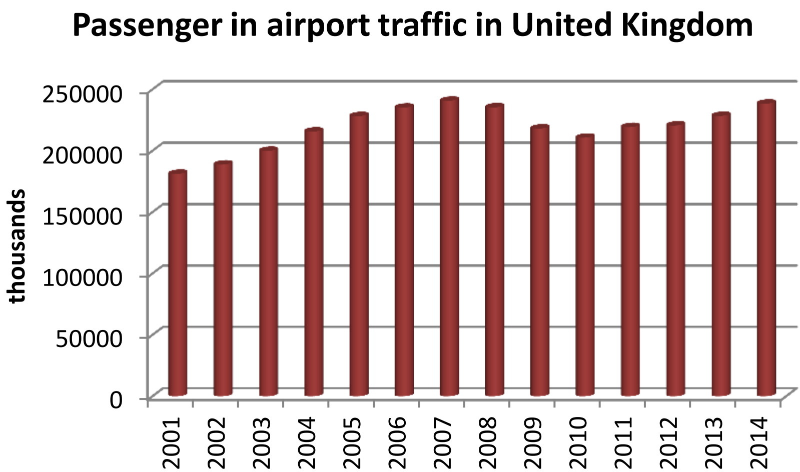


Source: Author, Ministry of Transport

Fig. 1: Passengers in airport traffic in Czech Republic

The crisis and its influence on transport performance showed a few months earlier in UK. Maximum of passengers was in 2007 and in next three years there was decrease. From the year 2011 has been the situation better, the number of passenger has been increasing and now it is almost at the level from 2007.



Source: Author, Civil Aviation Authority

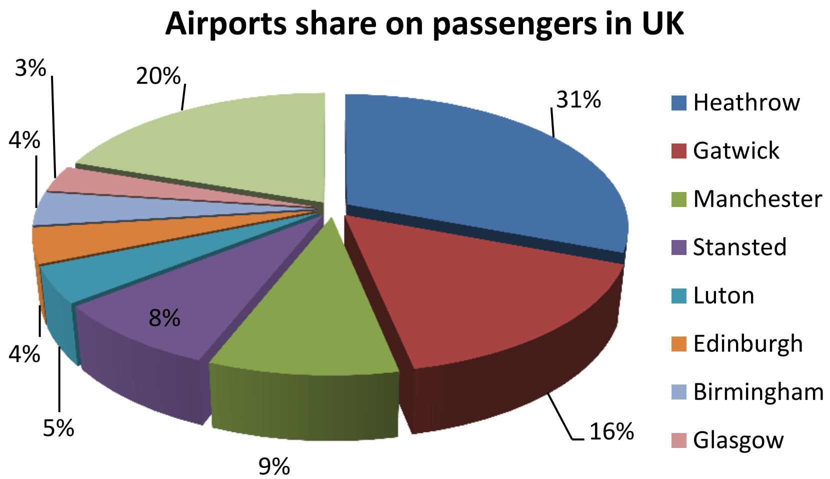
Fig. 2: Passengers in airport traffic in United Kingdom

3 Airports in Czech Republic and UK

Dominant position in Czech Republic has Vaclav Havel Airport Prague. In spite of several other airports in Czech Republic offer civil international transport, still the main airport is in Prague. During the last 5 years this airport was used by 93 % of all passengers in Czech Republic, who used air transport.

In United Kingdom there is also one main airport, it is London Heathrow, but the share of passenger is more even as it is shown at next picture.

London Heathrow (LHR) has about one-third share on the whole number of passengers in UK (the average in last 5 years is 31,4 %). The other important airports are London Gatwick, Manchester and London Stansted (these four airports share 64 % of transported passenger in 2014).



Source: Author, Civil Aviation Authority

Fig. 3: Airports share on passengers in UK

4 Seasonal deviations of airport performance

During a year there are significant differences in number of passenger, so as in airport performances. For testifying this hypothesis there were chosen the most important airports both in Czech Republic and United Kingdom from years 2009 to 2014. Monthly data were cleaned up from different lengths of months, so to be able to compare. These data were put to F-test where null hypothesis said that seasonal deviations during a year are not significant. Results of this test were compared with quantile for F-distribution with allowed error 1 % and the evidence can be also proved by p-value.

$$F = \frac{\dfrac{m\sum_{j=1}^{r}\left(\bar{y}_{.j} - \bar{y}\right)^2}{r-1}}{\dfrac{S_R}{(r-1)(m-1)}}$$

$$S_R = \sum_{i=1}^{m}\sum_{j=1}^{r}\left(y_{ij} - \bar{y}\right)^2 - r\sum_{i=1}^{m}\left(\bar{y}_{i.} - \bar{y}\right)^2 - m\sum_{j=1}^{r}\left(\bar{y}_{.j} - \bar{y}\right)^2$$

m … number of years
r … number of month in a year
$\bar{y}$ … average year value
$\bar{y}_{.j}$ … average value in season j
$\bar{y}_{i.}$ … average value in year i

Tab. 1: Seasonal deviation at significant airports

Airport	***F*-test**	***P*- value**	**Existence of deviation**
Prague	213,6	< 0,0001	Yes
London Heathrow	36,4	< 0,0001	Yes
London Gatwick	358,3	< 0,0001	Yes
Manchester	386,7	< 0,0001	Yes
London Stansted	53,0	< 0,0001	Yes

Source: Author, Prague Airport, Heathrow Airport, Gatwick Airport, Manchester Airport, Stansted Airport,

So we can see that existence of seasonal deviation was proved on all of the most important airports in Czech Republic and UK.

As a matter of interest, there is *F*-test for different destination flied from Vaclav Havel Airport Prague. In every case the seasonal deviation was also proved.

Tab. 2: Seasonal deviation at different destination flied from Prague

Destination	***F*-test**	***P*- value**	**Existence of deviation**
Paris	13,6	< 0,0001	Yes
Frankfurt	26,4	< 0,0001	Yes
Moscow	16,3	< 0,0001	Yes
Amsterdam	15,0	< 0,0001	Yes
London (LHR)	22,7	< 0,0001	Yes

Source: Author, Prague Airport

5 Seasonal deviation modelling

For finding out the size and direction of seasonal deviation there has been used the multiply model with moving averages. Increase above average is from April to October in Czech Republic; in UK it is from June to October. So here we can see some other difference between airports in these two countries. Also the size of deviation is different. In Czech Republic the highest decrease is more than 30 % and the highest increase about 35 %, in UK it is only 13 % (decrease) and less than 16 % (increase), so the airport transport is much more even.

Table 3 shows deviations in passengers in the most important airports in UK. Minimum of deviation is in London Heathrow Airport and unlike the others at this airport there is decrease in May. These specific trends could be influence thanks to existence of other airports in London (Gatwick, Stansted). Passenger could choose the cheaper tickets offered by low-cost airways, which used airports other than LHR, and offers more flights in spring and summer.

Tab. 3: Monthly deviation at UK airports [in %]

Airport	January	February	March	April	May	June	July	August	September	October	Nvoember	Devember
LHR	-13	-10	-5	-4	-2	9	16	13	10	3	-7	-9
Gatwick	-28	-20	-14	-2	6	18	27	33	22	2	-22	-22
Manchester	-30	-22	-16	-5	10	29	34	38	33	4	-21	-24
Stansted	-27	-18	-13	8	11	14	17	23	13	6	-17	-17

Source: Author, Heathrow Airport, Gatwick Airport, Manchester Airport, Stansted Airport

Tab. 4: Monthly deviation at different destination flied from Prague [in %]

Airport	January	February	March	April	May	June	July	August	September	October	Nvoember	Devember
Paris	-30	-19	-8	15	22	12	9	11	13	6	-11	-7
Frankfurt	-33	-28	-14	8	24	21	7	9	18	8	-4	-17
Moscow	-4	-23	-2	12	3	-3	8	14	9	4	-3	-10
Amsterdam	-28	-18	-6	6	12	9	9	9	16	10	-0	-15
LHR	-37	-18	-10	6	12	12	17	16	21	14	-9	-19

Source: Author, Prague Airport

As mention above he increase above average in Czech airport traffic is between April and October, and table 4 shows that doesn't matter where passenger fly, the deviation is alike. Exception is in Moscow, where decrease in in winter months and also in June. This could be done because there are more flights from smaller airports.

6 Conclusion

The influence of economic crisis was manifested in airport traffic, in UK that was happened earlier than in Czech Republic. In both countries are significant seasonal deviations and it is not depend on an airport – if it is the only one dominant in a country (Vaclav Havel Prague Airport) or if it is one of more important airport in a country (for example Manchester or London Stansted). Deviation during a year is slightly different in Czech Republic, where are bigger deviations, than in United Kingdom.

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PERSONAL ACCOUNTABILITY

Kateřina Pojkarová[1]

Abstract: To achieve any success in business, to make any progress in transport, develop anything new in this area or even in personal life there is absolute necessity to become aware of personal accountability and free agency to choose. Be conscious of and bear personal responsibility is not as common and natural behavior as it should be. This fact is shown on questions that people give to themselves. It can be questions that lead to appropriate actions or it can be questions leading to procrastination, complaints and victim posture. With analysis of variance and χ^2 test several factors that can influence ability and desire to bear responsibility, have been tested. These factors were gender, age, education etc.

Key words: personal accountability, question behind the question, analysis of variance, χ2 test.

1 Introduction

One of the 7 habits, which were described by Stephen Covey (Covey, 2007), gives advice to be proactive. It means to know that everyone is responsible for his own life and that everyone should be aware of this accountability. To search for and use excuses, stay in victim attitude or let others to make choices for him is not useful. And with this attitude there will be no sustainable development in transport. People need to search for ways ow to change things which lay both in their circle of concern and circle of influence.

"*Many people wait for something to happen or someone to take care of them… [They] take an irresponsible position and waits for someone else to make things happen or provide a solution.*"(Covey, 2007)

Also Jack Canfield (Canfield, 2006) states as first principle in his book The Success Take 100% Responsibility for Your Life. "*If you keep on doing what you've always done, you'll keep on getting what you've always got.*"

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2 Personal accountability

Accountability, or more precisely personal accountability, is something that any successful transport company or even any family and any individual cannot do without. Nevertheless it is something people don't realize and don't behave according it. It is easier to have victim attitude – easier but not more effective.

People like to search for culprit – for the one, who caused the bad situation. Rather than think how they can change the situation, they say: "It's not my problem," or they ask "Who have spoiled this?" or "Why someone doesn't help me?"

According John Miller (Miller, 2014) these questions are incorrect questions (IQ's), that are in direct contradiction to personal accountability. Instead of ask IQ's people should ask question behind the question (QBQ). Thanks to this type of question they can realize, that everyone has a choice in every moment. They can choose thoughts to think of, words to say or actions to do. Everyone makes these choose even unconsciously, so everyone bear the responsibility. Question behind the question is like a practical tool that can help us to live according the first habit described by Covey.

John Miller (Miller, 2006) stated: „*The QBQ is different. It's practical and it works. What makes it work are three easy-to-apply guidelines that show us how to construct effective questions:*

1. *QBQs begin with the words "What" or "How", not 'Why", "When", or "Who."*
2. *QBQs contain the word "I", not "they"', "them", "you" or even "we", because I can change only me.*
3. *QBQs always focus on action.*"

QBQ helps to avoid procrastination, because instead of IQ's such as "When they will give us the right information?" or "When the situation will be better?" people can ask "How can I contribute to solve this problem?", "What should I do to gain the information that I need?" or "How can I succeed with resources I have?" questions like these leads to action, not to wasting time with procrastination.

The basic principle of this concept is to ask "What can I do?" and then to do it.

So if people ask better questions, they can get better answers. And that is why it is so important to use the right questions – QBQ – instead of incorrect questions, because there cannot be anything positive or productive as results of these questions. They only bring impression that we cannot chose.

3 Results from survey

The research was done to verify if people bear accountability or how much. People were asked which type of question they often ask themselves. They could choose from incorrect questions and questions behind the question. Their options show if they prefer victim attitude or if they focus on action and their circle of influence.

More than 200 people were asked for this research. They were men and women, people with different level of education and income.

First group of questions was composed from general questions; all of the respondents answered them. To consider which of given factors have significant impact on bearing accountability, and to consider if there is significant difference between various groups of respondent, the analysis of variation and $\chi 2$ *t*est were used, with level significance level 5%.

In the set of questions from which respondent could choose, contained the same number of IQs and QBQs. Assumption is that people who acknowledge of their accountability in life would prefer (and choose) more QBQs then IQs. So the first analysis searches if selected factors have significant impact on the difference between chosen QBQs a IQs.

Tab. 1: Analysis of variation of difference between QBQs and IQs

Factor	**F test**	**P value**	**Significant impact**
Parent or not	6,197	0,014	Yes
Student or not	13,788	< 0,001	Yes
Employer or not	0,002	0,966	No
Leading position or not	3,784	0,053	No
Gender	0,091	0,764	No
Education	9,133	< 0,001	Yes
Age	3,973	0,002	Yes

Source: author

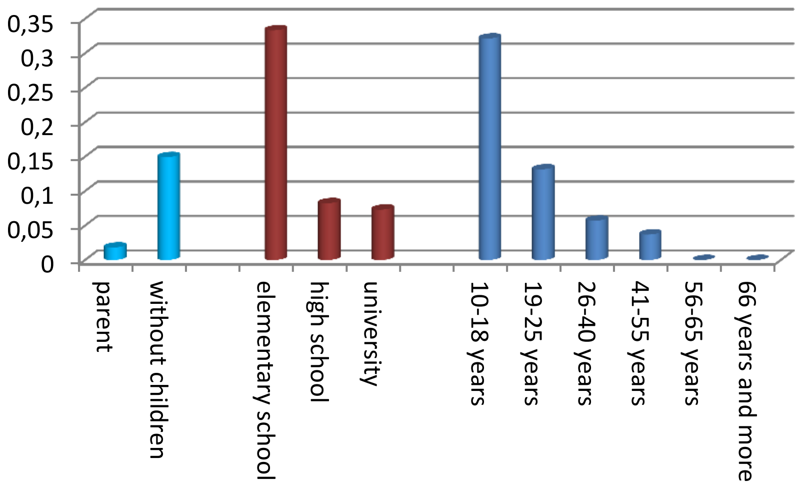
Gender, employment and leader position haven't got any impact on asking QBQs or IQs, but all the other factors have significant impact. Parents are more responsible, so as people with higher education and older people.

There are people who don't ask themselves any question behind the question, that means that they don't have any idea about accountability in their life. $\chi 2$ *t*est was used to verify, if selected factors has any impact on this.

Tab. 2: $\chi 2$test for null number of QBQ

Factor	**$\chi 2$ test**	**P value**	**Significant impact**
Parent or not	6,860	0,009	Yes
Student or not	6,161	0,013	Yes
Employer or not	5,899	0,015	Yes
Leading position or not	3,566	0,055	No
Gender	0,502	0,479	No
Education	16,490	< 0,001	Yes
Age	16,905	0,005	Yes

Source: author



Source: Author

Fig. 1: Share of respondents who don't ask any QBQ

In this case, again, there is no significant impact given by gender and leader position. There is only 2 % of respondents between parents who don't ask any QBQ, but 15 % between people without children. If we focus only on students, there were 18 % of them, who don't ask any QBQ – and only 7 % between those who finished their studies. Every third respondent from people with lower education don't ask himself any QBQ (and only 8 % of people with higher education). As for age, the higher number of irresponsible people is between age ten to eighteen. People older than 26 years ask at least one QBQ.

Third possible view on this topic is based on dominance of QBQ that means if respondents ask themselves more QBQs than IQs or if it is the opposite.

Tab. 3: χ2test for dominance of QBQ

Factor	***χ2* test**	**P value**	**Significant impact**
Parent or not	10,263	0,001	Yes
Student or not	20,139	< 0,001	Yes
Employer or not	7,307	0,007	No
Leading position or not	5,215	0,022	Yes
Gender	0,916	0,338	No
Education	22,668	< 0,001	Yes
Age	29,476	< 0,001	Yes

Source: author

Distinct dominance QBQs above IQs can be seen in the group of parents (88 % of them ask more QBQs than IQs), but people without children, students and people with elementary education don't ask so much QBQs.

Gender and employments don't have impact on bearing responsibility. On the other hand significant impact has education and age.

4 Nurturing children

Except for general question about responsibility, there were also question focused on specific area, such as nurturing of children, study and employment. In these areas can be made survey about accountability and factors as well.

Tab.4: Analysis of variation of difference between QBQs and IQs in nurturing of children

Factor	**F test**	**P value**	**Significant impact**
Employer or not	0,0465	0,83	No
Leading position or not	1,030	0,315	No

Factor	F test	P value	Significant impact
Gender	2,445	0,124	No
Education	1,677	0,195	No
Age	1,650	0,177	No

Source: author

Tab.5: $\chi 2$test for null number of QBQ in nurturing of children

Factor	$\chi 2$ test	P value	Significant impact
Employer or not	0,035	0,852	No
Leading position or not	1,429	0,232	No
Gender	1,123	0,289	No
Education	15,853	< 0,001	Yes
Age	19,068	< 0,001	Yes

Source: author

Tab. 6: $\chi 2$test for dominance of QBQ in nurturing of children

Factor	$\chi 2$ test	P value	Significant impact
Employer or not	0,521	0,470	No
Leading position or not	5,026	0,025	Yes
Gender	2,827	0,093	No
Education	6,198	0,045	Yes
Age	12,490	0,014	Yes

Source: author

From these analysis we can see that hypothesis of good impact of higher education of parents in nurturing their children was proved. Also there is almost anyone in this group who didn't ask any QBQ. As for age there is opposite trend than in previous survey – the older parents asks les QBQs. It could be given by the fact that their children are older, they had started to nurture them many years ago and now they don't realize importance of be responsible parents anymore.

5 Study at school

Another group among respondents was students. The area of study and student attitude was another researched topic. Following tables show analysis of variation and $\chi2$ test of impact of several factor on responsibility of students at school.

Tab.7: Analysis of variation of difference between QBQs and IQs during study

Factor	**F test**	**P value**	**Significant impact**
Employer or not	2,073	0,154	No
Leading position or not	1,100	0,297	No
Gender	0,008	0,931	No
Education	1,835	0,166	No
Age	1,807	0,152	No

Source: author

Tab.8: $\chi2$test for null number of QBQ during study

Factor	**$\chi2$ test**	**P value**	**Significant impact**
Employer or not	8,316	0,004	Yes
Leading position or not	1,877	0,171	No
Gender	0,154	0,695	No
Education	1,907	0,385	No
Age	7,560	0,056	No

Source: author

Tab. 9: $\chi2$test for dominance of QBQ during study

Factor	**$\chi2$ test**	**P value**	**Significant impact**
Employer or not	1,618	0,203	No
Leading position or not	1,173	0,279	No
Gender	0,003	0,955	No
Education	1,115	0,573	No
Age	1,740	0,628	No

Source: author

Any of chosen factors haven't significant impact on bearing responsibility during studies. The exception is whether the students are also employees or not.

Surprisingly students who are also employees hold less responsibility than those who only study.

6 Accountability at job

The third area to research was working environment.

Tab. 10: Analysis of variation of difference between QBQs and IQs at job

Factor	**F test**	**P value**	**Significant impact**
Parent or not	0,4332	0,512	No
Student or not	0,391	0,532	No
Leading position or not	2,405	0,124	No
Gender	0,283	0,596	No
Education	0,121	0,886	No
Age	0,752	0,558	No

Source: author

Tab. 11: $\chi 2$test for null number of QBQ at job

Factor	**$\chi 2$ test**	**P value**	**Significant impact**
Parent or not	0,251	0,616	No
Student or not	0,007	0,933	No
Leading position or not	1,858	0,173	No
Gender	0,038	0,847	No
Education	3,053	0,217	No
Age	2,078	0,838	No

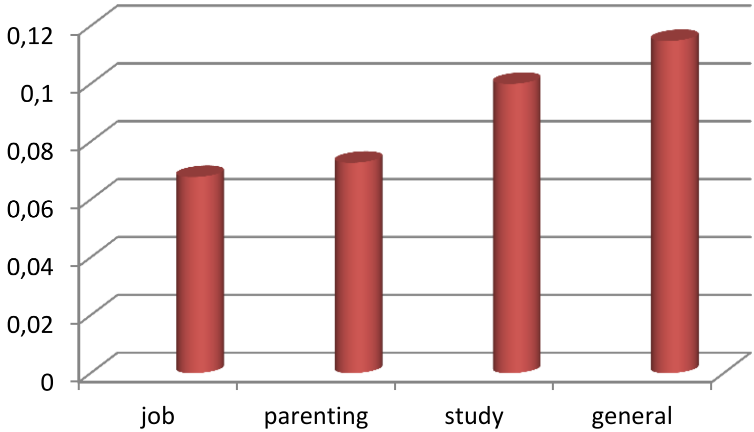
Source: author

Tab. 12: $\chi 2$test for dominance of QBQ at job

Factor	**$\chi 2$ test**	**P value**	**Significant impact**
Parent or not	4,171	0,0411	Yes
Student or not	4,535	0,0332	Yes
Leading position or not	3,1588	0,061	No
Gender	2,014	0,1559	No
Education	5,556	0,0622	No
Age	6,58	0,1597	No

Source: author

At working environment there hasn't been any significant impact that could influence how much QBQs and ICs employees asks and if they asks at least one QBQs. But we can see significant impact in the third area – the dominance of QBQ. Parents and non-students ask more QBQs than others.



Source: author

Fig. 2: Share of respondents who don't ask any QBQ in different areas

Given picture presents the fact, that during nurturing children and working at job people bear more accountability, there are less of people who don't ask any QBQ. On the other hand the percentages of student who don't ask any QBQ are higher.

7 Conclusion

From the survey follows the fact that in younger generation there are more people who are not aware of their own accountability, and so they accuse others from circumstances in which they live or wait for someone who will solve their problems. The question remains if it is natural tendency and during their life, maturity and gaining experiences they will realize their own accountability and begin to act according this truth or if it is given by upbringing and modern environment and their attitude will not change in in older age. For answer to this question it would be necessary to do another survey in 20 or 30 years and then compare the results.

Irresponsible attitude is more often between people with lower education. It gives another question – what is the root? People with irresponsible attitude are not willing to study more or because they don't study more, they don't realize their own accountability.

Even in groups with better results there is space for improvement. Instead of complain on other people can ask "What can I do with this?", "How can I be the one who will help with solution that the one who makes the situation worst with complains?"

Personal accountability is not something we can get some day. It is an everyday process. In every situation we should avoid incorrect questions and choose question behind the questions.

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USAGE OF THE TILTING PLATFOM IN VEHICLE PARAMETRS DETERMINATION

Jan Pokorný[1], Petr Jilek[2], Ondřej Voltr[3]

Abstract: This contribution deals with possibilities in usage of tilting platform in determination and exploring parameters of road vehicles. Article has been created on the basis of experiments made in the new Teaching and Research Center in Transport on tilting platform by tilting the car to one side. It is possible to explore parameters connected with change of centre of gravity and increasing of lateral force during tilting the car on the tilting platform. This has effect mainly on elastic parts of axes and tyres.

Key words: tilting platform, centre of gravity.

1 Introduction

On the vehicle during driving acts a number of forces that influence the behaviour of the vehicle. Effect of a number of these forces it can be observed dynamically during a driving test and also with certain restrictions during static or quasi-static tests in the laboratory. For static or quasi-static observation of the vehicle responses to acting forces is used tilting platform. Tilting platform is primarily used to detect static rollover threshold of the vehicle, to detect vertical coordinate of the centre of gravity and also to simulate the lateral forces acting on the vehicle. It can be used not only to identify the parameters of the vehicle itself, but also to simulate the centrifugal forces acting on the cargo transported on the vehicle. So it can be used not only to identify the parameters of the vehicle itself,

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but also to simulate the centrifugal forces acting on the cargo loaded on the vehicle. This enables for example to determine force acting on the restraint members or slings securing cargo on the vehicle. As one example of the usage of tilting platform can be mentioned a recent measurement of force action of logs on the stanchion of pole trailer (see. Figure 1) made for Hořické strojírny spol. s r.o.

Fig. 1: Experimental determination of force distribution along the stanchion

As was mentioned the tilting platform is among other used for determination of centre of gravity height. Experimental determination of the center of gravity may not be as easy as it seems at first glance. Although the methodology of determination of centre of gravity is given, performs here a number of factors that can affect the result.

2 Object of measurement

Experimental car was used as an object of measurement. This car was built for the purpose of examination of vehicle stability on Jan Perner Transport Faculty of University of Pardubice. The vehicle has truss frame welded from steel tubes of circle profile. Three cylinders combustion engine from Skoda-auto Company is used as a drive unit for this vehicle. Stroke volume of this engine is 1,2 dm^3. Both axles of the experimental vehicle are the same and there are taken from the 1st generation of Skoda Fabia. These both axles are used for steering and drive of the vehicle while the torque moment is divided in ratio of 50:50.

Fig. 2: Picture of the experimental vehicle

3 Determination of vertical coordinate of the centre of gravity

The method for determination centre of gravity height on tilting platform is based on tilting the car along its longitudinal axis. The center of gravity height of the unloaded car T_z is determined from figure 3 using equation of equilibrium of moments (1) and forces (2) compiled to the lower wheels – the wheels of right side of the car. Radial reactions of the left side of the car are equal zero ($Z_{13} = 0\ N$) at the tilt angle of the tilting platform α - component force of gravity of the car is passing through point (axis) of tilting A in this moment. Because wheel gauge both front and rear axle of the experimental car is the same, thus the tilt axis is parallel to the longitudinal axis of the car. In case of our experimental vehicle the value of tilt angle of the tilting platform, which leads to overcoming a stable position, is depend on:

- suspension,
- lateral stiffness of tyre,
- height of non-skid element under lower wheels,
- sense of tilting,
- velocity of tilting.

$$Z' \cdot T_z - Z'' \cdot (\frac{B}{2} - H_3) = 0 \tag{1}$$

$$Z_{13} + Z_{24} = Z \tag{2}$$

$$Z' = Z \cdot \sin \alpha \tag{3}$$

$$Z'' = Z \cdot \cos \alpha \tag{4}$$

$$T_z = \frac{Z'' \cdot \left(\frac{B}{2} - H_3\right)}{Z'} \tag{5}$$

where: Z' – sine component force of gravity
Z_{13} –radial reaction of driving wheel
Z'' –cosine component force of gravity
Z_{24} –radial reaction of lower wheels
T_z –center of gravity height
H_3 –lateral displacement of the vehicle
α –tilt angle of the platform

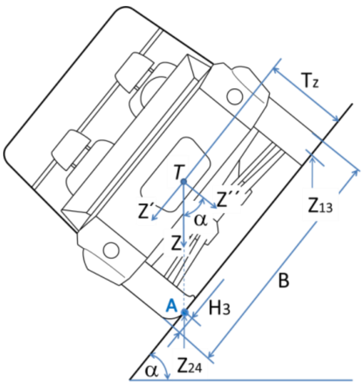


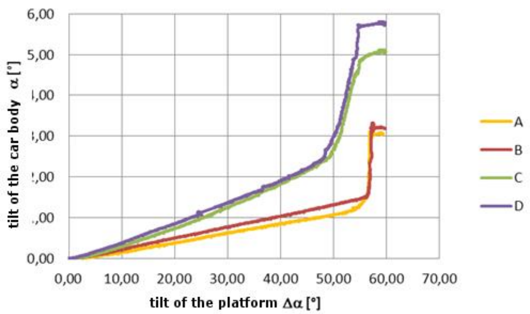
Fig. 3: Tilting platform in Teaching and Research Center in Transport

4 Parameters influencing determination center of gravity height

4.1 The Influence of suspension

Influence of suspension together with used type of axle is on the centre of gravity height evident. As the angle of tilting platform (with the vehicle resting on it) is increasing the radial reaction of the lower wheels also increases and suspension on this side of car is adequately pressed. The situation at upper wheels of the vehicle is opposite – suspension is stretched. Vehicle body thanks this fact turned about some angle around the point, which is given by kinematics of front and rear axles. Vehicle roll angle, when radial reactions of upper wheels with the plate is $Z_{13} = 0\ N$, is changed thanks this effect.

Static height of centre of gravity is such position of the centre of gravity of the vehicle when the vehicle is stationary. For determine of static center of gravity height is important to eliminate suspension – it must be hold unchanging position of sprung mass in the face of unstrung mass during tilting of the platform. To avoid deformation of suspension were used fixation members. Functionality of suspension blocking was monitored by pair of ultrasonic sensors used for measuring height between car body and tilting platform With blocked suspension was the break-off point of wheels (point when radial reaction of upper wheels is zero) reached at the value of tilt angle $\alpha = 55{,}87°$. Car body was just before break-off point relatively tilted to the platform about angle $\Delta\alpha = 1{,}45°$. It was caused by finitely rigidity of tires and used fixation members. The height of the centre of gravity has in the static mode value $T_z = 533\ mm$ above the ground.



A – blocked suspension, B – blocked upper suspension, C – blocked lower suspension, D – unblocked suspension

Fig. 4: Dependence of tilt of the car body on tilt of the platform

Dynamic position of centre of gravity corresponds to real position of the vehicle during driving tests. It is no necessary eliminate swing of car body on account of suspension for determination of centre of gravity. Value of relative tilt of the car body against tilting platform is $\Delta\alpha = 4{,}93$ for $Z_{13} = 0\ N$. Zero radial reaction of upper wheels Z_{13} is for tilting angle of the platform $\alpha = 54{,}25°$. Height of centre of gravity in dynamic mode is $T_z = 566\ mm$ above ground.

4.2 Sense of tilting

It is necessary gradually and fluently tilt adequate velocity during determination of height of center of gravity to unambiguously identify the angle, when upper wheels are losing contact with the platform $Z_{13} = 0\ N$. Value of angle of tilting platform for break-off point of upper wheels during lifting of platform can differ from angle of point of contact of these wheels with platform during its lowering. For comparison of these differences in angles or height of center of gravity was used maximal tilt angle of the platform, which has value 60°. Velocity of movement of the platform in both directions was the same. It means that the platform was lifted up without interruption in break-off point of the car till the angle 60°of the platform. And similarly was this hold during lowering.

Measured and calculated values for both senses of tilting of the car are evident in Table 1.

Tab. 1: Height of center of gravity dependent on sense of tilting

	upward lifting		downward lifting	
	T_z [mm]	α [°]	T_z [mm]	α [°]
blocked suspension	533	55,87	565	54,32
free suspension	566	54,25	588	53,24

4.3 Lateral movement of the car and height of non-skid element

Non-skid element prevents in movement of lower wheels and sliding down of the vehicle from the platform during its tilting. It is practically a support for lower wheel of the car.

As a non-skid members were used wooden blocks with width of *c*= 70 mm and stepped height of *b*= 1,6, 3,4, 5,2 a 70 mm. Influence of height of non-skid member was measured for both senses of tilting.

The experimental vehicle was during measurement tilting up to given angle and at the same time lateral movement of the wheel (axle) was being measured. Each following measurement was made with non-skid member of 18 mm smaller than previous step. It was measured absolute distance between wheel and sensor that was mounted on the tilting platform near the non-skid member. The larger is lateral displacement, the smaller is distance between the wheel and sensor. The default position of the wheel is defined in distance of 132 mm from the sensor. Due to safety aspects of measurement was tilting platform tilted only up to angle of 51°. On figure 5 is evident dependence between lateral movement of the wheel, angle of tilting platform and height of non-skid member.

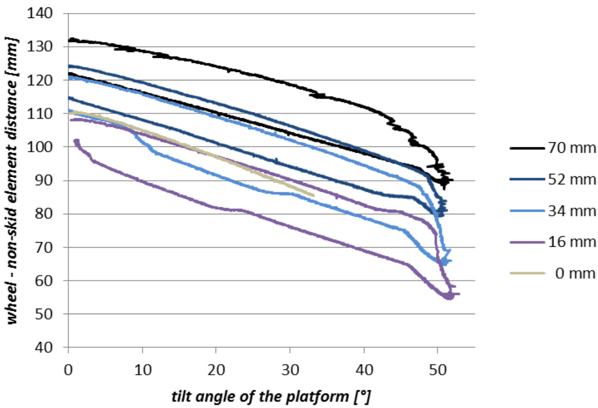


Fig. 5: Dependence between lateral movement of the wheel and height of non-skid member during tilting of the platform

5 Conclusion

Determination of the centre of gravity height on tilting platform is influenced with a number of factors that can affect the result of measurement.

Influence of suspension on the centre of gravity height is evident from measured data. As was expected, the springs of suspension units are deformed during tilting the car on the platform, that has influence on the moment of rollover the car. For evaluation this effect is important to compare this free suspension to locked one. Tilt of sprung mass against the platform has in our case effect of 30 mm in difference of the centre of gravity height.

Upper suspension units have dominant influence on tilting. When is upper suspension unit unblocked, the centre of gravity height is close to dynamic position. If upper suspension units are blocked and lower ones are free, the centre of gravity height is close to static position.

The centre of gravity is also dependent on sense of tilting – if it is found out during lifting of the vehicle or lowering. Usually is used procedure of lifting of the vehicle – thus by gradual tilting. Difference in tilting angles of the tilting platform, when radial reaction of upper wheels is Z13 = 0 N, is around one degree. Higher values are for upward tilting – so during downward tilting is centre of gravity height bigger than during opposite sense of tilting.

The height of non-skid member influences lateral movement of car and also rollover resistance during tilting. From the point of view of rollover of the car is better to use non-skid member as low as possible. On the other hand low non-skid member causes bigger lateral movement of the car. Effect of these contradictory requirements was not able to fully evaluate due to safety aspects. It was only possible to observe lateral movement in dependence on the degree of tilt and height of the non-stick element up to tilt angle of 51°.

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Summary: Determination of the centre of gravity height on tilting platform and some influencing factors. The tilting platform, object of measurement and methodology of determination of the centre of gravity height are briefly introduced. Three parameters influencing the determination of the centre of gravity height are briefly described and shown results of measurements.

THE MODERN STORAGES OF ELECTRIC ENERGY FOR TRACTION APLICATIONS

Ondřej Sadílek[1]

Abstract: The paper deals with research activities about technical aspects of modern storages of electric energy in aplication of dual source railway vehicles on the Czech railway traffic system. The thought vehicle uses for powered traction equipment the catenary and traction battery system. The battery system design is based on the traction and vehicular simulations.

Keywords: battery, li-ion, railway vehicle, catenary.

1 Introduction

The multisource railway vehicles are solving at Department of Electrical and Electronic Engineering and Signaling in Transport. Research activities are focused on the traction and propulsion computer simulations and on the real measurement of the experimental vehicle. The paper discusses a design of dual source railway vehicle (DSRV) with the trolley collector and the traction battery. It is expected that this vehicle will be operating in the Czech district.

The designed vehicle has a lot of advantages unlike conventional one. Among these advantages we might include operation in a short section without an electric line, elimination of combustion engine, using a principle of regenerative braking and recharging battery under catenary. Recharging in a station is not necessary. This realities lead to more effective vehicle using.

2 Conception of DSRV

This research goes by way of the battery position analyses in the vehicle powered by catenary. In this case it is talking about DSRV, because there are the collector and the battery. This vehicle can be operating in short sections without catenary that are ordinary in the Czech Republic.

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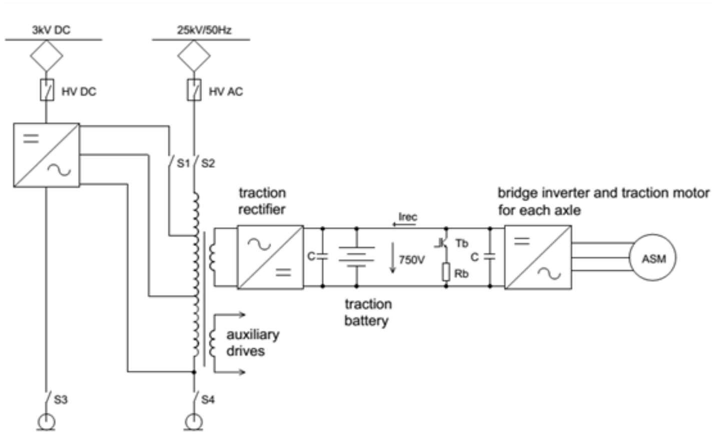

Fig. 1: Two power supplies railway vehicle

The electric equipment described by Fig. 1 was designed on base of a metropolitan railway vehicle. For this vehicle is 750 V a typical value of voltage in DC link. This is very advantageous because there is the battery inside DC link. The battery has to be connected to the DC link by converter and the isolating transformer when the voltage will be higher than 1000 V. Furthermore, the electric equipment must be constructed for a high voltage. This solution is more expensive and more complicated in comparison with the 750 V DC link technologies. If the battery would get high voltage on the ports she will be destroyed. It would be very dangerous situation for the passengers and staff. Furthermore, the conception that is in Fig. 1 has higher efficiency. The vehicle that is described above is powered from the catenary with 25 kV 50 Hz and 3 kV DC. The value of an alternate voltage is changed by a transformer and rectified by a rectifier. The DC voltage is led to the transformer through an inverter that creates an alternate voltage. The accumulator can be charged in the same time when traction inverters are consuming an electric energy from the DC link in case of intelligent control. The energy from regenerative braking can be saving to the accumulator or returning to the trolley wire. Energy storing to the battery is naturally preferable because the vehicle works with a higher efficiency.

3 Design and dimensioning of the battery systém

The most restrictive equipment of DSRV is the accumulator of energy – the battery. This element determines the main parameters of non-electrified track - DSRV output power and range. It is necessary to design a battery for this track which will comply with these parameters: energy, power, safety and life time.

It seems that the best way for DSRV is to use electrochemical battery based on lithium (Li-ion). Li-ion batteries are the most modern one, because they have a lot of benefits in comparison with other batteries (Lead acid, NiMH, etc.). The main benefits are for mobile applications higher volumetric and mass energy density. Another benefit is relatively high nominal voltage around 3.2V/cell because of the big potential difference between negative carbon electrode and positive lithium electrode. The disadvantages of Li-ion batteries are higher price and necessity of supervisor management system (BMS – battery management system). The Li-ion technology based on LiFePO4 was selected for the proposal of traction calculations. This is the most used and safe technology nowadays.

3.1 Ideological proposal design of battery system

The battery system design is based on the knowledge of required energy for non-electrified section, required circumference wheel power and required converter DC link voltage. To achieve the needed voltage it is necessary to calculate the number of cells connected in series:

$$n_{cells} = U_{dclink\_nom}/U_{a\_nom} \text{ [-, V, V]} \quad (1)$$

Where n_{cells} is the number of cells in battery, U_{dclink_nom} is the voltage of converter DC link and U_{a_nom} is the nominal cell voltage. The next step is to determine the battery capacity in connection with track energy intensity and required power.

The traction drive chain consists of: traction converter, traction motors, transmissions and wheels. The battery contains internal resistance and the supply of electro motoric voltage. If the required circumference wheel power is known, the power from the battery (battery ports) is calculated as:

$$P_{bp}=P_{wheel/ηdrive} \text{ [W, W, \%]} \quad (2)$$

Where P_{bp} is the required power on the battery ports, P_{wheel} is the required circumference wheel power and η_{drive} is the total drive efficiency. Next step is to calculate the current from the battery ports:

$$I_{bp}=P_{bp}/U_{dclink\_nom} \text{ [A, W, V]} \tag{3}$$

Where I_{bp} is the current from the battery ports. Every traction battery contains internal parasite resistance which becomes energy loss. The energy loss depends on value of charging and discharging current. The efficiency of charging and discharging is reduced. During research activities it was determined on battery TS-LFP40AHA 40 Ah that internal resistance of LiFePO4 technology is not dependent on depth of discharge (DOD) and also the value of charging/discharging current. The nominal battery capacity should be measured by standard CSN EN 62660-1 at discharging current of magnitude 0.3 C (current corresponding to 0.3 multiple of battery capacity). It means that if the battery is discharging by the current 0.3 C, the measured capacity of this current is equal to the catalog capacity. It is not possible to declare the compliance of this standard nowadays. For this reason it is necessary to determine the methodology which would make energetic safe solution. The model of DSRV uses for the simulation the capacity from catalogue which is used as internal capacity. It means that the energy from the battery is used for energy losses on internal battery resistance and traction work. Dependence of charging and discharging on current from battery with capacity 1000 Ah (WB- LYP1000AHA) was described in . The defining is based on available parameters from manufacturer. After approximations is possible to express equation for efficiency as:

$$\eta_{char\_dischar} = -0.0094 \cdot I_{bp} + 100 \text{ [\%, A]} \tag{4}$$

Where $\eta_{char\_dischar}$ is the efficiency of charging and discharging. For the required battery capacity is possible to use this equation:

$$C_{acu\_nom} = A_{wheel} / (U_{dclink\_nom} \cdot \eta_{drive} \cdot \eta_{char\_dischar}) \text{ [Ah, Wh, V, \%, \%]} \tag{5}$$

Where C_{acu_nom} is the required battery capacity and A_{wheel} is the required circumference wheel energy. For the increasing of energy and power reserve is necessary to increase energy capacity by at least 25 %.

$$C_{acu\_real} = C_{acu\_nom} / 0.8 = C_{acu\_nom} \cdot 1.25 \text{ [Ah, Ah]} \qquad (6)$$

Where A_{acu_real} is the total battery capacity. Battery capacity meets energy requirements now. Now it is necessary to check if it is possible to give the battery a full traction load. In general this condition must be met:

$$I_{bp} \leq 3C \text{ [A, Ah]} \qquad (7)$$

Where 3C is triple capacity – it is the current maximal allowed for LiFePO4 technology. If the condition is not met, the capacity has to be increased.

3.2 Design validation in the context of DSRV

The design of vehicle battery system needs the detailed knowledge of driving cycle – energy claims and work part of traction characteristics. The next premise for sophisticated battery system design is represented by the comprehensive set of technical parameters about exact type of battery. If is not possible to find out or measure the required parameters, the calculations must be done with a big reserve of energy and power.

4 Simulation of DSRV and operating

The primary problem of DSRV design is a calculation necessary battery capacity. The valid capacity value is obtained if the numeric simulation for the required tracks is used. All simulations were done by Matlab.

The ground of simulation model was calculated the train motion equation. All the tractions calculations are solved with 20 ms period that was verified during testing of simulation model. At first the model loads parameters of the track and rail vehicle. The main parameters of the track are locations of gradient changes, speed changes and stations. The vehicle is characterized by the traction characteristic and the braking characteristic. In the next step model needs dates about a propulsion system for solving energetics calculations. The valid information about propulsion system is obtained after analyses of energy flows inside a propulsion chain. For the valid value of the accumulator capacity and the power dimensioning simulation model needs dates about auxiliary consumption. The air-conditioning and the heating are the significant components of the total auxiliary consumption.

After loading important parameters the program will calculate the traction force. In the next step the program compares the traction force Ft [N] with speed of the train v [kph] and computes the actual power (Pwheel_act = v · F_t) on circumferences of wheels. The consumed energy E [kWh] can be determined by integration of infinitesimal elements of the power. The mathematical operation of the integration is transformed to the summation in the simulation model. The energy increments are calculated by multiplication an actual power Pwheel_act with a period of the simulation T [ms]. The mentioned principle describes the equation (12).

$$E_n = E_{n-1} + P_{wheel\_act} \cdot T \qquad (12)$$

The results are graphically presented as progresses after the simulation. The graphs describe the changing values during the vehicular ride. The energy in the battery is calculated from the traction energy and the efficiency of the propulsion system. Fig. 2 and Fig. 3 demonstrate the interpretations which come up from the simulation algorithms.

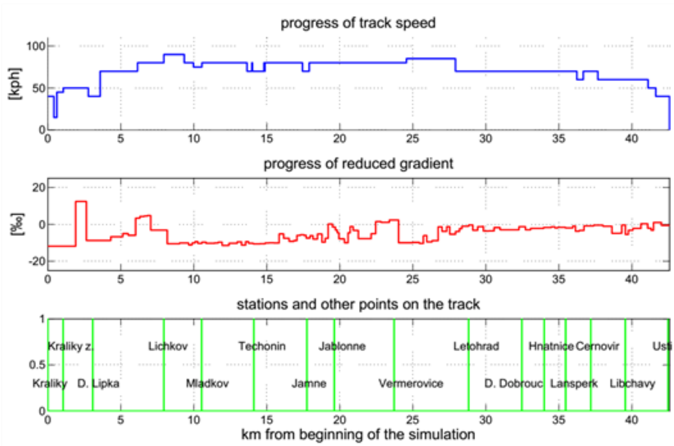

Fig. 2: Examples of input quantities

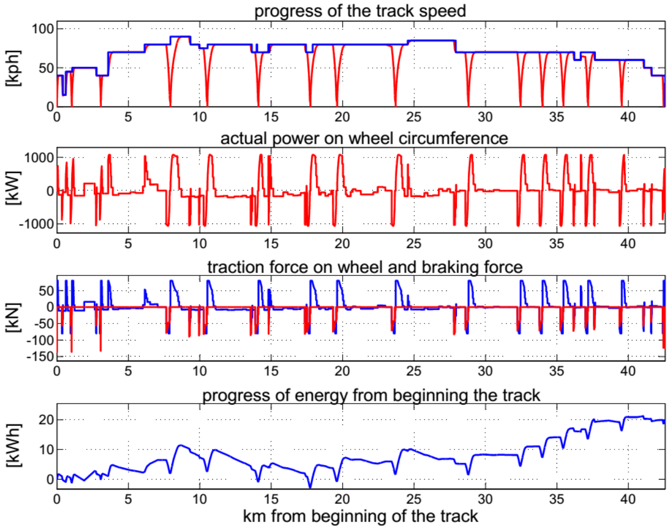

Fig. 3: Examples of output quantities

For a better transparency, simulation results were given to the average of 15 tracks that were passed by eight axels DSRV vehicle. The vehicle weight was 110 t with included 115 passengers. The capacity of the battery was specified to the value 750 kWh. Than weight of lithium cells is 8 t. With this battery the vehicle should be able to pass 50 to 80 km ride. Note that the battery is designed with 50 % DOD. Note that the length of the ride depends mainly on the gradient. These same simulations were repeated for the dieselelectric railway vehicle, the clearly electric railway vehicle, the battery railway vehicle and the dieselelectric railway vehicle with a catenary collector.

It was followed that the vehicle of the DSRV type is more effective for an operation than other vehicles designed for the nonelectric section operation. Furthermore, the DSRV might be suitable for a clearly electricity operation after an irreversible death of the battery.

5 Conclusion

During the research activities it has noticed many contributions of the collector/battery DSRV against the conventional collector/combustion engine vehicle. In the comparison of the cost of electric energy and the fuel wins the electric energy. Therefore, the clearly electric operating vehicle is cheapest. On the second hand the operation of a vehicle powered by the combustion engine is the most expensive. The average way is to use DSRV with a battery. Therefore, the maintaining vehicle with the battery is cheaper than the maintaining vehicle with the combustion engine. Furthermore the energy from braking can be partly returnedto the battery. Next an advantage is covered in more effective traffic flows. DSRV goes on the track with and without catenary. Consequently the people cannot change the train. The electric buses get more and more popularity around the world. The railway has to respond fast on this trend for keeping customers.

Acknowledgement

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EXPERIMENTAL INVESTIGATION OF THE PROPERTIES OF THE SPECIAL CONCRETE AFTER THE INCIDENT – AFTER FIRE

Vladimír Suchánek[1], Jiří Pokorný[2]

Abstract: It is necessary to consider so-called extreme design situations (for example fire exposure structures) in addition to usual design situations already in its own design of structures. This is true for public works, such as transport structures and civil engineering works undoubtedly are.

These extreme conditions can cause structural failure (eg. bridge construction, underground construction) before the end of its design life.

More generally fires caused material damage but pose a risk to health threats, or even death.

This paper deals with the analysis of the effects of extreme thermal stresses on selected special concrete used or usable for transport structures. It focuses on changing mechanical and physical properties of composite materials based on hydraulically hardened cement binders, but also on the alkali activated materials.

This article deals with the description and evaluation of experimental work carried out by the Department of Transport Structures of Jan Perner Transport Faculty, University of Pardubice in the laboratory facilities of the Educational and Research Centre in Transport.

Keywords: high temperature, fire, self-compacting concrete, fibre reinforced concrete, steel fibre reinforced concrete, lightweight concrete.

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1 Introduction

Currently, so-called special concrete is increasingly used in construction practice. This is a concrete, in which some essential property reaches abnormal values or unusual use than conventional concrete.

Today applicable standard for the design of concrete structures – structural fire design [2] does not affect the behavior of special concrete – particularly for simple and refined methods. This rule describes the material properties as a function of temperature of normal concrete, depending on the type of aggregate (silica or limestone). Does not apply, however, to describe the lightweight concrete.

Aim of this article is to demonstrate the different characteristics of special concrete after exposed to extreme temperature stress. Knowledge of these mechanical and physical properties should help to develop principles for assessing the effect of fire on selected special concrete.

Fire resistance is one of the key factors when assessing structures, or in the design of buildings. Fire resistance is defined as the ability of structures to withstand temperatures generated during a fire without violating their functions.

Appropriate choice of materials used in construction can contribute to the improvement of passive fire protection.

2 Behavior of concrete under fire conditions

It is known that the physico-chemical properties of the concrete change at high temperatures. There is a high internal stresses due to different thermal expansion of the components of the concrete element or structure.

When physical degradation takes place in the concrete, there is an increase of permeability and porosity to explosive spalling concrete and ultimately to the loss of structural strength and to reduce the modulus of elasticity (i.e. reduction in strength and strain properties).

These changes depend on the speed of heating, the moisture concrete, maximum temperature achieved, and on the used materials in concrete.

2.1 Raw material base

At temperatures above 500 °C the conversion of α-to β-quartz, accompanied by an increase in volume of quartz of about 5 %. Internal stresses in concrete with limestone aggregate is lower than in concrete with silica aggregate. The combination of both types of aggregates is not suitable [8].

In contrast, the hardened cement paste shrinks when heated. At temperatures around 1000 °C already leads to a complete breakdown of CSH gel [6].

"To achieve a good resistance to fire conventional concrete contributes not only its porous structure, but also the amount of free and bound water." [1].

Tab. 1: Influence of temperature on the surface of concrete [4]

Heating temperature [°C]	Color changes	Design changes	Status of concrete	Strength changes
0–290	-	Without damage.	Without damage.	
290–590	pink-red	Surface cracks: 300 °C. Deep cracks: 550 °C.	Strength greatly reduced.	Significant loss of strength around 400 °C (40 %).
590–950	gray and white	Spalling: 800 °C.	Unbearable and crumbly concrete.	
≥ 950	brownish yellow	Extensive spalling.	Unbearable and crumbly concrete.	The loss of strength at temperatures above 800 °C (> 90 %).

3 Fire resistance tests

3.1 Experimental methods

It is known that the basis for determining the fire resistance of structures are testing methods. In comparison with the theoretical procedures, or computational models they are temporally and economically more complicated. For calculations, it is not possible to capture the integrity of the surface structure, waveforms cracks, spalling layers etc. The results of computational models amount to less economical solution.

Test of fire resistance can be determined in the test furnaces. Estimated duration time of fire was set to 120 minutes.

3.2 Preparation of test specimens

For the purpose of the experiment bodies of ordinary vibrated concrete C 30/37, C 25/30 and COMB25/30 were made. Further samples were produced from self-compacting concrete C 45/55 and lightweight concrete LC 25/28 D1,8.

The concrete mixture was subsequently supplemented by dispersed omnidirectional reinforcement of various kinds and different types of variable weight dozes. It was the (micro) polypropylene fibres, Texiplast – TEXZEM PPF 370 (fibrillated tapes), at doses of 2 („2PP“) and 4 $kg.m^{-3}$ („4PP“). (Macro – large diameter) fibres Synmix 55 of the same weight doses were also applied, 2 („Syn2“) and 4 $kg.m^{-3}$ („Syn4“). Steel wires Dramix 3D 45/50 BL were used to produce wire reinforced concrete. They were dosed of 25, 50 and 75 $kg.m^{-3}$ („25“, „50“ and „75“).

Concrete „Comb25/30“ is supplemented by a combination of synthetic fibres and steel wires. It was the (micro) polypropylene fibres (the same type) at dose of 2 $kg.m^{-3}$. Steel wires (applied another type: Dramix 3D 65/35 BG) were dosed of 75 $kg.m^{-3}$.

Artificial lightweight aggregate Rugen was used in the production of fresh lightweight concrete. It, compared with other artificial stone, excels in processing high proportion of fine inorganic waste materials while maintaining the lowest energy intensity of the production temperature.

Used recipes of concrete are applied on real structures.

Besides cement concrete, samples from an alkali activated material were made. Generally, these materials are produced by alkali activation of waste materials (e.g. slag, fly ash), or with materials used in concreting (e.g. clinker, metakaolin, Portland cement without gypsum). As activators are used alkali metal silicates, carbonates, hydroxides, and its various combinations.

Before starting any fire resistance tests, determination of moisture was performed with thermally unloaded samples (made from the same mixes). Humidity value is approaching the upper limit of moisture in real structures, such as tunnel lining concrete moisture [3]. Therefore, there was no body dried.

Tab. 2: Used recipes of concrete

Initial substances	**Vibrated concrete**			**Self-compacting concrete**		**Alkali activated material**
STONE AGGREGATE	**C 30/37**	**C 25/30**	**COMB 25/30**	**C 45/55**	**LC 25/28**	**AAM**
0/4	Y	Y	Y	Y	Y	Y
4/8	Y	-	Y	Y	-	Y
8/16	Y	Y	Y	Y	-	Y
4/8 artificial lightweight aggregate Rugen	-	-	-	-	Y	-
8/16 artificial lightweight aggregate Rugen	-	-	-	-	Y	-
ADMIXTURES						
Very finely ground limestone	Y	-	-	Y	Y	-
Granulated blast-furnace slag	-	-	-	-	-	Y
Sodium silicate	-	-	-	-	-	Y
Potassium hydroxide KOH	-	-	-	-	-	Y
CEMENT						
[kg.m^{-3}]	340	360	340	400	380	-
ANOTHER PROPERTIES						
Water-cement ratio w	0,47	0,50	0,36	0,47	0,42	-

Tab. 2: Used recipes of concrete (continuation)

Initial substances	**C 30/37**	**C 25/30**	**COMB 25/30**	**C 45/55**	**LC 25/28**	**AAM**
ADDED STEEL WIRES [kg.m-3]						
Dramix 3D 45/50 BL	-	-	-	25, 50, 75	-	-
Dramix 3D 65/35 BG	-	-	75	-	-	-
ADDED POLYPROPYLENE FIBRES						
Micro fibres – Fibrillated tapes	-	-	2	2, 4	-	-
Macro fibres – large diameter	-	-	-	2, 4	-	-
Combination of fiber types	-	-	Steel wires + micro fibres	-	-	-

3.3 Fire resistance tests in the furnace

The three months old test samples were exposed to extreme thermal stress in an electric furnace (BVD 800/K).

There was an effort to get them closer to model fully developed fire to the maximum extent possible (subject to device). According to DIN EN 1363-2, namely the description of the nominal standardized curves (in the older literature known as ISO 834) and curves according to external fire.

The curves are indicated in Fig. 1 (1 = hydrocarbon curve, 2 = standardized curve, 3 = slow heating curve, 4 = external fire curve, records of loading = max. 1049 °C and max. 680 °C and max. 750 °C).

Nominal standardized curve was derived for a fire in the underground structures. It is therefore used for assessing the fire resistance of tunnels, which has the lowest speed of heating.

As a result of spalling of concrete, the furnace was turned off earlier (at 750 °C).

After reaching the maximum temperature the heating was finished in all cases and there was a spontaneous temperature decrease down to laboratory temperature.

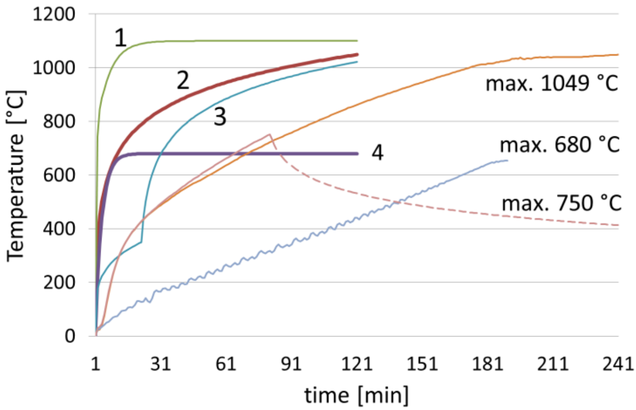

Fig. 1: Temperature curves

3.4 Loading by local fire

Loading by local fire took place at the broken chips of prisms, previously used during the test, flexural strength. Adjustable propane-butane burner was aimed into the centre of each loaded fraction prisms. Again there was an effort to get them closer to model fully developed fire, namely the description of the nominal standardized curves.

The temperature was measured at the exposed points on the surface exposed to the fire and on the surface indisposed from fire (records of loading LC No. 3 – see Fig. 2, Fig. 3).

Residual compressive strength was determined after spontaneous cooling.

After that compressive strength was converted to the basic cube dimension (150 x 150 x 150 mm), based on the experimentally expressed conversion factors ($\kappa_{c,cube,i}$) of particular mixtures.

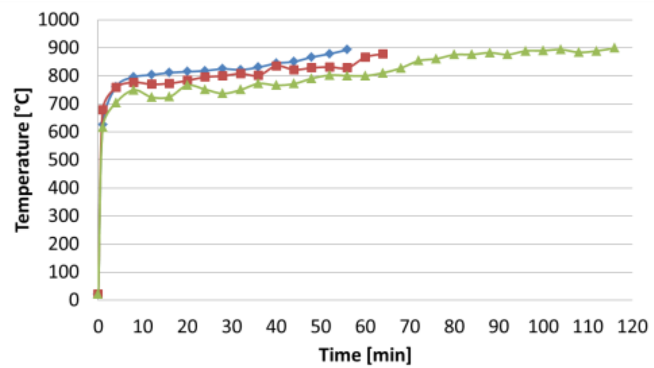

Fig. 2: Temperature on the surface - heating

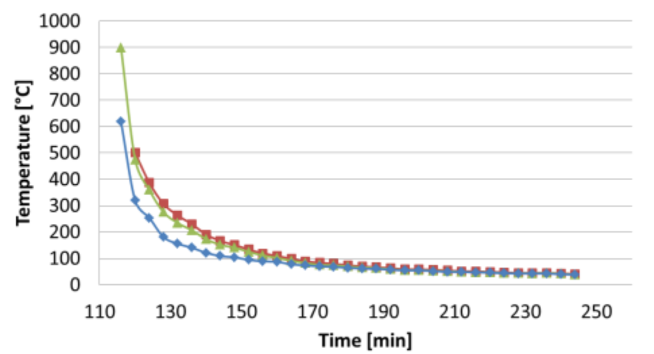

Fig. 3: Temperature on the surface - cooling

4 Conclusion

The aim of the experiment was to expose specimens to effects of a fully developed fire and compare the resistance of selected concretes. The fire effect is manifested by structure disturbances - scrolled edges or corners.

4.1 Testing in the furnace

Based on the experimental work conducted so far, we can say that explosive spalling occured (except a prism SYN2) only with samples of steel fibre reinforced concrete (total of 4 cubes, 2 cylinders and 1 prism) at high solids loading by high furnace temperature due to internal stress and pressure of steam in the wet concrete (see Fig. 8, Fig. 9 and Fig. 10).

On the other hand concrete „Comb25/30“ is supplemented by a combination of steel wires and polypropylene fibres (at dose of 2 $kg.m^{-3}$). In this case, it was confirmed that explosive spalling will not happen.

The percentage decreases in strength compared to the reference (ref = unloaded) samples of concrete are shown in Fig. 4, Fig. 5, Fig. 6 and Fig. 7.

The most significant differences between the reference densities and the thermally loaded samples appeared in lightweight concrete. This was probably caused by the use of artificial porous lightweight aggregates.

Tests do not confirmed the lowest loss of strength in samples of alkali activated materials. it would need to make more test specimens from this material.

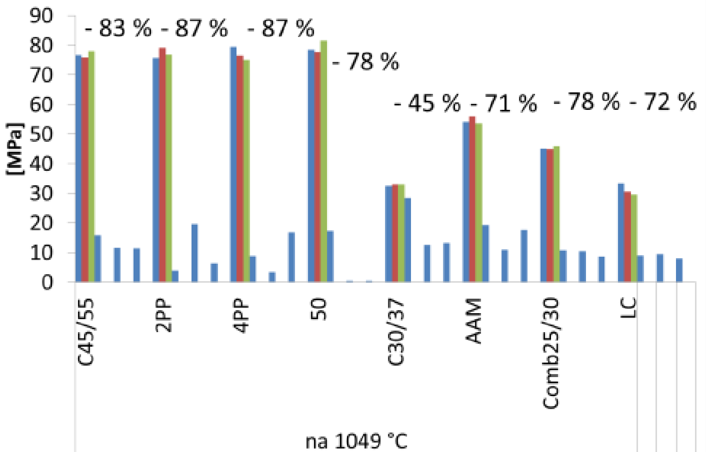

Fig. 4: Compressive strength, max 1049 °C

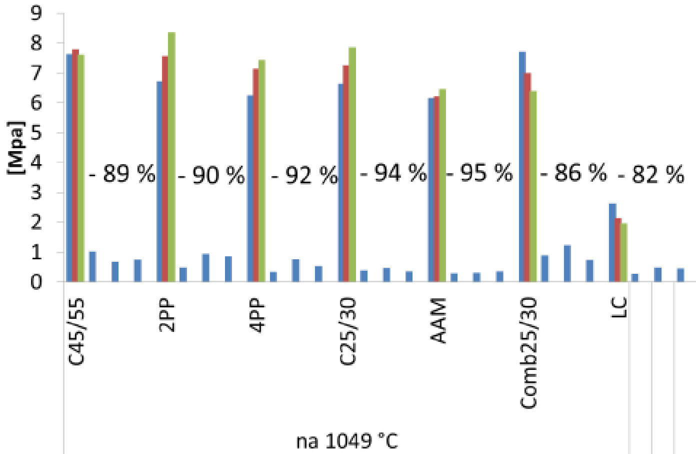

Fig. 5: Flexural strength, max 1049 °C

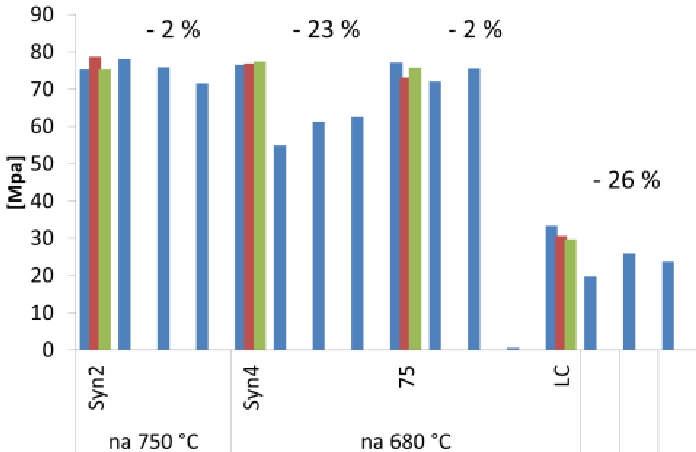

Fig. 6: Compressive strength

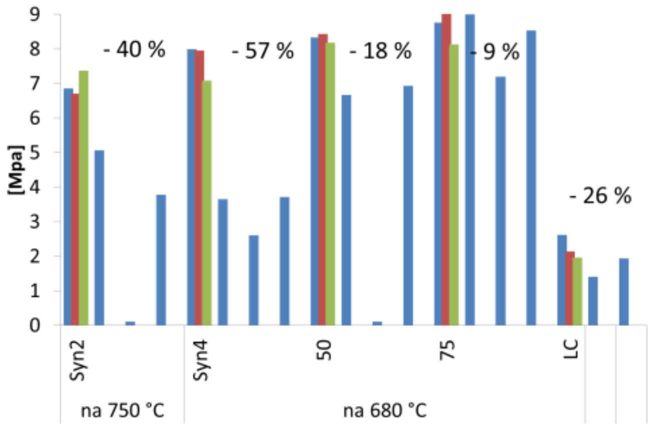

Fig. 7: Flexural strength

4.2 Testing by local fire

When loaded by the local fire, all specimens were subjected to considerable internal stresses due to uneven temperature distribution over the cross section.

Breach occurred on the heated side of the test samples.

Superficial layers of concrete of the of 50 x 50 mm were cleaved with the sample Syn2_1. Amazingly, the spalling occurred within two minutes after the start of loading.

The increased thermal insulation is confirmed with lightweight concrete. The maximum temperature recorded on the unheated side was on average by 42 % lower than with the samples of concrete C 45/55 and it was 52 % lower than with the simple concrete C 25/30.

In case of samples with added polypropylene fibres firing fibre was seen within the first minutes. Tests confirmed melting of synthetic fibres at about 160 °C.

The most significant condensation of water vapour resulted in samples with added macro fibres - "Syn" and in samples from alkali activated material.

Fig. 8: Cylinder „25“ (max. 1049 °C)

Fig. 9: Cube „50“ (max. 1049 °C)

Fig. 10: Prism „50“ (max. 680 °C)

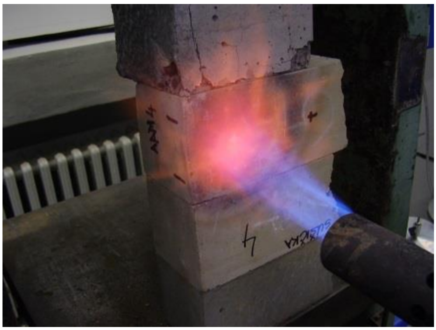

Fig. 11: Testing by local fire

The percentage decreases in strength reduction compared to reference samples are shown in Fig. 12 and Fig. 13. It is apparent that the reduction is not so significant as compared to heating in the furnace.

Currently we finalized testing hardened concrete, namely determination of secant modulus of elasticity in compression.

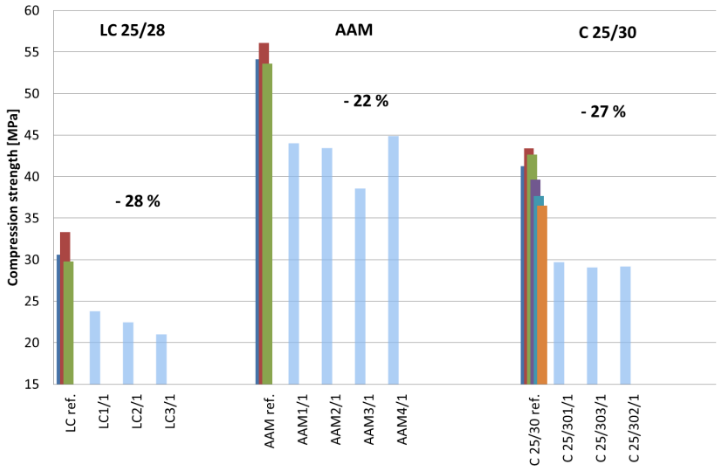

Fig. 12: Compressive strength after loaded by local fire

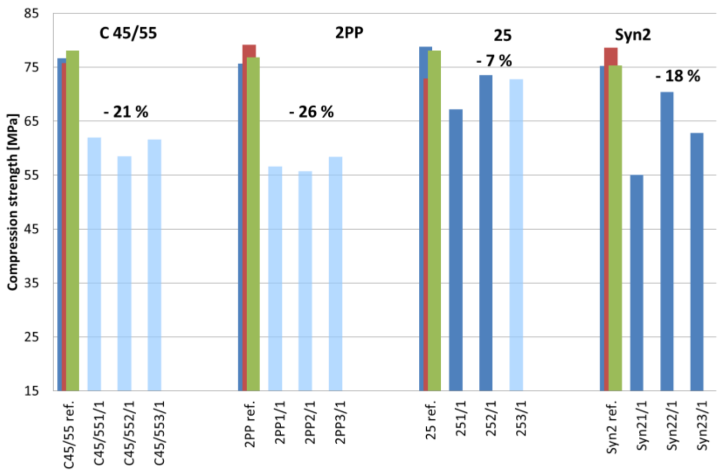

Fig. 13: Compressive strength after loaded by local fire

5 Acknowledgment

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RESEARCH IN AREA OF PHOTOVOLTAIC FEEDING OF LIGHT RAILWAY VEHICLE

Petr Sýkora[1], Jaroslav Novák[2]

Abstract: This paper describes research activities, that do Department of Electrical and Electronic Engineering and Signalling in Transport in area of photovoltaic feeding of light railway vehicle, the biggest part is focused on experimental part of this research.

Key words: photovoltaic panel, rolling stock, LRV.

1 Introduction

Passenger and freight transport around the world consumes more and more energy – the biggest part of it is covered by crude oil products, so it has quite adverse reaction for environment, economic impacts of this addiction is negative too. Rail transport is a little bit more environment – friendly, because big part of main railway lines use electric traction - the electric energy for this lines is produced in mixture of electric station, where heat, nuclear and renewable energy sources are used. Low movement resistance, using integrated trains and regeneration during braking make transport on this lines more ecological and economical, than other kinds of transport.

Problem of electrical feeding is on regional railway lines – it is not possible to use their electric traction, because the costs are huge in comparison to incomes. Solution of this problem is using electric traction with battery feeding. Tempting possibility of this solution is to use photovoltaic panels directly on vehicle roof as some kind of energy saver of this vehicle. This paper shows experimental research, that is done at Department of Electrical and Electronic Engineering and Signalling in Transport in this area.

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2 Experimental vehicle

In our research we lay stress on experiments – as an experimental base we use our experimental railway vehicle, that is shown at Fig. 1.

Fig. 1: Experimental railway vehicle

This vehicle has gauge 600mm and own weight 2100kg. The traction drive, supplied from Li traction battery 96V/100Ah, is realised by four PMSM, that drive without any gears four wheels, maximum traction power is less, than 10kW.

Block diagram of power traction circuit is shown on Fig. 2.

On the main DC bus is connected everything – charger, that allows charging from electrical net, photovoltaic generator, traction accumulator battery, four traction drives and finally inverters for auxiliary consumption.

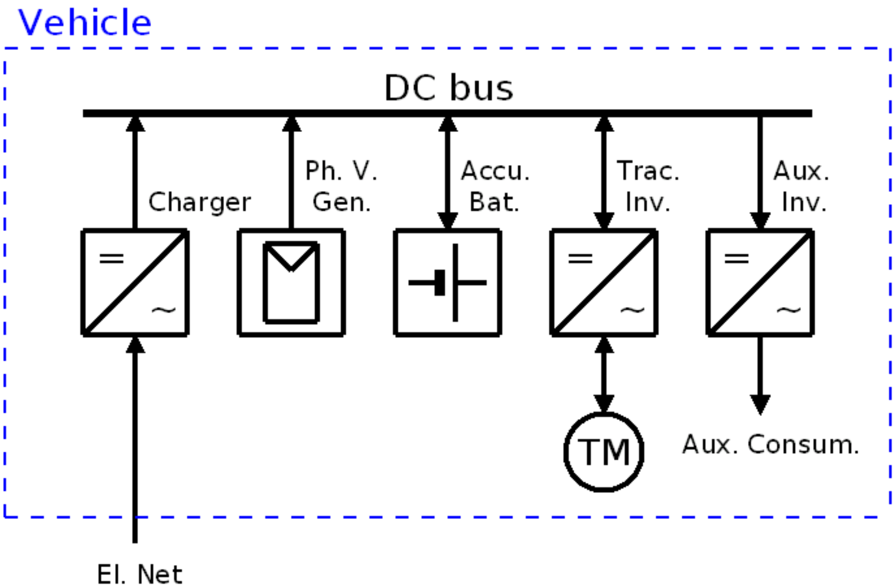

Fig. 2: Block diagram of traction power circuit

Photovoltaic generator, placed on roof of the vehicle, consists of four photovoltaic panels Panasonic VBHN240SJ25 with maximum power Pmax 240W each according to standard test conditions. The couples of them are serial connected together and only through separation diode connected to main DC bus – there is no inverter between the photovoltaic generator and battery, This method of connection is quite simple, but no maximum point tracking is realized, only the voltage of traction battery is set to characteristics bend of photovoltaic generator by number of traction battery cells.

3 Results of experimental research

Now the vehicle and measurement system is operational. On Fig. 3 are one of the first measured data from drives at Mladejov industrial railway line – this data was measured on 28.7.2015 during sunny weather, so get maximum output of photovoltaic generator about 0,75kW is probably maximum real possible output.

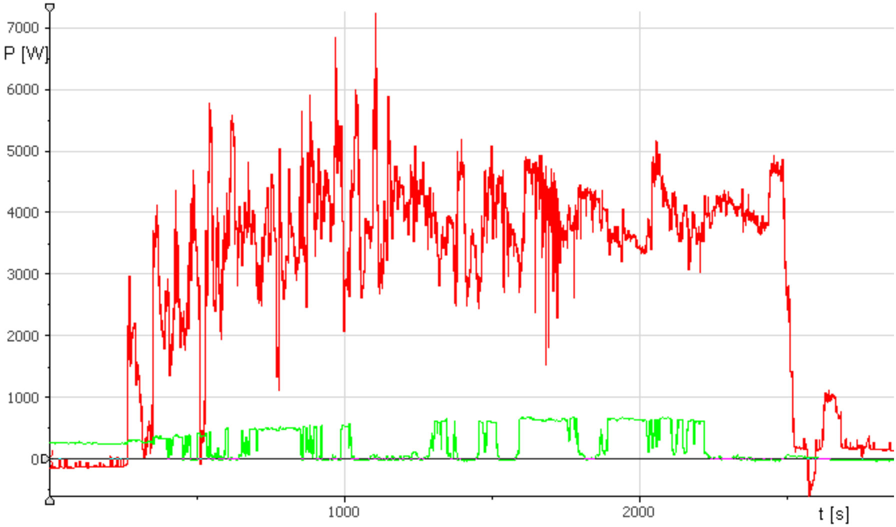

Fig. 3: Traction power (RED) and power of photovoltaic generator (GREEN) during one of the first testing drives

In comparison to traction power – maximum 7kW – it is not enough. But as I wrote at the beginning, this conception is planned as a ‚energy saver‘, not as a main power supply. In this way, it seems, that it will have significant impact.

4 Conclusion

Now we are planning to do many measurements and explore real impact of many external condititons - such as temperature, real sun energy and depth of battery dicharge – on real energy gain. The measured data will be statistical analyzed. The final outcome should be real energy influence modelling for using photovoltaic generators on railway rolling stock roofs.

Summary: This paper describes research activities in area of photovoltaic feeding of light railway vehicle, the biggest part is focused on experimental part of this research – the description of experimental railway vehicle, its electrical equipment and first measured data. The conclusion sets direction of next research activities.

ANALYSIS OF BEHAVIOR OF RAILWAYS TRACK SUBSTRUCTURE

Aleš Šmejda[1], Bohumil Culek[2], Filip Ševčík[3],

Abstract: In this paper we discuss experimental measurements of pressures in the substructure of railway track on the railway line Pardubice hl. n — Jaroměř. In preparing the experimental measurement of pressures in the substructure of railway track were carried out using the findings from the strain gauge measurements and for extracting data from experimental measurements were fitted with strain gauge sensors in the substructure of railway track.

Key words: monitor pressures, tensometric measurement of pressures, sampling frequency, soil mechanics, temperature measurement, substructure of railway track, pressure measurement, experiment

1 Introduction

Mounting tensometric indicators on the railway line Pardubice (main station) – Jaroměř was carried out in cooperation with Railway Transport Administration and Chládek a Tintěra company, Pardubice a.s. in November 2010. Place which was chosen for floor pressure analysis lies nearly 574 m far from the dispatching building of Stéblová railway station in the direction Pardubice – Rosice nad Labem on an electrified rail. Superstructure here consists of a contactless track and a rail of shape R65 fixed to concrete sleepers SB 8P by means of an assembly sort K. Detailed description with a technical specification is to be found in the chart n.1. On the basis of carried out numerical analysis the pressure indicators were placed into the substructure body in three vertical levels and altogether 5 indicators were placed in each level.

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Tab. 1: Technical specification

Railway	Pardubice hl. n. - Jaroměř (TTP) 505c
TUDU	1612B1
The stationing [km]	9,032
Class trackside load	D4
Order Railway	4
Railway speed [km/h]	100
Directional and height ratios	direct
Station track	number 1, main rail
Traction lines	3 kV DC

2 Description of the measured spot

Considering the fact that these indicators were put into one In the third layer of vertical level -1,085 m under the bottom loading area of the sleeper, the indicators S12,S11, S1,S20 a S15 were laid. Each indicator was fixed into a bed and covered up with siliceous sand PR30/31. Everything was made according to the rule of geometric analogy of a model and reality, where in the spot of an indicator there must be the same conditions as during laboratory calibration of used indicators.

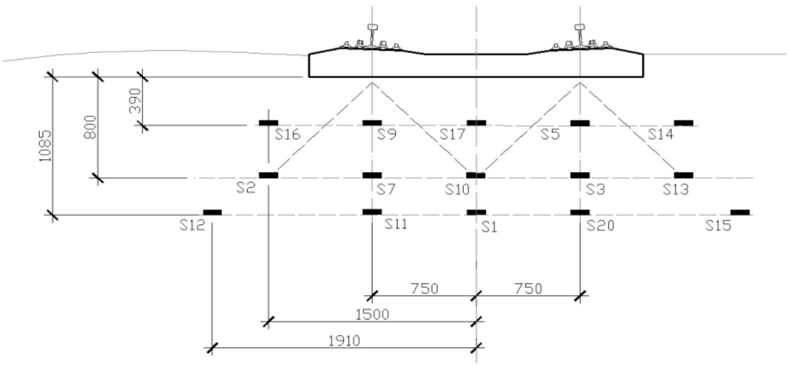

Fig. 1: Detailed description of pressure indicators placement

After fixing all the five indicators into the profile there followed ground bashing by means of a vibratory rammer NTC NT – 65 and a vibratory roller Stavostroj VVW 3400. The second layer of indicators S2, S7, S10, S3, S13 lies in the hight of 0,8 m and the first layer of indicators S16, S9, S17, S5, S14 lies in the hight of 0,39 m under the loading area of a sleeper. All the shielded cables were protected against machanical damage by protective pipes Kopoflex 40. Detailed description of pressure indicators placement is shown in the picture Figure 1.

3 Description of the Tensometric force sensors

Pressure tensometric indicators consist of two parts. Bottom and top parts of the indicator were made of stainless round steel Ø 80 mm. After turning out the exact shape of the indicator, threads for screws were drilled and carved in the border. They enabled creating a firm joint of bottom and top part of the indicator into one unit. In the joint of both areas there is a gasket that hermetically seals the indicator. In the inside area of the indicator there were stuck tensometres of type 6/120LY11 with a linear grid, carrier – polyamide, grid – constantan, grid resistance 120 Ω. For attaching tensometre on stainless parts of the indicator, cyanoacrylate glue Z70 was used (low hysteresis order of points from the total measured deformation value). Indicator instability from the point of view of temperature influence is eliminated by compensatory tensometres. There are two active tensometres in one indicator, first on the bottom part and the second on the top part of the indicator and two compensatory tensometres, each of them thermally compensates one active tensometre. Outlets of tensometres into the measuring chain were connected on a terminal block by soldering with a soft solder. Tensometre connection in the indicator is made as a full Wheatston bridge. Interconnection between indicators and a logger is realized by means of six-core shielded cables of type P1-CABA1/100. All the active parts are protected by silicone rubber. For the evaluation of a response from tensometric indicators is used a dynamic logger from the company Hottinger Baldwin Mestechnik of the type DMC Plus. The logger contains on the whole 20 measuring channels which are parallelly connected through a busbar with the central processing unit. It is possible to select measuring speed up to 9600 scanned values per second. Input data are passed into the inside busbars of the device where they can be digitally filtred, linearized or processed by mathematical function. Digital filtres can be switched off or set up for the mode of floating or arithmetic average, exponential filter or rounding. Maximum accuracy of measurement is 20 bits. If it is not possible to transfer measured data from the device in on-line mode, we can record them into data memory with the capacity of 500 000 measured values. Signal scanned by the logger was processed in the program BEAM-DMC made by AMS producer. For interconnection with PC there was used standard interface RS-232 or RS-485.

4 Laboratory calibration of indicators

Each tensometric indicator was calibrated in the laboratory of The Highway Construction Department before fixing into measured profile. Deformational sensitivity dependence was determined for every indicator with statistic check. All the process of calibration was carried out by gradual loading of indicators in several cycles. At the beginning of the whole calibration process the tensometres were zeroed and relevant resistance values were set up. Calibration itself ran for each loading state separately and it was possible to observe the loading progress directly on tensometre outputs. For calibration it was used a steel cylinder of 400 mm diameter and 800 mm hight with a firm bottom, where there was developed necessary power on solid top board of the calibration container through a compound lever.

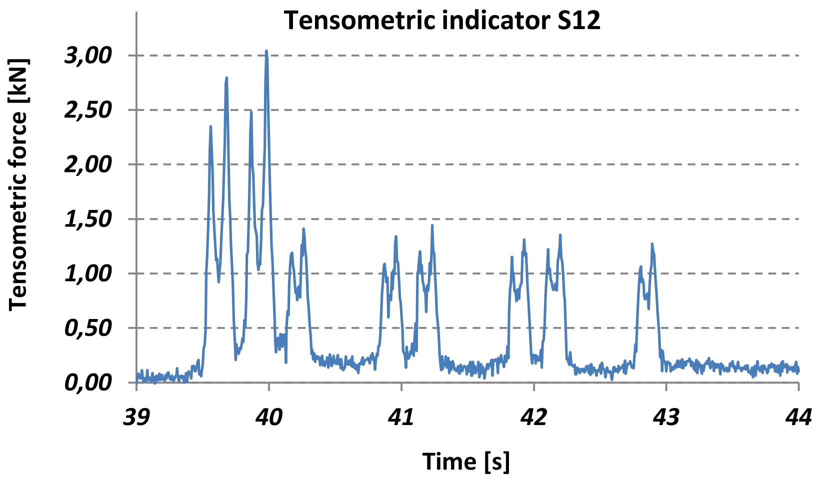

Fig. 2: Example sensor S12, 163 [CZ-ČD] + 3 Bdtn / Bdtn [ČD]

This board developed necessary pressure on the indicator, which was laid into siliceous sand PR30/31 with exactly defined granulation curve. The indicator was laid in half hight of the cylindrical container, which is 400 mm from the bottom. Desired changes of pressure were determined from the change of resistances by given values from calibrating curves of individual indicators.

5 Results of measurement

Tensometric measurement of pressures was running in regular intervals on the basis of elaborated measuring method. Individual cabels from indicators are permanently laid in a shaft which lies about 8 metres from the track axis. During a preparation of measuring itself it was necessary just to gauge indicators with cables and to treat connectors against corrosion. After connecting individual connectors to the logger, parameters of indicators were set up on the basis of carried out calibration. For the successful process of measuring itself it was necessary to ensure failure-free function of all elements of the measuring chain including measurands indication also from the point of view of chosen way of measuring results processing.

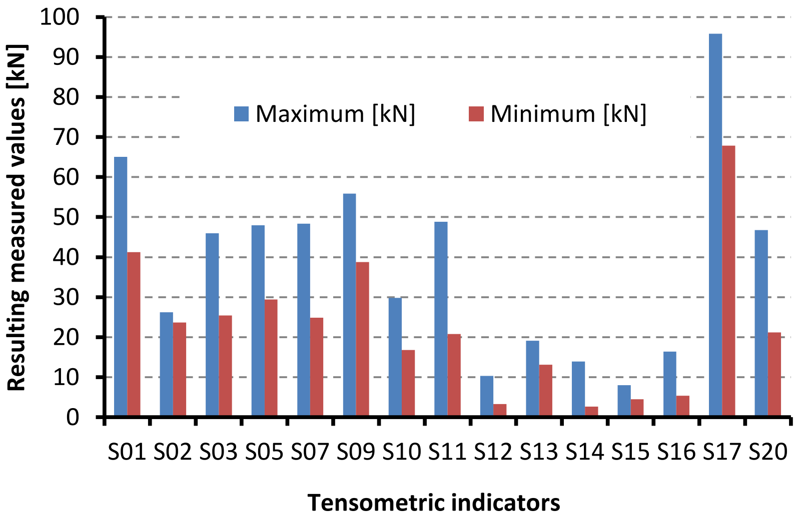

Fig. 3: Resulting measured values

Measuring chain is composed of a tensometric pressure indicator, a logger (A/D converter), a personal computer for recording and processing measured data. Sampling frequency was chosen 150 Hz with the use of a manual recording start with recording length 180 seconds. In the selected spot of measurement there were scanned transits of fast trains, passenger trains and also express trains.

Evaluation of the response of pressure tensometric indicators was carried out for composition of propulsive and tractional vehicles which run regularly on the railway line Pardubice (main station) – Jaroměř. From the results of pressures recorded on the indicators it is possible to define an interval of resulting measured values which are summarised in the chart n.2. Dispersions of measured pressure values on the indicators in individual layers of substructure body are necessary to attribute to different speeds of sets of wagons during their passing through the measured spot and also to technical states of vehicles and also to the quality of substructure and superstructure.

6 Conclusion

From monitored values of train transits with HV ř. 163 (in approximately equal thermal conditions) there was carried out an analysis of dependence of measured values of pressure in the sleeper bed on the speed of a passing vehicle. However, by this analysis from so far taken measurements there wasn´t found any significant dependence of pressures in a sleeper bed on the speed of a passing vehicle. Nevertheless, these results are still very preliminary, because the fact that follows from the location of a measuring spot is that trains pass through it at quite similar speeds, specifically from about 80 to 100 km/h and the difference is relatively very small to state a conclusion from these specific measurements about significantly increasing pressures in sleeper beds at increasing speed of vehicles on a track of so called classical construction.

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Summary

Measured data will be a base for creating another measuring spot in cooperation with SŽDC,s.o., probably in station parent tracks or main tracks on the railway line between Pardubice and Česká Třebová. This spot will be selected with the goal to monitor pressures in a sleeper bed also at higher speeds of passing vehicles than so far (that is higher than 100 km p/h).

SUSTAINABILITY ON REGIONAL RAILWAY LINES

Martin Šustr[1], David Hrdý[2]

Abstract: The Article deals the possibility of renewal of mixed trains in Czech Republic. The Article mainly solves the economic evaluation of the mixed trains operation.

Key words: Mixed train, freight transport, passenger transport, costs per km

1 Introduction

The railway transport is the most effective in the carrying of larger volume of goods in comparison with road transport. If it transported smaller quantity of goods (to 50 tons) railway transport is not such profitable. In the history (turn of 19th and 20th century) was existed for this types of transports the system of mixed trains. But this system can't be overtake without changes. The historical system was very effective but mixed trains were slow and it was for passengers very uncomfortable.

For renewal of this system is necessary to make changes in the old system. Especially mixed train can't prolong the travel time of passenger train.

With higher operability and lower costs, the mixed trains could create the new and interesting business segment for rail freight operators.

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2 History of Mixed trains

In the Czech Republic mixed trains operated on regional lines from the beginning of railways to the year 2004. After this year the state railway operator was fractionalized from unitary railway company to the more transport companies and railroad operators. The transport company was separated to the freight operator and passenger operator. This step greatly reduces the possibility of recovery and develops of mixed trains.

3 Conditions for renewal of mixed trains

3.1 Problems during renewal of Mixed Trains

The System of Mixed Trains is good system for saving financial cost and for lower ecological burden. But this system is not useable for all regional lines. On regional lines with big transport streams (it means rail lines with 60 minutes tact with enough passengers using in the saddle times too) mixed trains are unfit. Mixed trains caused longer travel time and on track with enough passengers is not possible going with longer travel time[3].

For mixed trains is appropriate using diesel single railcars or diesel multiple units or electric multiple units with sufficient power effort (for operation without goods is good for acceleration).

For renewal of mixed trains in Czech Republic will be good inspiration in the abroad (especially in Switzerland or Austria). In these countries the System of Mixed Trains is in operation on the some private railway lines.

Abroad railway lines with operation of mixed trains

[3] This problem is not in long-distance transport and express delivery of goods. But this paper solving mixed trains only on regional trains.

The mixed trains are in the operation still on the Montafonerbahn (MBS) in Austria, Rhätischebahn (Rhaetian railways, RhB). MBS is operated with mixed trains on line from Bludenz to Schrunz in west Austria. RhB operated with mixed trains on all of their net except commuter trains near Chur in Switzerland. The both of companies have different approach for mixed trains operation. On the net of RhB all trains have longer travel time (but it is not only for mixed trains, it is like prevention for autumn and winter too). MBS operated with mixed trains only in saddle times (only train at 9:04 from Schrunz to Bludenz and any train in the opposite direction).

In the Czech Republic is more appropriate the MBS system, because the only one train (one pair of trains) must have longer travel times caused by cargo wagon. Furthermore advantage of this solution is there could be a Just in Time technology without addition activities.

3.2 Vehicles for mixed trains hauling

In the Czech Republic on regional tracks are mainly used diesel single railcars or diesel multiple units. Electric multiple units which operated in Czech Republic are not suitable for regional lines with low passenger flow. Last not least disadvantage of electric multiple units in the automatic Scharfenberg coupling. For technology of mixed trains is easier using vehicles with classic buffers and towing hook.

Until 2004 was for mixed trains used the diesel single railcar class 810. This vehicle has a lot of disadvantages for example it has low power output (only 155 kW on 20 tons and only one driving axle) and it is already outdated (production between 1975 and 1982). On the other hand this vehicle was verified for mixed trains in practical service. Class 810 have classic UIC coupling (buffer and towing hook) for hauling other vehicles.

Fig. 1: Mixed train before 2004 (hauling by class 810)

As a substitute of class 810 was invited diesel multiple unit class 814-914. This diesel multiple unit is reconstruction of class 810. This class of diesel multiple units has same disadvantages (only one driving axle and 242 kW on 39.6 tons) like a class 810. This multiple units are not such suitable for mixed trains.

The better choice for operation with mixed trains is the Regioshuttle RS-1. These diesel single railcars operated in the Czech Republic like a class 840. This class of diesel single railcar has sufficient power and four driven axles. This multiple unit is suitable for the Mixed Trains operation.

In the table “Tab. 1” is selected parameters of vehicles which are suitable for mixed trains.

4 Calculation of mixed train of selected track

For a model example was chosen line from Lichkov to Štíty on the border of Bohemia and Moravia. This line was chosen because there is one end with dead end, low population density and bad road infrastructure in this area furthermore on this track is not use interval timetable (it is good for longer travel time of mixed train). For calculation was chosen diesel single railcar class 810 and diesel single railcar class 840 on this track. The calculation is based on public available data and the real cost can be different. But ratio of cost is a same.

Tab. 1: Comparison of class 810 and 840

	Class 810	Class 840
Years of production	1973 – 1982	2011
Number built	680	33
Capacity (seats)	55	71
Length	13 970 mm	25 500 mm
Maximum speed	80 km/h	120 km/h
Weight	20 t	48 t
Axles / driven axles	2 / 1	4 / 4
Power output	155 kW	2x 265 kW
Traction	29 kN	29 kN
Transmission	Hydromechanic	Hydromechanic

4.1 Economic calculation for class 810

Diesel single railcar of class 810 is a low cost option. The operation of this railcar is very cheap (low fuel consumption, no depreciation, easy maintenance). For Freight train is calculated with diesel locomotive class 742 (which is often using for shunting and local freight operations). The calculation of cost is in the table "Tab. 2".

Tab. 2: Cost of Mixed train hauling by railcar class 810

Train category	Passenger	Mixed	Freight
Costs of using the infrastructure	23.27 €	74.32 €	73.21 €
Costs of energy (diesel)	24.00 €	48.00 €	53.66 €
Residual value of vehicles	18 181.82 €	18 181.82 €	54 545.45 €
Cost of operation (depreciations and service)	34.53 €	68.49 €	15.86 €
Days of operation	252	252	252
Cost of staffs	26.24 €	50.00 €	106.00 €
Overhead costs 20 %	21.61 €	48.16 €	49.75 €
Total costs per journey	**129.65 €**	**288.97 €**	**298.47 €**
Costs of train per km	**2.95 €**	**6.57 €**	**6.78 €**

4.2 Economic calculation for class 840

Diesel single railcar of class 840 for passengers is modern and comfortable. For mixed trains it has high power output. On the other hand class 840 has high purchase cost and depreciation. In the table "Tab. 3" is calculation of cost for mixed trains which is operated by class 840.

Tab. 3: Cost of mixed train hauling by class 840

Train category	Passenger	Mixed	Freight
Costs of using the infrastructure	24.38 €	75.55 €	73.21 €
Costs of energy (diesel)	39.00 €	58.50 €	53.66 €
Residual value of vehicles	1 963 636.36 €	1 963 636.36 €	54 545.45 €
Cost of operation (depreciations and service)	95.10 €	112.08 €	15.86 €
Days of operation	252	252	252
Cost of staffs	26.24 €	50.00 €	106.00 €
Overhead costs 20 %	36.94 €	59.23 €	49.75 €
Total costs per journey	**221.66 €**	**355.36 €**	**298.47 €**
Costs of train per km	**5.04 €**	**8.08 €**	**6.78 €**

The graph “Fig. 2” and table “Tab. 4” show the comparison of cost on the two models of transport (classic transport by passenger trains and Freight trains or Mixed Trains). In the graph are both of railcar classes.

Tab. 4: Results and Comparison

Vehicle	810	840
Increased costs of passenger operator	133.55 €	133.70 €
Costs of Freight operator (increased about 20 % for passenger operator)	160.25 €	160.44 €
Costs per km	3.64 €	3.65 €
Savings of Freight operator	138.22 €	138.03 €
Savings of Freight operator per km	3.14 €	3.14 €
Savings of freight operator per year	34 830.60 €	34 784.66 €
Total savings (undistinguished subject)	164.92 €	164.77 €
Total savings per km	**3.75 €**	**3.74 €**
Total savings per year	41 561.29 €	41 523.01 €

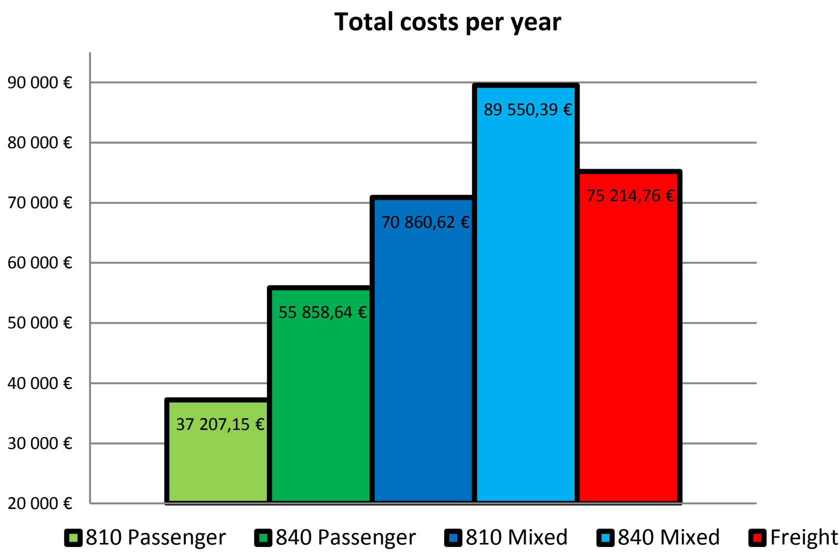

Fig. 2: Comparison of passenger, freight and mixed train (total cost per year)

5 Conclusion

The mixed train is solution for railway lines with low transport flows in passenger transport and in freight transport too. Very important is fact, that technology of mixed trains is not solution for all regional railway lines (due to longer travel times for passengers).

This article is based on diploma thesis of author. In the thesis are describe other conditions of implementation of mixed trains. This article solves only economic part of the mixed train operation because other problems about the mixed trains operation are very wide.

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THE DEVELOPMENT OF E-COMMERCE IN EU AND THE CZECH REPUBLIC AND LINKAGE TO DISTRIBUTION OF GOODS TO CUSTOMERS

Libor Švadlenka[1], Daniel Salava[2], Petra Juránková[3]

Abstract: This article is focused on current situation of e-commerce in the European and Czech environment. It deals with contemporary issues and e-commerce capabilities to their solutions. It also monitor the importance of distribution of ordered goods for future development of e-commerce and it also analyses existing distribution models used by e-shops, carriers or independent mediators for distribution of ordered goods related to future trends in this area.

Key words: e-commerce, e-shop, carrier, parcel machine, distribution.

1 Introduction

According to the Commission staff working document dealing with the A Digital Single Market Strategy for Europe's cross-border e-commerce an important element because it allows citizens and businesses to benefit from a wider range of goods and services and lower prices through increased price competition (ie the possibility to purchase goods or services, that better responds to the desires of consumers). Businesses benefit from cross-border e-commerce by exploiting economies of scale which reduce costs, increase efficiency and promote competitiveness, improving total factor productivity. [1]

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It is estimated that consumer welfare gains from e-commerce in goods in an integrated DSM (Digital Single Market) could reach over EUR 200 billion, with two thirds of these gains coming from increased online choice. [1]

Interesting facts derive from A Digital Single Market Strategy for Europe from 2015 such as that EU consumers could save EUR 11.7 billion each year if they could choose from a full range of EU goods and services when shopping online, 61 % of EU consumers feel confident about purchasing via the Internet from a retailer located in their own Member State while only 38 % feel confident about purchasing from another EU Member State and only 7 % of SMEs in the EU sell cross-border. Nevertheless consumers in smaller Member States have a greater tendency to cross-border shopping, because the local supply and variety is limited and lower cost deals can be found across borders. [2]

One of the reasons why consumers and smaller companies do not engage more in cross-border e-commerce is because the rules that apply to these transactions can be complex, unclear and may differ between Member States. In Europe namely exists 28 different national consumer protection and contract laws which discourage companies from cross-border trading. Some aspects of consumer and contract law have already been fully harmonised for online sales (such as the information that should be provided to consumers before they enter into a contract or the rules governing their right to withdraw from the deal if they have second thoughts). However, other aspects of the contract (such as what remedies are available if tangible goods are not in conformity with the contract of sale) are only subject to EU rules providing minimum harmonisation, with the possibility for Member States to go further. If the same rules for e-commerce were applied in all EU Member States 57 % of companies say they would either start or increase their online sales to other EU Member States. [2]

One of the other problems according to stakeholders, are the high costs for small consignments. For example 62 % of companies claim that transport costs are too high. The tariffs for cross-border parcel delivery charged by national postal operators are estimated to be two to five times higher than domestic prices. The further steps to increase cross-border e-commerce will be the harmonization of core rights and obligations of the participants of the purchase contract or faster, agile and consistent enforcement of consumer purchases online. The Commission also plans to submit a proposal to clarify and develop the powers of law enforcement agencies and improve coordination of their activities and market monitoring warning mechanisms to detect breaches quickly. The Commission will launch complementary measures to improve price transparency for European deliveries, including for prices of small shipments, and to enhance regulatory oversight of the cross-border parcel markets to ensure well-functioning cross-border delivery. [2]

From the overview it´s clear that the digital market (e-commerce) is developing and has great potential, despite the problems (especially cross-border service) that have been mentioned.

2 E-commerce in the Czech Republic

In the beginning it is necessary to state that Czech e-commerce is in very good condition. The European e-commerce had successful year according to the Association for Electronic Commerce (APEK) in collaboration with the European Association of Ecommerce Europe. In 2014, it achieved a turnover of sales over the Internet to EUR 423.8 billion, which represents an increase of more than 14 percent over the previous year. EU countries amounted to EUR 368.7 billion, of which Czech Republic approximately EUR 3.1 billion which is over 80 billion crowns.

While in 2009 the e-commerce participated in the Europe-wide GDP of 1.27 %, in 2014 it had fallen to 2.45 %. Given the expected further growth with the support of the European Commission online sales could reach up to 6 % of European GDP in 2020. Currently the e-commerce directly and indirectly provides employment almost 2.5 million of Europeans. [3]

But the Czech e-commerce market is not important because of amount of the turnover but before all because of the unbelievable number of active e-shops (about 35 000).

But this even in international matching huge number includes also small and very small e-shops, provided only as source of extra money with turnover about tens of thousands Czech crowns per year. These small e-shops contrast with the biggest with turnover in milliards of Czech crowns as Alza.cz or Mall.cz are. Alza.cz, the seller of electronics with more than 3 million orders and 9,2 million of Czech crowns strengthen its leader position on the market. From the turnover point of view is the second biggest player on the Czech e-commerce market Mall.cz. The mother company of Mall.cz reached in fiscal period 2013/2014 with total turnover 8 milliards Czech crowns. On other places are travel agency Invia and seller of electronics T.S. Bohemia with return on the level 2 milliards of Czech crowns and another seller of electronics CZC.cz with return 1,75 milliard of Czech crowns. APEK and buying guide Heureka.cz also indicated that consumers bought goods over the net worth of 67 billion crown in 2014.

2.1 The satisfaction of customers

In the Czech Republic were implemented the research of the satisfaction of customers with the distribution of goods (for example Heureka.cz, 2014/1 and 2014/2). From these research shows:

- 82 % of 2,000 respondents evaluated e-shop by the quality of service,
- for up to 90% of the customers is an important choice of different distribution alternatives,
- 93% of respondents are satisfied with the services of carriers implementing the distribution of the goods ordered,
- the customers have the greatest awareness with PPL and a Czech post (55 and 30%).

For example, research conducted by APEK showed that the respondents to the carrier chosen primarily on the basis of the prices (31%), services offered according to the specific order (24%) and previous experience (23%). On the contrary respondents are ready to pay extra money for following services: bear the consignment to chosen floor (41 %), transportation of old appliance (39 %), installation of product (39 %) and delivery during weekends and holidays (25 %). But on the other hand the research also showed that Internet traders think that their customers would prefer following extra services: evening delivery of goods, flexible change of delivery time and above mentioned weekend delivery of goods. [6]

Altogether we can say that the standard of ordered goods distribution to customers is in the Czech Republic on high level particularly because of existing high competitive environment.

3 Current models of distribution of goods to customers

There will be summarised all alternatives of distribution of goods ordered by customers in e-shops, which could help the obstacles to cross-border e-commerce, which were outlined in the introduction.

3.1 Usage of carriers services

The most traditional way of distribution of ordered goods is of course delivery by the force of traditional carrier as for example the Czech Post or PPL are. But even these are forced to react on still growing requirements of customers. Therefor is nowadays quite common previous notice by SMS, phone or e-mail with information about incoming consignment in specific time interval with possibility of eventual change of place or time of delivery and in case of come carrier cash on delivery or payment by card. For example company DPD activated new web application “DPD Courier” in June 2014. This application eases double-sided communication between recipient of the consignment and courier because it unites functions of up to now offered functions of different communication channels.

Recently is for carrier typical effort to react on trend of growing gain in personal purchase of goods in time complying with customer needs. Typical representative of this trend is company PPL with own net PPL where customers can collect (but also register or swap consignments ordered in e-shop) their consignments (of course during working hours of PPL partner which sometimes means also during weekend). Similarly to PPL bought Geis company half share of company E-shop partner.

3.2 Logistic services of e-shops

Internet traders themselves are nowadays very active in the distribution of ordered goods area. They monitor customer behaviour and adapt of it. Their activities focus namely on:

a) Construction of their own subdivision net with possibility of consignment purchase (as example we can mention company Datart, Alza or Mall.
b) Alliance with partners and usage of their subdivisions for personal purchase of consignments (as example we can mention CZC with net of CZC partners which are regional sellers of computers and electronics with possibility of personal purchase of goods ordered by the force of CZC free of charge, Datart which enable to purchase small consignments nowadays

in Pont shops placed mainly on big railway stations and selling mainly food)

c) Building of own net with automatic purchase boxes (as example we can mention Alza which launched in May 2014 net of purchase boxes starting with 11 boxes placed in Prague).
d) Ensuring of distribution by own force (as example we can again mention Alza with express delivery in Prague by the force of own cars)

It is necessary to note that above mentioned possibilities are before all typical for big players in the market. The smaller ones have obviously one or two dispensing places and use dispensing places as for example "Zasilkovna" or "Ulozenka" are for to simulate the distribution net (as mentioned in chapter 3.3).

3.3 Using independent distribution nets services

More than 6000 e-shops cooperate with independent distribution nets. Smaller e-shops realize up to 40 % of their takings by the force of these nets. Biggest private net of dispensing places is above mentioned Geis Point (provided by carrier Geis) and Mediaprint & Kappa (distributor of printed material mentioned in the chapter 3.1). Other independent distribution nets are "Zasilkovna" (with "Z-points") and "Ulozenka". Some of them are only dispensing places, some of them enable to try goods or as filing place or mediate complaint of goods. Typical is nowadays effort to extend the net abroad, primarily to Slovak Republic.

3.4 Using parcel machines

Except above mentioned company Alza.cz which provides own parcel machines it is necessary to mention company In Time in this chapter. This company gained licence to provide post machines of biggest Polish private operator InPost in 2013. This net contains nowadays 100 parcel machines with consignments prepared to be removed next working day after order in e-shop. The Czech Post works on development of net of parcel machines since 2010. Has been activated 10 parcel machines after the trial run. Another 30 should be activated in the future. Consignments are generally deposited in parcel machines for three days and then for four days on specified subdivision (if nobody collect them). Collection of consignments is realized by the force of PIN code or QR code. Customer receives this code in SMS. Parcel machines enable also payment – cash payment (in first phase of the project of Czech Post parcel machines) or by payment card (as in case of parcel machines In Time and in second phase of the project of Czech Post) or there is no possibility to pay (as parcel machines of Alza) where payment on account is required. Parcel machines enable not only dispensation of consignments but in future also submission of consignments, telephone credit recharge, pay postal order (in case of parcel machines of Czech Post) or consignment refund (for example in case of In Time parcel machines).[5]

4 New models of distribution of goods

Except above mentioned possibilities, carriers and e-shops are still trying and plan to the future push into the praxis some new less traditional ways of distribution of goods ordered in e-shops to customers which may speed up or simplify of the delivery process.

Here we can also mention drones (known also as UAV - Unmanned Aerial Vehicle or according to ICAO rules RPA - Remotely Piloted Aircraft) used by Amazon to deliver consignments up to 2,3 kg which means overwhelming majority of Amazon orders (in concrete i tis 86 %) up to 30 minutes in gradient area of storehouse (which means about 16 kilometres). As general manager of the company Jeff Bezos says this method of delivery may be in operation in time horizon 4-5 years (this time is needed to gain all necessary permissions for commercial provide of these RPA – namely from Federal Aviation Administration).

Another example of new possibilities of goods delivery in so called “last mile” is the initiative of company DHL called “MyWays”. This initiative is based on possibility of delivery to customer by the force of private users of the system.

The principal is based on application MyWays installed in smartphone of the user that enables to register consignment addressed to him into the system which means assign DHL Truckong number, time and place of delivery and also price he is ready to pay for this service. The consignment is deposited in the DHL subdivision and is visible for all users of the MyWays system. They can now decide if they are ready to deliver this consignment (with given parameters as time, place and price are) on the way to work and earn this way some extra money. This system is tested in Stockholm since the end of 2013.[4] As another possibility the company DHL is testing rent of post boxes which may customer have placed near his house.

5 Conclusion

As follows from this article, the development of e-commerce in the Czech Republic and in Europe generally is faster than expected, specifically in the turnover of sales. Jan Vetyška (CEO APEK) concretely states that according to information from the first quarter of this year, it appears that growth in the Czech Republic reaches even higher values than originally expected. Compared to 2014, it registered about 18% growth. Still there are problems that need to be resolved, such as different national consumer protection and contract laws or the high costs for small consignments.

From this article also follows the importance of ordered goods distribution to customers is unquestionable. Customers want the quickest, cheapest and most flexible delivery and traders and e-shops are working hard to make the wish of customers come true because they wise up to importance of this factor as one of those that determine the choice of their e-shop. So in future we can look forward another improves in this area.

Acknowledgement

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INDUSTRIAL ROBOTS IN TRANSPORTATION

Jan Tlučhoř[1]

Abstract: With permanently growing volume transported material and increasing demands for transport speed, it is necessary to consider a certain automatization rate in this field, too. One possibility how to solve the automatization can be using of industrial robots.

Key words: industrial robot, Universal robots, automatization

1 Introdustion

With permanently growing volume transported material and increasing demands for transport speed, it is necessary to consider a certain automatization rate in this field, too. Of course, this field has already partially been automatizated. Beginning with delivery following, automatizated packets classifying up to automatical delivery of the parcel to the particular customer. This recent idea has recently come from an American internet shop called Amazon, which is testing small robotic unmanned helicopter for delivering of parcels up to 2,3 kg and at the same Amazon is fighting with the US legislative which bans commercial using of these machines. It is necessary to ask for a permission for every flight. However the aim of this study is to check the possibility of classical industrial robots setting, which we know from manufacturing factories. The robots are set there in production processes as substitution of human service. The robots do monotonous and pernamently repeating work there.

2 Analysis

In this case it was necessary to divide the analysis into tho parts. In the first part I was dealing with a survey in transportation and logistic field and following

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choice of places where it would be possible to substitute human service by an industrial robot. The result of this analysis was the finding that also in this field there have still been lots of permanently repeating operations, which have to be performed by humans. One of examples can be human service substitution at a post office at parcel or mail release.

In the second part it was necessary to analyse market with industrial robots.Surprisingly there is really huge competition in this field and all producers mostly offer the same or at least similar products portfolio. And that is the reason why I am interested in products by Universal robots company from a Danish city Odense.

3 Universal robots

Universal robots is a Danish producer of industrial robots. Although they haven't got any huge robots with load capacity of hundreds kilogrammes in its offer, I started to be interested in their products very much. I decided to use the robots for this study.

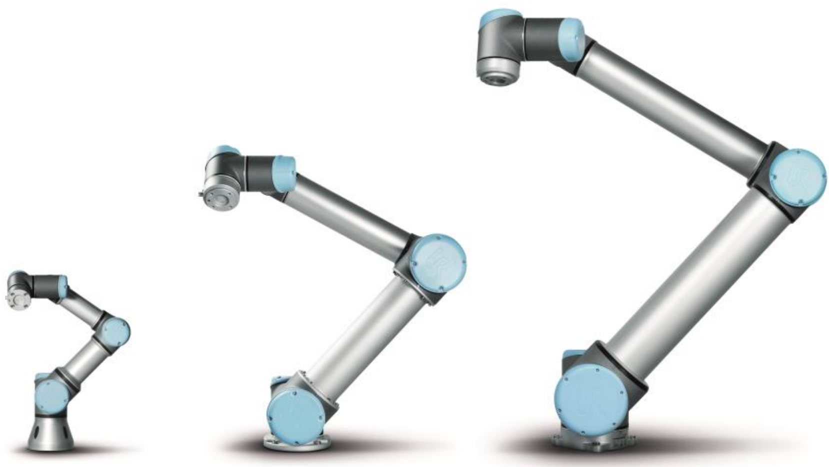

Fig. 1: Universal robots product range (UR3, UR5, UR10 from left)

3.1 History

Universal robots was established by three Danish cybernetics students, who had set a particular goal, based on the analysis of industrial robots market. Their goal was to develop a robot which would be light, safe, user friendly and which would be able to fill a gap at the industrial robots market. Their effort was crowned in 2003 when the Universal robots was set up and the first UR6 robot appeared. This robot became the first industrial robot in the world which obtained the ISO certificate and fulfilled the norm concerning cooperation between a man and machine.

3.2 Products

Universal robots has nowadays three types of robots on the market. The newest type which appeared on the market in the half of the year 2015 is called UR3. With its radius 500 mm, weight 11 kg and load capacity 3 kg it is the smallest one of these robots. In 2011 the biggest robot from this product serie called UR 10, appeared on the market. The UR10 has load capacity 10 kg, weight 29 kg and radius 1300 mm. The last and at the same time the first type is UR5, which originates from UR6. This robot has load capacity 5 kg, weight 18 kg and radius 800 mm.

3.3 Construction

The robot is constructed as a 6-axis one and the last three joints are moved to the robot wrist to that the robot would look like a human arm. Its construction is designed to be hard and at same time light. The robot shoulders are made from hard aluminium alloy, the joint cases are made by a metod of exact molding. The drive is performed by brushless AC engines of the Universal robots own construction with long lifetime. These engines are made in the Czech republic. This robot also uses harmonic gear boxes Harmonic Drive AG, which are also used by many competitive robots.

Universal robots uses two types of joints, which compatible and moreover it is possible to use a bigger UR5 joint as a smaller UR10 joint

All the types are maintenance – free, their lifetime is cca 70 000 working hours.

3.4 Controller

The controller has for all types the same size (470x424x270mm) and shape. The only differences are the embedded PC and powerful moduls. The controller and also the whole robot is controlled by 12‘‘ touch colourful LCD panel. 16D I/O, 2A I/O, Ethernet, Modbus TCP, USB, optionally Euromap 67 are in charge of communication with surroundings. Consumption of electro energy is 200W for UR3 a UR5 and 400W for UR10.

3.5 Programming

Robot programing and controlling is done by interactive on-screen menu on 12‘‘ touch colorful display and clear GUI really easily. The robot is moved to needed positions manually or by a touch to correctly organized arrows and axis crosses, to even a „robotically“ unexperienced service can understand programming and robot orientation in space very fast. The movements can be connected with signals on I/O controller, or with another communication type and by using of this procedure it is possible to create the needed sequentions and logic of robot activity.

For advenced there is also an original script programming language URScript, which is a standard part of controller instalation and it enables (in a common way) to write and edit programmes, set up comunication through Modbus/Ethernet, solve cooperation with camera systems and other periferies and of course, to check inputs and outputs.

3.6 Safety

As it has already been mentioned, UR robots can work without protective fences and light barriers and they can be placed on the assembly line next to people. Each UR robot is certificated according to norm ISO10218-1:2006, which specifies cooperation between a man and machine. The newest types CB3 have even TUV certificate.

The ability also decreases price of the complete project, because covering, lockers, barriers, safety PLC, relay etc. Are usually an important part of the budget.

3.7 Technical specifications

Tab. 1: Technical specification of robot arms

Robot arm	**UR3**	**UR5**	**UR10**
Degrees of freedom:	6 otočných kloubů		
Joint ranges:	+/- 360°		
Reach:	500 mm	850 mm	1300 mm
Payload:	3 kg	5 kg	10 kg
Speed:	180°/sec		
Repeatability:	+/- 0,1 mm		
Weight	11 kg	18 kg	29 kg

4 Recoverability

One of the most important things by setting of industrial robots is their economical recoverability. For this robot, the producer states recoverability within ½ year. Unfortunatelly, in the Czech republic salaries are quite different from Denmark. And to, if we calculate average salary in Czech republic (cca 25 000 CZK) and the robot UR10 price (28 500 EUR), our recoverability is cca 2,5 years. With robot life time 70 000 working hours in two shift operation, the robot could serve us for up to 12 years. Unfortunatelly, by setting into operation the robot itself isn't enough, but it is necessary to consider a gripper, a tool changer, a component feeder etc. For this reason it might happen easily that the final project price can be several times higher than the robot price.

5 Conclusion

In my opinion, the way which the Universal robots has started, it the correct one. I believe that in future even much bigger robots that the Universal robots ones are, will be working with people. During the last few years industrial robot price have decreased so much, that also automatization of a one – shift operation needn't be a wrong step. In transportation and logistic we can ready find industrial robots by goods packaging, palletizing and depaletizing. But because robot development has made huge progress recently we can expect their setting also in other new applications.

Finally, I would like to thank the trade department of the company Exactec Liberec, which is a representative of the Universal robots on Czech market, for cooperation and provided information.

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FOUNDATIONS OF TALL STRUCTURES UNDER DIFFICULT CONDITIONS

Petr Vnenk[1], Tomáš Frontz[2]

Abstract: This paper deals with specifications of tall structures foundations under difficult conditions, summarizes current findings and the most up-to-date methods of their present design. Applied procedures are presented on many cases from past and present times. After a short introduction and few notes on engineering structures, specifications of tall structures foundations are summarized in Chapter 3. The next two chapters are dedicated to a brief description of experience from two historical structures of a great importance. Chapters 6 and 7 return kind readers to the present time; encapsulate current knowledge in tall structures foundations and sum up design methods and tools. The ultimate chapter, provided the epilogue is disregarded, presents the application of the knowledge and methods to a structure currently under construction.

Key words: Foundation, Geotechnics, Structure, Tall, Tower

1 Introduction

There are many types of engineering structures of different size and shape. Anyway, all of them have a common feature – need for a high quality foundation. Especially for tall structures, this need is of a special importance. Tall structures concentrate very high loads on minimum areas. The subsoil is therefore requested to bear extreme pressures and ensure that the structure will not suffer any damage.

This aspect is rising in concern as the number of tall structures notably increased in the last century. In highly populated areas, it is necessary to increase the usable space by expanding buildings upwards.

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2 General Notes On Engineering Structures

Engineering structures are such ground or underground structures whose purpose is not only to provide shelter and comfort to people, animals or objects but also fulfill a special engineering task. Transport (railways, roads, airports, waterways, tunnels, bridges, but also railway stations, airport terminals, pipelines), telecommunication, energy and many other types of structures serving for a special purpose are to be counted in this definition.

Unfortunately, engineers cannot usually choose the location of a desired structure and thus, very difficult conditions are to be fought with on site. Moreover, in many cases, the difficult foundation conditions are met with very demanding requirements on bearing capacity of the structure.

3 Specifications of Tall Structures Foundations

Six major characteristics of tall structures which have a great influence on foundation design are set as follows: [7]

- Weight increase of a structure with respect to its height is nonlinear; this results in a substantial vertical loading on foundation.
- Tall structures are often surrounded by low structures with very low load; therefore, differences in settlements of the particular structures have to be kept under control.
- Horizontal forces caused by wind and consequent bending moments carried to the foundations can be high. These moments can jointly affect with vertical loadings on foundation, especially on outer piles of the foundation system.
- Horizontal loads and moments caused by wind are naturally cyclic. Therefore, there is a need to include the influence of vertical and horizontal cyclic load on foundations, because cyclic loading potentially decreases bearing capacity of foundations and increases settlement.
- Seismic activity produces additional horizontal forces in structures and causes horizontal movements in soil bearing the structures. Because of this, additional forces and moments can have some effect on foundations mostly through two mechanisms: Internal forces and moments caused by horizontal movement of the structure; Kinematic forces and moments acting on foundation piles caused by soil movement against the piles.

- Wind and seismic loadings are of a dynamic nature. Because of this reason, their influence on possible resonance excitation of structures must be evaluated. First resonance frequencies of very tall buildings are very low and due to typically much higher predominant frequencies of conventional sources of dynamic loading, like wind or earthquakes, it will not usually excite structures in the first resonance frequencies. Some of modal masses, however, have much higher resonance frequencies and can be set to oscillation by wind or seismicity.

4 The Leaning Tower of Pisa

It has been nearly 1000 years since a construction of a tower in an Italian town of Pisa commenced. This construction has become a symbol of what a bad foundation of a structure can cause. The stratified subsoil under the Archbishop Square is displayed in Fig. 1. The upper stratum is approximately 10m thick and contains mostly fluvial and tidal silts that create variable layer of sandy and clayey mud. In the lower part of the upper stratum, there is roughly 2m thick, moderately compacted layer of fine-grained sand.

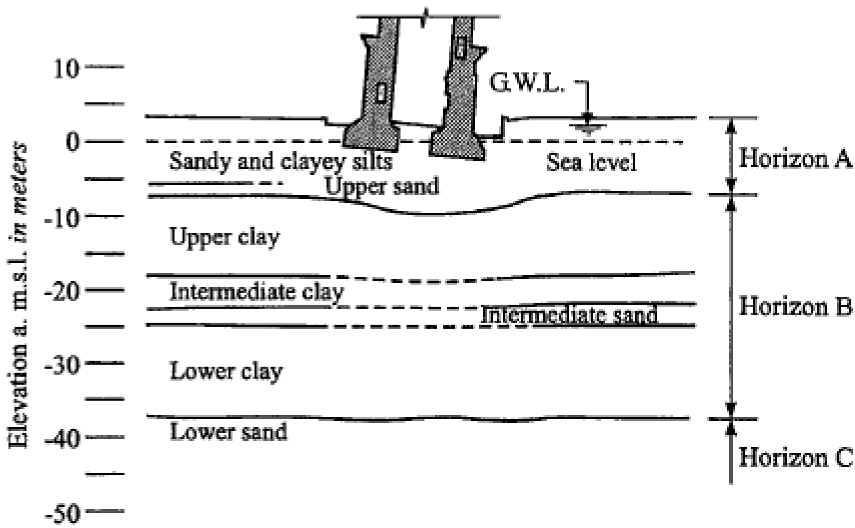

Fig. 1: Subsoil Profile of the Leaning Tower of Pisa [2]

According to scientific analyses, the material in the upper stratum to the south of the tower appears to be more muddy and clayey than to the north of the tower, while the sandy layer appears to be thinner here. It is assumed that this is the reason of the south leaning of the tower.

Fig. 2: The Leaning Tower of Pisa [1]

The middle stratum is mostly made out of marine clay and reaches the depth of 40m. It can be divided into 4 different layers. The upper layer is made out of soft clay. A layer of stiff clay lies under this layer. Even deeper, there is a sandy layer. Lower part of the middle stratum is made out of moderately compacted clay, known as the lower clay. The middle stratum appears to be homogenous everywhere in the vicinity of the tower. The lower stratum is made out of dense sand, known as the lower sand, which reaches significant depths. The water table is in the upper stratum, approximately 1 to 2 m under the Earth's surface.

In 1173, construction of the tower commenced in these very difficult foundation conditions. First 3 of desired 8 floors had been built when the works stopped in 1178. The reason for this interruption is not known, but it is thought that a potential continuation would result in exceeding the bearing capacity of the foundation. The works recommenced in 1272, almost 100 years later, during which the bearing capacity of the subsoil increased due to the loading of the existing structure. Approximately in 1278, after the construction had reached the 7th floor, the works were stopped again. It is thought again that the construction would have collapsed if the works had not stopped. Around 1360, the belfry construction commenced and the construction was finished around 1370, 200 years after the commencement of the construction of the tower.

It is apparent that the leaning had to be evident as soon as during the construction. E.g. the builders attempted to counterbalance the tower by placing the belfry axis in a different inclination than the axis of the rest of the tower. In Fig. 2, the more vertical inclination of the belfry is recognizable. This fact is also represented by placing only 4 steps from the tower to the belfry in the north part and as much as 6 steps in the south part.

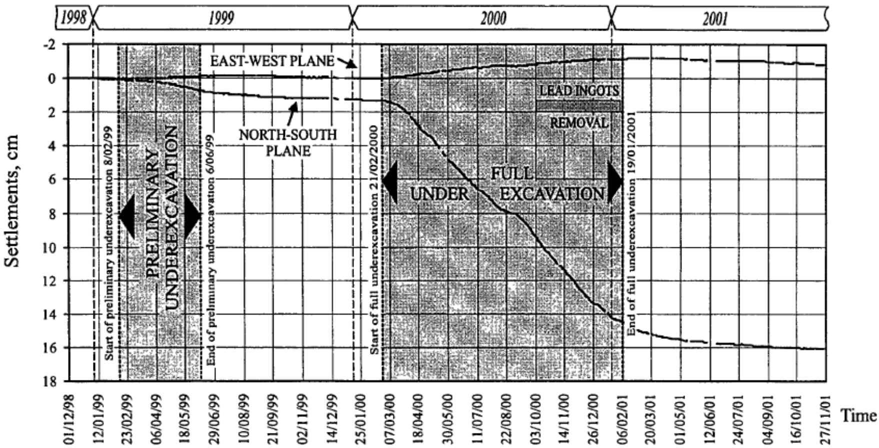

Fig. 3: Time-Settlement Diagram of the Leaning Tower of Pisa [2]

In the last decades, a lot of effort was given to solve the problem of the tower inclination as it dangerously increased. Over initial unsuccessful attempts like placing 800 tons of lead weight on the northern side of the tower, the situation came to establishment of an international committee to save the Leaning Tower of Pisa. The committee proposed a solution consisting from careful removal of 38 cubic meters of soil from under the northern part of the tower which straightened the tower by 45 cm. The time-settlement diagram in east-west and north-south axis is shown in Fig. 3. In the next phase in 2008, additional 70 tons of soil was removed what resulted in final incline of the tower of 3.99° and also, for the first time in history, the tower completely stopped leaning as it was confirmed by sensors permanently controlling its position. [3]

Even though the case of the Leaning Tower of Pisa was not a new construction but a rescue of an existing structure with bad foundations in difficult conditions, the selected method proved to be suitable to save the tower and it seems the stability of the tower is increased again.

5 Bell Rock and Eddystone Lighthouses

Other examples of tall structures foundations are the lighthouses Bell Rock and Eddystone. The Bell Rock Lighthouse is located on the Inchcape Rock, about 10 miles to the east-southeast of Arbroath town in Scotland. When the tide is low, the rocky crag rises above the water surface. At high tide, however, it is well submerged. [4]

Fig. 4: Bell Rock Lighthouse [8]

Considering the foundation, no problem with the quality of subsoil was faced. The problem was, however, the fact that the rock sticks out of the sea only by low tide. Being 20 hours per day submerged, the situation allowed workmen to work on site no more than 2 hours daily and then row back to the vessel at anchor one mile off the rock. The pace of the construction was increased after a temporary beacon, serving as quarters, too, was raised and the workmen could spend more time working on the rock.

A similar issue had been solved years before at the construction of the Eddystone lighthouse in Devon County. The slight alleviation at the Eddystone lighthouse, however, was given by the fact that a piece of rock was above the water surface all the time. This area was not sufficient for construction, yet the conditions were much better than those at the Bell Rock's 4 feet below water surface.

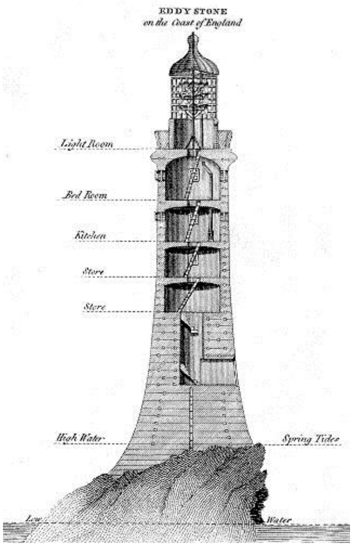

Fig. 5: Oak-Shaped Masoned Smeaton's Eddystone Lighthouse [9]

The assets of the Eddystone lighthouse construction for the Bell Rock lighthouse construction, and for many others, were in the shape of the structure. After the first two lighthouses at Eddystone were destroyed, engineer John

Smeaton designed an oak-shaped masoned structure. This structure, curved in the lower part, had a much larger foundation, and the curvature enabled the wave energy to turn upwards and dissipate instead of act destructively on the lighthouse construction.

6 Contemporary Findings in Tall Structures Foundations

Before the contemporary solutions in tall structures foundations under difficult conditions, it is good to pay attention to settlements. The settlement at conventional structures shall not exceed 50-65mm. [7] At tall structures, however, bigger settlements may appear without the danger of loss of stability of the structure. For instance, the skyscrapers in Frankfurt, Germany, founded on piles in stiff Frankfurt clay, settled by more than 100mm and the structure does not have any signs of damage or loss of bearing capacity. Summary of settlements of selected existing tall structures is presented in Table 1.

Tab. 1: Examples of Tall Structures Settlements

Foundation Type	Geological Conditions	Location	Number of Cases	Settlement per a Pressure Unit [mm·Mpa^{-1}]
Raft	Stiff Clay	Houston	2	227-308
Raft	Limestone	Amman, Riyadh	2	25-44
Piled raft	Stiff Clay	Frankfurt	5	218-258
Piled raft	Compacted Sand	Berlin, Niigata	2	83-130
Piled raft	Bedrock with Low Bearing Capacity	Dubai	5	32-66
Piled raft	Limestone	Frankfurt	1	38

Prof. Harry G. Poulos sets the design of tall structures foundations in ten points: [7]

- Research in geology and hydrogeology in the locality where the structure shall be placed.
- Survey in the construction site in order to recognize the stratification and variability of subsoil.
- In-situ tests for evaluation of particular engineering attributes of the key stratum.
- Laboratory tests, in addition to the in-situ tests, to ensure more accurate information about the attributes of the key stratum.
- Creation of a geotechnical model for construction site that contains information about attributes of the key stratum. Provided the subsoil in the construction site is very variable, it is recommended to create series of models.
- Preliminary evaluation of foundations requirements based on experience and simple analytic and design methods. In this evaluation, it is inevitable to significantly simplify both the geotechnical profile and the structural loading.
- More detailed design based on more accurate construction data, loading and subsoil state. From this point on, close cooperation with construction engineer is necessary to get a successful foundation design.
- Detailed design in cooperation with construction engineer. In case of a foundation system change, loadings calculated by designer are also a subject to change. Therefore, it is generally necessary to iterate in the course of balanced loadings and deformations.
- In-situ foundations tests are strongly recommended, if not quite necessary, to prove that the real behavior of foundations complies with design assumptions. This is usually applied to piles prototypes. If the observed behavior differs from the expected one, the foundations design has to be revised.
- Structure behavior observation during and after construction. Except for this, settlements of piles, raft slab and the surrounding of the structure shall be observed to enable distribution of loads on particular foundation elements. Unlike standard structures, tall structures apply these observations as a common practice. If the observed values differ from expectations, alternative plan shall be considered.

The foundation design is often made through the Ultimate Limit State, as it is defined in Eurocode 7. Design criteria for the Ultimate Limit State are as follows:

$$R_S{*} \geq S{*} \quad (1)$$

$$R_g{*} \geq S{*} \quad (2)$$

where R_S* is designed bearing capacity of the structure, R_g* is designed geotechnical bearing capacity and S* is structural loading (multiplied by loading coefficient combinations).

These criteria are applicable to the whole foundation system. Equation 1 is applicable to the particular piles, too. It is not suitable to apply Equation 2 to the particular piles, as this procedure leads to a significantly excessive design of the structure. [7]

When considering tall structures, it is reasonable to add 3rd criterion to the previous 2. A criterion that takes into account cyclic loading by wind and/or waves: [7]

$$\eta R_{gS}{*} \geq S_C{*} \quad (3)$$

where R_{gS}* is designed geotechnical capacity of pile shaft, S_C* is maximum amplitude of wind (waves) loading and η is a reduction coefficient.

The purpose of this criterion is to prevent the foundations from excess in frictional bearing capacity along the piles and reduce the danger of degradation of piles shaft frictional bearing capacity. In most cases, η is of a value 0.5 and S_C* is get from a computer analysis of a cycling loading component on each pile for different cyclic loading states.

The Ultimate State of Serviceability is defined through the following criteria: [7]

$$\rho_{\max} \leq \rho_{dov} \quad (4)$$

$$\theta_{\max} \leq \theta_{dov} \quad (5)$$

where ρ_{max} is maximum calculated foundations settlement, ρ_{dov} is allowed foundations settlement, θ_{max} is maximum calculated local angular distortion and θ_{dov} is allowed angular distortion.

Values ρ_{dov} and θ_{dov} depend on structure type and subsoil. Zhang and Ng propose criteria of serviceability for structures summarized in Table 2.

At dynamic loading, it is good to note that the fundamental frequency of a foundation system shall be higher than the fundamental frequency of the structure above to avoid resonance. Natural frequencies depend especially on stiffness and weight of the foundation system. Damping characteristics can also have a significant importance, however. Amplitudes of the dynamic system structure-foundation shall stick within an appropriate range. In this case, amplitude depends on stiffness and damping characteristics of both foundations and structure.

Tab. 2: Proposed Criteria of Serviceability for Structures [10]

Quantity	Value	Notes
Limit Settlement [mm]	106	Based on 52 Cases of Deep Foundation
Observed Over Limit Settlement [mm]	349	Based on 52 Cases of Deep Foundation
Limit Angular Distortion [rad]	1/500	Based on 57 Cases of Deep Foundation
Limit Angular Distortion [rad]	1/250 (H < 24m) to 1/1000 (H > 100m)	From Chinese 2002 Standards; H = Structural Height
Observed Over Limit Angular Distortion [rad]	1/125	Based on 57 Cases of Deep Foundation

Foundation design has always aimed on structural loading. Earth movement can, however, cause significant loads, too. There are many sources of these movements. Those of them, relevant for tall buildings, are listed below: [7]

- Soil settlement due to construction soils, its recycling, or drainage. These effects can persist many years and can emerge from activities that happened many years ago, even on places just in vicinity of the structure.
- Soil lifting in foundation structure excavation.
- Horizontal and vertical movements emerging from piles installation in vicinity of already installed piles. These movements can induce other axial and tangential forces and bending moments in existing piles.

- Dynamic soil movements caused by seismic activity. These kinematic movements can induce additional moments and tangential forces in piles that jointly affect with structural internal forces on foundations.

7 Design Methods and Tools

As soon as the necessary geological and geotechnical data are obtained, the foundation design can be made. The design procedure can be divided into three key phases: [7]

- Preliminary analysis, evaluation and design.
- Main design process.
- Detailed analysis for check of the comprehensiveness of the solution, which might not be taken into account in the main design process.

On the preliminary analysis level, it is enough to use a table processor, MATHCAD program, or other simple computer programs. For the main design process, it is advised to use computer methods for piles or pile-raft analysis like DEFPIG, PIGLET, GROUP8, REPUTE, GARP and NAPRA. All of these programs have some limitations; however, they are able to make nonlinear calculation of a pile-raft system. Using the analysis from the above mentioned programs, the optimal amount and distribution of piles can be obtained. In the final stage of design, when the decision on piles configuration has been made, a finite element method program, 3D preferentially, is recommended to use and verify so the foundation design from the previous step and the piles reaction on different effects, like horizontal resistance, too. [7]

As the height of a structure increases, so do the requirements on the bearing capacity of piles. And this underpins the importance of the Osterberg test. Unlike many other tests, the Osterberg test allows loading pile feet and shafts as much as to damage. A much appreciated feature of this test is the ability to identify weaknesses made during construction. [5]

8 Incheon Tower

Incheon Tower is 151 storey skyscraper built on soft marine clay in Songdo, South Korea. The construction started in 2008 and after many delays, it is expected to finish in 2018. The height of 600m puts this building among the highest buildings in the world.

The Incheon area covers wide sandy, muddy and coastal tidal locations. The construction site is situated completely in the area of land reclamation. This area is formed by 8m thick layer of sand and sandy silt that lies on 20m thick layer of soft fine deposited marine clay, known as the Upper Marine Deposits (UMD). Under this layer, there are 2m of moderately compacted sandy silt, known as the Lower Marine Deposits (LMD). Even more down, there are rest deposits and weathered bedrock. This bedrock is made out of granite, granodiorite, gneiss and aplite. The weathering of the bedrock material reaches the depth of 50m and weakens the bearing capacity of the rock.

Fig. 6: Incheon Tower [6]

The building is in top view divided into 8 parts so that each single one can better represent local geological and geotechnical aspects. In-situ and laboratory tests discovered the necessary geotechnical parameters. These parameters are summarized in Table 3.

Foundations consist from 5.5m thick concrete raft and piles supporting columns and core walls. The amount and distribution of piles, as well as their dimensions, were obtained from analysis of many tests. The depth of piles used for securing of requested settlement of the structure is higher than the one needed for sufficient geotechnical bearing capacity. The final design included 172 piles with diameter of 2.5m reaching the depth of 36 to 66m under the bottom surface of the raft foundation which is situated 14.6m under the surface of the original terrain. A simplified scheme of the foundation distribution is displayed in Fig. 7. The total loads used in the foundation design are listed in the Table 4.

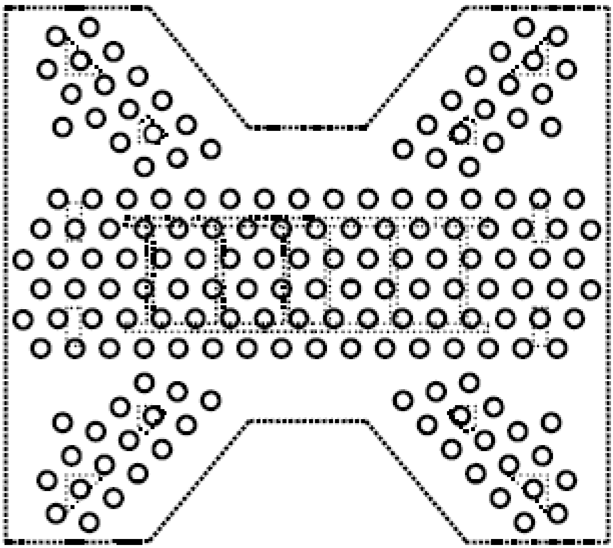

Fig. 7: Top View of Incheon Tower Foundations [7]

Tab. 3: Design Loading Components [7]

Loading Component	Value
Permanent Loading	5921.4MN
Moving Loading	639MN
Wind Loading (in x direction)	149MN
Wind Loading (in y direction)	115MN
Earthquake (in x direction)	110MN
Earthquake (in y direction)	110MN

Loading Component	Value
Moment (in x direction)	21600MNm
Moment (in y direction)	12710MNm

In the preliminary evaluation, constant layer thicknesses in subsoil and only vertical loading were considered. The piles length has been set to 50m. The total axial bearing capacity of one pile has been determined as 244MN. All 172 piles together reach the bearing capacity of 41968MN. After addition of the bearing capacity of the raft slab, which is 5930MN, the total bearing capacity of foundations equals 47898MN. The total safety coefficient under clearly vertical loading can be determined as 47898/6560.4 = 7.3, which can be assumed as satisfactory. Reduction coefficient for the bearing capacity of foundations has been set to 0.65. Coefficient of permanent loading has been set to 1.25 andcoefficient of variable loading to 1.5. The average settlement has been calculated as 75mm. This was assumed as satisfactory. [7]

In the detailed evaluation, loading combinations in the Ultimate Limit State and many nonlinear piles analyses using the CLAP program were used. The foundation system was determined as stable in all cases. The settlement has never exceeded 100 mm. [7]

The design was in the final stage verified in a 3D finite element method model. [7]

9 Conclusion

Foundations of tall structures are not just one of their construction parts but one of the most important ones. This discipline is even more important provided the construction is carried out in difficult geological conditions. Specifications accompanying such difficult conditions and attributes that are supposed to attract the attention of a geotechnical engineer were summarized in the paper.

Additionally, examples of tall structures with interesting foundation issues were presented. These chapters were followed by description of modern methods of tall structures foundations. In the latter part, an example of a brand-new tall structure was presented and its foundation design procedure was briefly delineated.

Acknowledgement

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ADVANCED MODELLING OF WHEEL–RAIL ADHESION

Petr Voltr[1], **Michael Lata**[2]

Abstract: Wheel–rail adhesion is a complex of physical phenomena involved in transmission of forces between wheels and rail. Various models of the adhesion contact and corresponding computational algorithms are available for rail vehicle dynamics. The paper describes basic classes of models and further focuses on advanced modelling in two areas: firstly, modelling of more complicated friction conditions, secondly, dealing with the problem of transient rolling.

Key words: Adhesion, friction, rolling contact, transient phenomena

1 Introduction

Motion of a rail vehicle is largely determined by forces which act upon it through the small areas of contact between wheels and rails. The nature of mechanics of this contact is such that under presence of compressive normal force, tangential forces are also transmitted, although the wheels and rails are macroscopically smooth. This finding gave rise to the term „adhesion" (wheels „stick" to the rails) as referring to the complex of physical principles and practical properties of transmission of forces between wheels and rails. More information may be found in [1, 2].

Dynamical investigation understands the vehicle and track as a dynamical system of bodies and joints, as illustrated in Fig. 1, in which the wheel–rail contact constitutes a joint (force element). There are various possibilities of modelling of this element, among which one decides in dependence on purpose of the study, operational modes and precision required. For vehicle dynamics, the adhesion model usually means an element representing the dependence of contact forces

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on creepages [3] (creepage is a kinematic quantity describing relative movement of a wheel to a rail).

The next section describes basic adhesion models which are currently in use for the purpose of vehicle dynamics investigations.

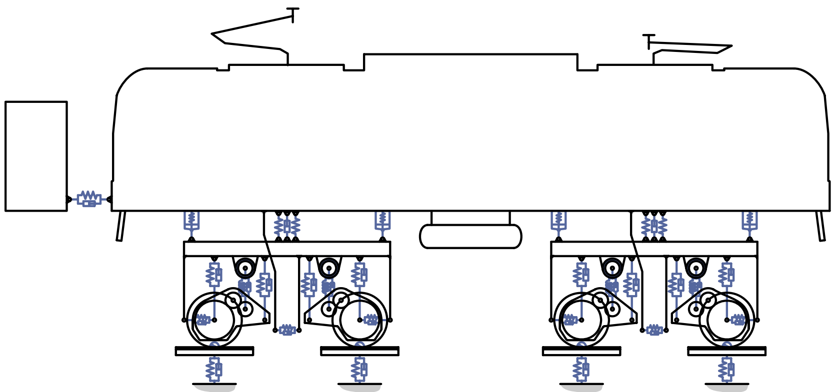

Fig. 1: Multi-body mechanical model of an electric locomotive for purposes of drive dynamics simulations

2 Wheel–rail contact models

2.1 The exact theory of Kalker

It may be stated that the works by J. J. Kalker, see e.g. [3, 4], form a solid base of today's wheel–rail contact theory and computational algorithms. The term „exact" in the title is used in contact mechanics to describe a theory which regards the wheel and rail as elastic continual bodies (see Fig. 2 left). This theory takes into account all possible relative movements in the contact area (longitudinal, lateral and spin creepage) and determines distribution of contact stresses using a boundary element method (BEM). These are integrated to obtain the total forces.

Kalker's exact theory, implemented in the algorithm CONTACT [4, 5, 6], is accurate and is applicable to non-hertzian contact geometry, too, but takes much computational time. Therefore it is not normally used in numerical simulation of vehicle dynamics.

2.2 The simplified theory of Kalker

Considerable computational effort may be saved by introducing a simplified model of the material of the bodies in contact. The surface layers of wheel and rail are represented by the brush model, consisting of flexible „bristles“ attached to a rigid base (Fig. 2 right). There is no interconnection between the bristles so that tangential deformation in any point is proportional to tangential stress in that point, and independent of stress present in any other point. This departure from continual model brings a significant simplification, yet provides acceptable results if the stiffness of the „bristles“ is appropriately set.

The Kalker’s simplified theory of rolling contact is embodied in the algorithm FASTSIM [5, 7, 8] which is now widely used in simulation software. For practical purposes, it is limited to Hertzian contact geometry and steady rolling but the principle of the brush model allows utilization in more complicated models, too.

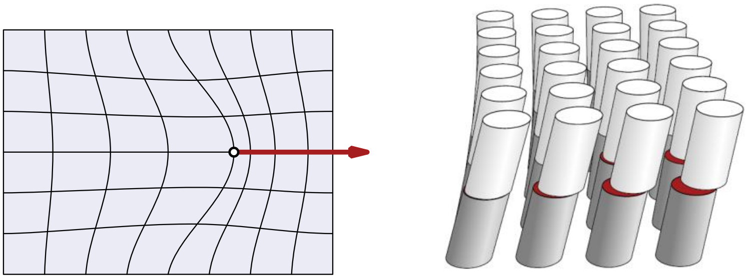

Fig. 2: Illustration to material models – left: continuum for exact theories of rolling contact; right: bristle model for simplified theories

2.3 Analytical calculation methods

Both CONTACT and FASTSIM are essentially numerical methods which make use of discretized (meshed) contact area for calculation of stress as well as its integration. However if further simplification is accepted, consisting in the omission of spin, the distribution of tangential stress is simplified so that analytical formula can be found for its integration and presented in the form of adhesion characteristic (see Fig. 3). This was shown by Kalker in his paper [7] but, to the our knowledge, it has had no significant utilization. More successful was the theory of Freibauer [9], later extended by Polách [10, 11] to form one of today’s well known adhesion models. The original model consists of several quite simple formulae and is suitable for fast calculation namely in vehicle traction, and for education. One of the elaborations of Polách includes approximate effect of spin, which makes the equations more complicated but provides a fast alternative to FASTSIM in vehicle dynamics simulations.

3 Advanced models of friction

3.1 Basic friction modelling

Friction between contacting bodies is one of the physical principles and phenomena which govern the transmission of forces between wheel and rail. A concise explanation of the relation of adhesion (in the general railway meaning) and friction might be such that friction is a limit for adhesion.

The model of friction consists a sub-system of the overall contact model. The most simple frictional model is the Coulomb's law with a constant coefficient of friction (COF), which is often sufficient for investigation of vehicle running behaviour but inadequate in studies of drive dynamics or wear. The theories of Freibauer and Polách already include the effect that COF decreases with increasing sliding velocity, as shown in Fig. 3, which is described by an exponential function with three parameters which are obtained empirically. This function is shown to conform to measurements well [11, 12].

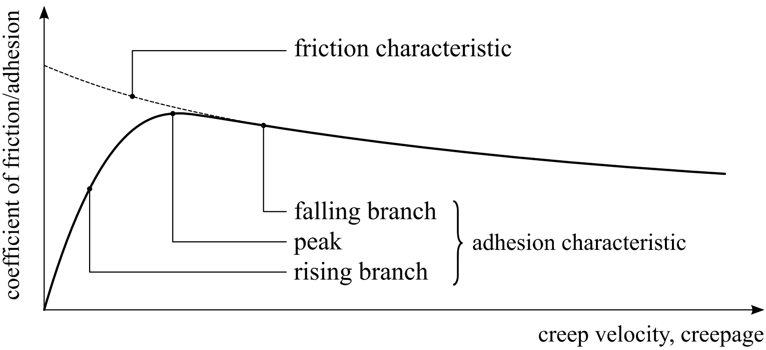

Fig. 3: Sketch of a basic adhesion characteristic together with a velocity-dependent function of friction

3.2 Detailed models

To create a more accurate description of friction in wheel–rail contact, advanced models are developed, as seen e.g. in [13, 14]. A detailed analysis of contact conditions is employed to bring the model closer to the actual physical phenomena. The following facts may be taken into account in such models:

- contact of metallic bodies through „micro-contacts“ of asperities in elasto-plastic mode,
- presence of a viscous layer of contaminants between the bodies (in gaps between the asperities),
- increase of temperature in contact by dissipation of energy in rolling with sliding,
- temperature-dependent hardness, strength and elasticity modulus of the materials.

In advanced friction models, the coefficient of friction is not based upon several empirically determined parameters; instead, actual physical properties, as elasticity modulus or fluid viscosity, are employed in their calculation.

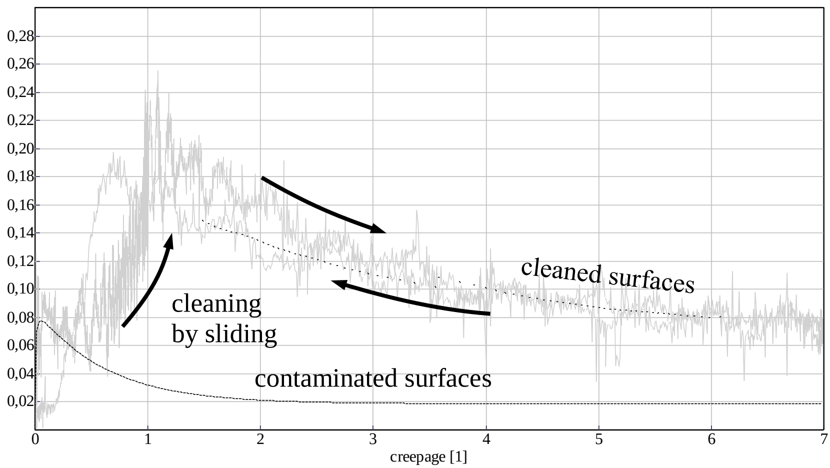

Fig. 4: One of transient adhesion characteristics measured at a roller rig (wheels contaminated with oil, rolling speed 10 km/h)

3.3 Surface conditioning

Advanced modelling of friction in contact is connected with a dynamic (time-dependent) effect which may be denoted as conditioning, or cleaning effect. Low adhesion is caused by contaminants (water, oil, leaf layer) present between wheel and rail. In such conditions, the wheel may start sliding; sliding brings dissipation of energy in the contact – temperature rises, moisture evaporates, oil loses viscosity, contaminants are forced out of contact, as a result of which the coefficient of friction increases.

The authors of the present paper studied these effects in order to explain the unexpected results of experiments carried out at a roller rig of the University of Pardubice [12, 15]. Basic adhesion theory tells that maximum tractive force is reached at several percent creepage, shortly before adhesion is lost. In the experiments, however, increase of the force was often observed in the mode of full sliding, forming false peaks of adhesion characteristic (Fig. 4), not accounted for by theory (compare Fig. 3).

Analysis has shown that changing friction conditions are responsible for the recorded behaviour, and a mathematical model of the changes has been proposed. This model uses a variable coefficient of friction which increases in dependence on frictional work spent in contact during a short time interval. It is seen that the model is able to reproduce the measured „dynamic“ adhesion characteristics well, if suitable values of its parameters are provided.

4 Transient rolling

4.1 Overview

The typical mode of motion of a railway wheel may be characterized as rolling with sliding, which differs from pure rolling in presence of certain relative velocities – creep velocities, creepages. If creepage (as well as other relevant quantities, e.g. wheel load) is constant in time, the wheel is in steady rolling. Otherwise there is transient rolling.

A transient phenomenon of rolling typically lasts for such time in which the wheel advances by the length of the contact area. For contact length $2a$ = 15 mm and running speed V = 40 km/h, this is as short as 0,01 s – therefore the transient rolling effect may be completely disregarded in many problems of vehicle dynamics. Consequently, few studies have been published on this phenomenon (see e.g. [4], [16]).

However, there are situations in which it is necessary to deal with transient rolling. For very low vehicle speeds, the transient effect lasts longer and a steady rolling model may be inaccurate; and in the very moment of first movement of a vehicle from zero speed, the situation in the wheel–rail contact does not resemble steady rolling at all. For this reasons, very low speeds are to be avoided in many simulation tools, unless a transient rolling model is utilized.

4.2 Simplified model of transient rolling

The authors developed a simplified model of transient rolling (STR) in order to allow simulation of traction dynamics at arbitrarily variable speed [17]. The model uses the assumptions of the theory of Hertz for normal contact, bristle model for tangential contact whose stiffness is derived from Kalker's linear theory. Therefore it is similar to FASTSIM except that it does not accept steady rolling. It is in principle suitable for all components of creepage but at present, only the algorithm for longitudinal creepage is complete (which is sufficient for driving system dynamics).

In STR, change of distribution of tangential stress (traction) in the contact area is calculated in each time step. Let us explain this by Fig. 5: at the beginning, general traction distribution is present. As the wheel advances by the distance Δx_p forward, the material which carries its stress with it shifts in the opposite direction. At the same time, it increases by $\Delta\tau$ if creepage is present. A new traction distribution forms from the leading edge, keeping constant slope if creepage is constant (as assumed in the illustration). After the wheel advances by the whole contact length, nothing is left of the original stress distribution and the transient effect is at its end.

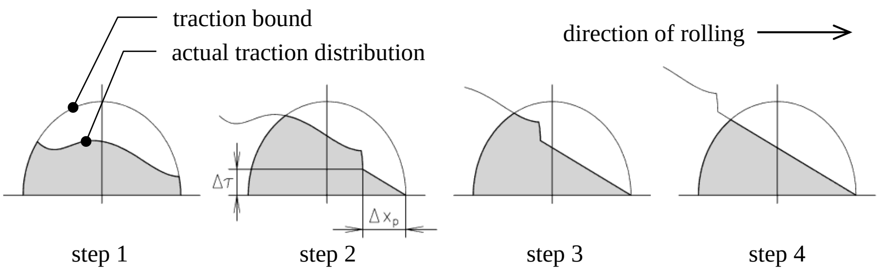

Fig. 5: Illustration to the simplified model of transient rolling – distribution of tangential stress in contact in transition from general initial state to steady rolling with constant creepage

Thanks to the STR, it was possible to do simulations of traction drive dynamics at very low speed, including startup from zero speed and the mode of interrupted sliding (stick-slip effect at the wheel–rail interface) where significant dynamical effects in the system occur. Comparison with experiments [18] shows that the simulation is capable of displaying the important phenomena without numerical problems in calculation.

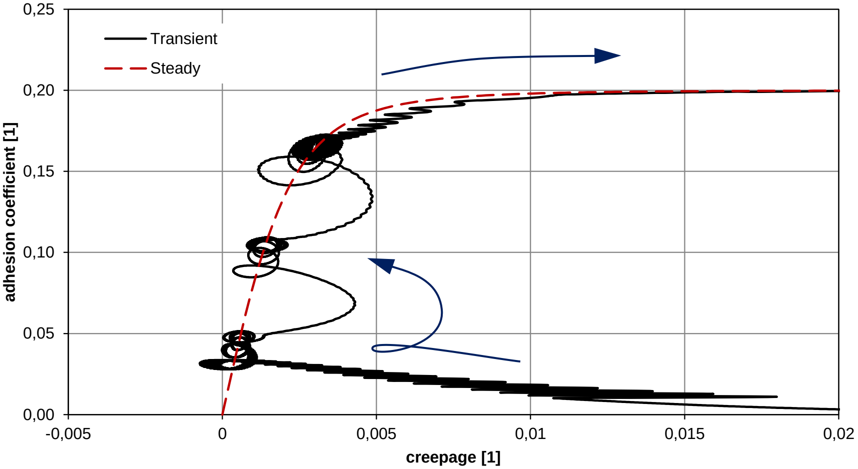

Fig. 6: Adhesion characteristic recorded in simulation of an accelerating locomotive using the simplified model of transient rolling

Fig. 6 shows a recording from such simulation where the „dynamic“ adhesion characteristic (black line) is seen. The locomotive starts at zero speed and accelerates as the simulated driver moves the controller. Each step of the controller means introduction of a transient effect, the working point departs from the steady-state red dashed line just to converge to it again in loops. Three such clusters of loops are seen in the plot in the microslip regime; at the fourth controller notch, adhesion is lost and wheelset starts sliding, the black line continues out of the plot limits.

5 Conclusion

The small area of adhesion contact between wheel and rail has been described by extensive theory but still there are efforts to extend it further. These are driven not only by curiosity of researchers but also by needs of railway industry and operation. The present paper shows two directions of advanced modelling of the wheel–rail contact.

The first of them concerns friction modelling and focuses on the phenomena of cleaning (conditioning) of wheel and rail by sliding. The description is based on laboratory experiments which, thanks to their large extent, allowed to propose a mathematical model for changes of friction coefficient during sliding. The outputs show that sometimes it is really necessary to include the axis of time when thinking about adhesion characteristics, and that unexpected shapes seen in measurement results may be caused by the effect of conditioning.

Another extension of adhesion models consists in simplified modelling of transient rolling, allowing to include transient rolling in fast numerical simulations. In our work, this was produced upon the requirement that the simulation should work for very low speeds where loss of adhesion in traction is probable; this would be a problem in commercial simulation tools with steady rolling algorithms. It was seen that the model is serviceable even in complicated rolling-sliding states of locomotive motion.

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ANTENNA ARRAY FEEDER FOR SECONDARY SURVEILLANCE RADAR INTEGRATED IN PRIMARY RADAR

Tomáš Zálabský[1], Vladimír Schejbal[2], Pavel Bezoušek[3]

Abstrakt: In the paper antenna feeders of an integrated 3D primary surveillance radar and a monopulse secondary surveillance radar (MSSR) antenna array are described. Collocation of the both antenna arrays at the same place assigned the feeders and radiators design with considerable demands. The analysis and design of these feeders and of the used power dividers are presented in the paper. The simulated and experimentally verified parameters are compared.

Key words: secondary surveillance radar, primary surveillance radar, integrated antenna, stripline coupler, power dividers.

1 Introduction

Design of radars for Air Traffic Control (ATC) have a long tradition in the Czech Republic. Mainly Primary Surveillance Radars (PSR) in S band, Precise Approach Radars (PAR) and Secondary Surveillance Radars (SSR) were built and supplied to many countries all over the world [1], [2] a [3].

Frequently the primary and the secondary surveillance radars are situated at the same airport or at one stand close to each other. Then it is advantageous to have the both radars integrated in one device with antennas collocated at the same turntable. A couple of years the secondary radar antennas of such systems were located over the primary radar ones on the same pivots. In modern

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applications secondary radars with a sufficient earth reflections suppression using large vertical SSR antenna apertures [1] are prevalent. It enlarges the total vertical dimension of the antenna system structure in the described configuration and complicates the radar transportation mainly in the case of military applications. Integrated PSR/SSR reflector antennas occasionally emerged [2] but with no substantial spread due to inevitably compromised parameters.

Here we deal with a novel design of an antenna array, combining a 3D primary surveillance radar antenna and a monopulse secondary surveillance radar one. The integration of the both antennas laid serious demands on the design and construction of the elements of the individual antennas. This article reports the design and the achieved parameters of this integrated antenna array feeders and power dividers.

The primary antenna, working in the S band (2.7 – 2.9 GHz) consists of 32 horizontal slotted waveguide rows each containing 77 radiating slots. Each waveguide is equipped with its own transmitter – receiver module and forms the same horizontal diagram. The transmitted signal covers all the elevation range at once through the favored cosecance vertical diagram. The bundle of the received beams is created beyond the receivers. The residual vertical polarization component of the irradiated field is suppressed by pairs of conductive vertical diaphragms between individual slots, forming vertical fins (see the Fig. 1).

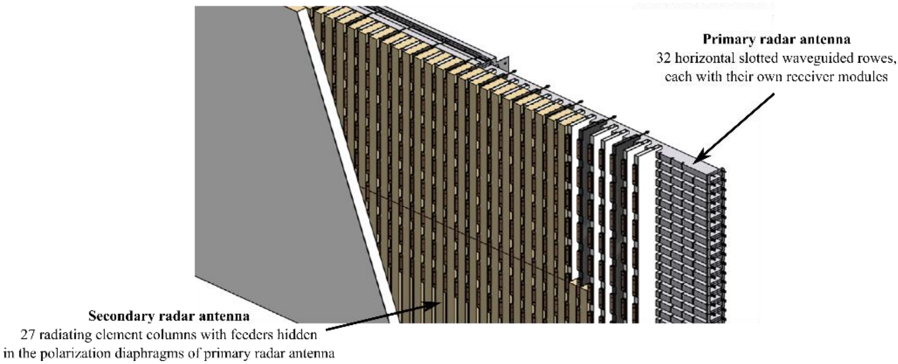

Fig. 1: The integrated PSR/SSR antenna design

The L band (1.03 – 1.09 GHz) secondary radar antenna is made up of 27 identical antenna columns each containing a vertical feeder and eight radiators, creating the same vertical antenna pattern. The feeders are closed in the mentioned vertical fins of the primary antenna. The SSR antenna columns are fed by a horizontal feeder, creating the three standard horizontal beams: the sum, the difference and the control beam of the secondary radar. The design of the whole integrated antenna in more details is described in [4].

2 MSSR Antenna Array Feeders

2.1 Horizontal feeder

The horizontal MSSR antenna feeder diagram is shown in the Fig. 2. The central section of this feeder forms a 3pole-6throw divider network distributing the three Σ, Δ and Ω beam signals to 6 groups of vertical irradiator columns with specific amplitude and phase distributions.

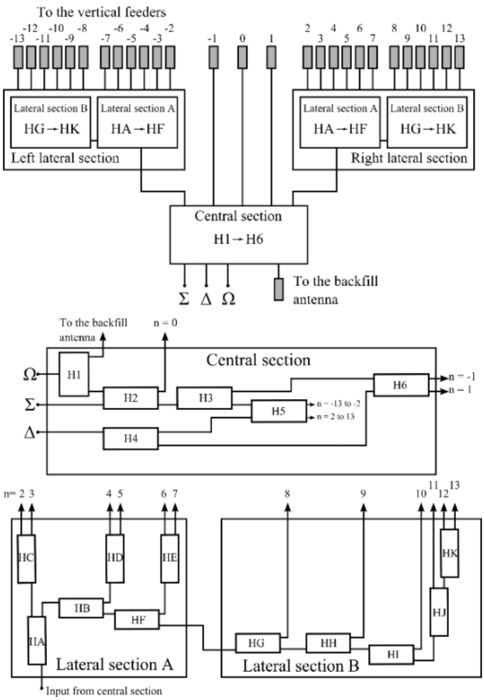

Fig. 2: The horizontal MSSR antenna feeder circuit diagram

The two identical lateral sections, fed by the central section either in phase or in opposite phase, depending on the applied input signal (ie. the Σ, Δ or Ω inputs) supply the vertical irradiator columns (vertical feeders) No. ±2 through ±13. Semirigid coaxial cables were chosen for interconnections between individual sections and between sections outputs and the vertical feeders to avoid printed circuits of very large dimensions and to simplify the final antenna assembling.

Inside the individual feeder sections an air filled suspended stripline (Fig. 3) was used for realization of dividers and interconnecting transmission lines to minimize the feeder insertion loss. The center strips of these lines are printed on a 1 mm thick FR4 dielectric slab by a standard double-sided PCB technology. This makes the feeders production very cheap and reliable.

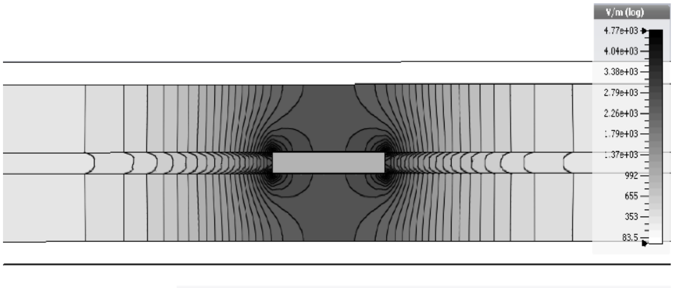

Fig. 3: The employed suspended stripline cross-section with electrical field distribution computed by the CST Studio

As we can see from the Fig. 2 the dividers H2, H5 and H6 are four port devices and due to topological considerations it is advantageous to use forward coupled line couplers for them. Therefore the branch line couplers are the convenient solution in these cases. The H1 device is a symmetrical power divider and it was realized as a Wilkinson power divider. The other dividers are unsymmetrical. Matched unsymmetrical Wilkinson or Gysel power dividers occupy a large area so the branch line couplers were chosen for their realization. The topology of the lateral sections of the horizontal feeder was optimized to get dividers with power divisions as small as possible. As a result dividers with output powers ratios of 0.5 – 3 dB were obtained mostly for the whole horizontal feeder. In the case of H2, H3 and H4 dividers the design was more critical due to its output power ratio higher than 6 dB. Usually the parallel coupled line couplers are used in such cases. But due to a choice of the suspended stripline configuration we finally decided to use a branch line coupler at a lower input characteristic impedance at this place.

As we can see from the Fig. 3, an appreciable part of the electrical field in the used suspended stripline is accumulated also in the dielectric substrate.

A dependence of a stripline width and a wavelength on a homogeneous line characteristic impedance, computed using the CST Studio EM field solver [7] for the selected suspended stripline configuration in comparison to the simplified configurations at frequency 1.06 GHz is shown in the Fig. 4. We can see substantial differences in the strip width and the wavelength between those methods even in the case of such a relatively thin supporting substrate. Hence the usual simplification of the dimensions calculation neglecting the substrate dielectric constant is not directly applicable. In the Fig. 4 also a change in the transmission line width due to a cartridge side wall vicinity is demonstrated. A more detailed analysis shows, that the side wall may be situated as near as only 12 mm of the strip axis with a negligible effect on the line parameters.

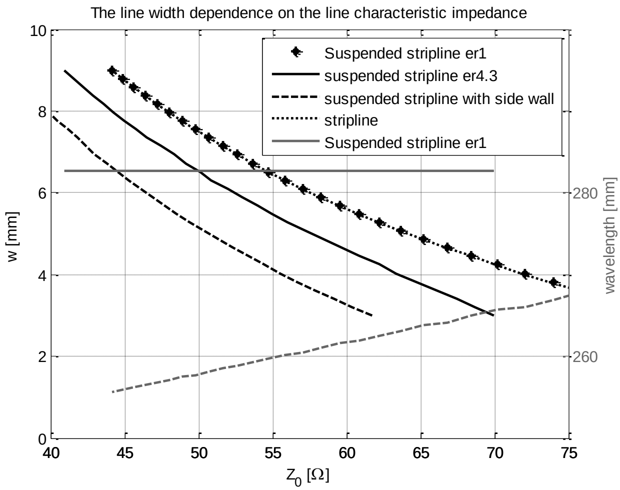

Fig. 4: The line width and wavelength dependence on the line characteristic impedance for the suspended stripline and substitutive configurations.

In the design of dividers, each divider was modeled in the mentioned CST Studio SW and its dimensions were optimized by repeated EM field simulations. At a start always the individual branch characteristic impedances were computed using a standard method for a one stage branch line couplers (see the Fig. 5) [8]:

$$Z_A = \frac{Z_0^2}{Z_B}\sqrt{1+\frac{P_2}{P_3}}; \quad Z_B = Z_0\sqrt{\frac{P_2}{P_3}}; \quad \beta = \sqrt{\frac{P_3}{P_2+P_3}} \qquad (1)$$

where: Z_0 … divider input impedance (at the port 1)

P_2, P_3 … output signal powers at the ports 2, 3
β … voltage coupling coefficient.

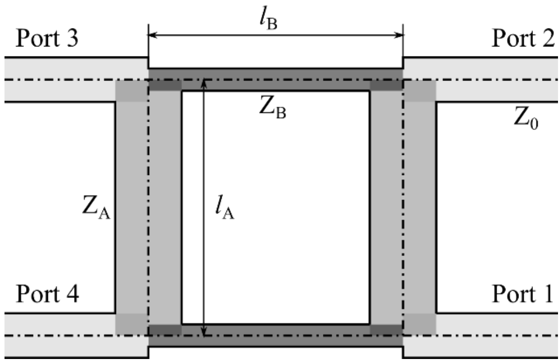

Fig. 5: One stage branch line divider circuit diagram

The initial values of the line widths and lengths for the optimization were then extracted from $w(Z_0)$ and $\lambda_g(Z_0)$ dependences obtained from the previously mentioned simulations using CST Studio SW Package (Fig. 4).

After obtaining the optimized dimensions, the experimental dividers were made and measured. A comparison of the selected dividers dimensions optimized using the complex dividers CST models and those obtained from the preliminary homogeneous line analyses are shown in the Fig 6. We may see that only small experimental corrections were needed. That is why only dividers with selected coupling coefficients were optimized, realized and measured in this procedure and dimensions of the dividers with intermediate couplings were then designed and readily fabricated.

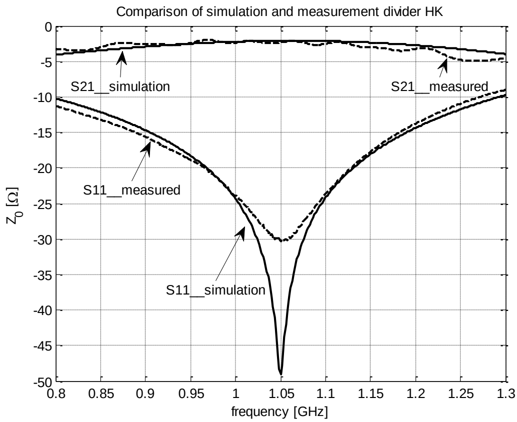

Fig. 6: The measured vs simulated S parameters of the divider H5 comparison

For the horizontal feeder central section in the Fig. 2 a double layered structure according to the Fig. 7 was chosen with the H4 divider situated in the first layer and the rest of dividers in the other one to avoid stripline crossings while keeping the necessary feeder symmetry.

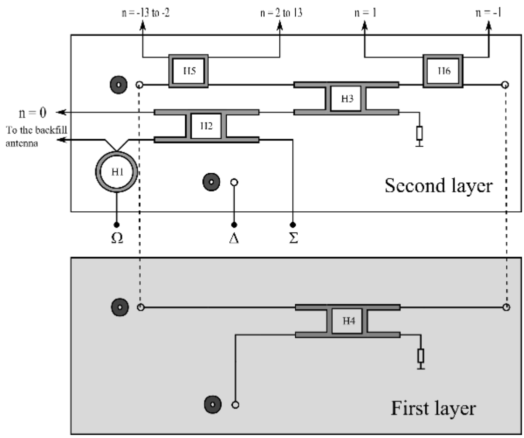

Fig. 7: The double layer structure of the horizontal feeder central section

2.2 Vertical feeder

The vertical irradiator's columns of the SSR antenna are situated in front of the PSR antenna so their forms and dimensions considerable affect the PSR antenna parameters, particularly its sidelobe level. Using EM field simulation and experimental verification it was found that the columns should not exceed a profile of about 85 mm x 25 mm including irradiators. Those were designed as unsymmetrically back - fed patch antennas, with contours corresponding to the fins widths. The design and parameters of the SSR antenna irradiators are described in [5].

The vertical feeder circuit diagram and the signal distribution, generating the required cosec^2 vertical antenna diagram are shown in the Fig. 8. Due to the highly non-uniform signal amplitude distribution at the feeder outputs mainly non-symmetrical branch line power dividers were used and only the symmetrical D7 divider was realized as a Wilkinson power divider.

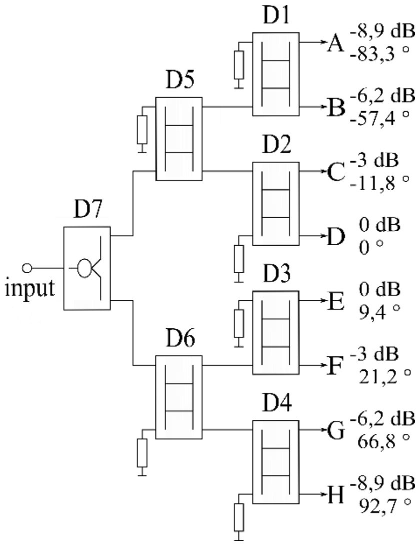

Fig. 8: The SSR antenna vertical feeder circuit diagram

To meet the dimension constrains the vertical feeder is designed in a two level configuration similarly to the central section of the horizontal feeder. In the first level dividers D1 through D4 and all feeder outputs and the feeder input are situated. At the second level only the dividers D5, D6 and D7 are placed with interconnecting lines. The circuits at the individual levels are interconnected using a special perpendicular transitions, described in the section 2.3. To further save space we used a highly distorted form of the branch line couplers with folded longitudinal branches and bended output arms as shown in the Fig. 9. This solution resulted in the circuit width of 72.5 mm meeting the above mentioned overall fins depth limit.

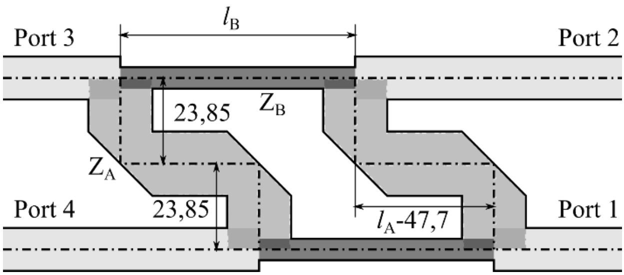

Fig. 9: The vertical feeder dividers layout

2.3 The SSR feeder accessories - termination and layers interconnections

Some of the SSR antenna power dividers were designed as four port devices with terminations at their isolated ports. The central section of the horizontal feeder and the whole vertical feeder have got the double layer configurations with perpendicular interconnections between the individual layers. These terminations and interconnections were developed using the CST Studio simulation again. The layouts of the both circuit elements are shown in the Fig. 10.

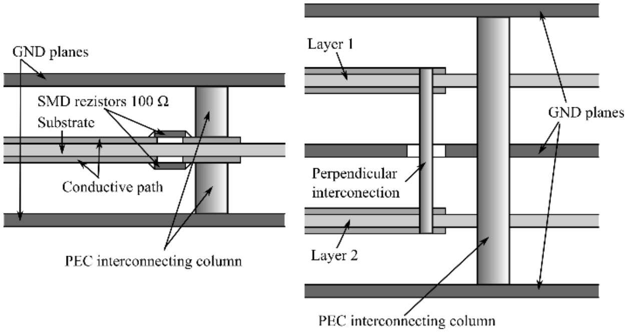

Fig. 10: The 50 Ω termination and the perpendicular interconnection design

For the termination two 100 Ω SMD resistors had to be used in parallel situated on the opposite sides of the dielectric slab to reach the reverse attenuation of more than 20 dB in the whole frequency band.

In the case of interconnection an additional grounded conductor was supplemented to compensate a smaller center conductor capacity to ground.

3 Conclusion

The design of integrated 3D primary surveillance radar and a monopulse secondary surveillance radar (MSSR) antenna array is briefly described. The topology and parameters of horizontal and vertical feeders are proposed and discussed. Individual power dividers were calculated and designed and some problematic part of feeder (for example perpendicular interconnection) are described in detail. Some simulated parameters are compared with real measurement and it is obvious that they are very close.

Acknowledgement

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