

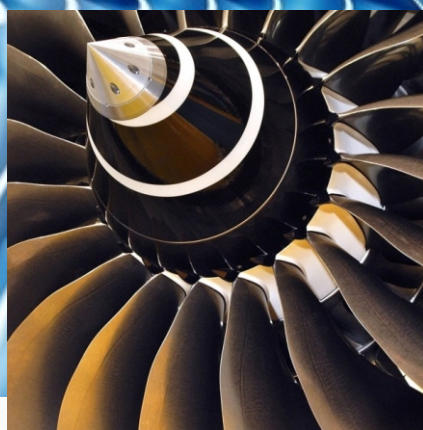
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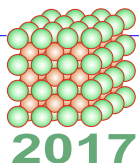
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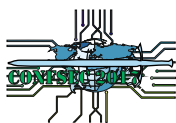
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ANALYSIS OF THE METHOD FOR PREDICTING THE TECHNICAL CONDITION OF AIRCRAFT EQUIPMENT

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Abstract: This report analyzes the accuracy of predicting by the method of least squares and neuron networks. This study compares the errors and deviations of the predicted results from the actual ones. Considered are three options - when the parameter is defined by linear, quadratic and exponential law.

KEYWORDS: NEURON NETWORKS, PREDICTING, TECHNICAL CONDITION, AIRCRAFT EQUIPMENT

АНАЛИЗ НА МЕТОДИ ЗА ПРОГНОЗИРАНЕ НА ТЕХНИЧЕСКОТО СЪСТОЯНИЕТО НА АВИАЦИОННОТО ОБОРУДВАНЕ

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Abstract: В настоящия доклад е направен анализ на точността на прогнозиране чрез метода на най-малките квадрати и невроните мрежи. При изследването се сравняват грешките и отклоненията на прогнозните резултати от реалните. Разглеждат се три варианта – когато изменението на параметъра се описва чрез линеен, квадратичен и експоненциален закон.

KEYWORDS: НЕВРОННИ МРЕЖИ, ПРОГНОЗИРАНЕ, ТЕХНИЧЕСКО СЪСТОЯНИЕ, АВИАЦИОННО ОБОРУДВАНЕ

1. Introduction

Recently, the interest in predicting the technical condition and reliability of technical systems has greatly increased. Of particular interest is the task of individual forecasting. It's solution allows not only to obtain an assessment of the condition and reliability of each particular site, but also under certain conditions to move from service to time and resource to conditional operation.

In modern aviation equipment (AE), different types of reservations are used to increase flight safety. Despite the measures implemented, it is not entirely possible to exclude the possibility of AE failures. Even the malfunction of the device that switches between the main and the backup unit can be considered a failure.

The condition of the AE is assessed by the specific values of the initial parameters determining its working capacity. These parameters, influenced by various factors depending on the conditions of storage and operation, change their values following random law.

The determination of the law of variation of a given parameter in the task of predicting is based on one of the basic postulates of physics formulated by K. Shenon. This postulate is based on the assumption that the fundamental patterns observed in the past will be preserved in the future.

The general task of predicting the change in the parameters characterizing AO is to predict the characteristics of the random process $y(t)$ at a certain future time using the results of the control. [1]

The most common methods for solving this task are the various methods of approximation, regression analysis and analysis of time series.

This report discusses three variants of possible changes in the analyzed parameter when it is described following linear, quadratic and exponential laws. In order to predict the future values of the parameter, two methods are used - the least squares method and neural networks.

2 Experimental part

2.1 Model of control parameter

Here is considered a control parameter that varies over time:

-by linear law:

$$(1) \quad y(t) = a_0 + a_1 t + \varepsilon$$

- by quadratic law:

$$(2) \quad y(t) = a_0 + a_1 t + a_2 t^2 + \varepsilon$$

- by exponential law:

$$(3) \quad y(t) = a_0 e^{a_1 t} + \varepsilon$$

where a_0 , a_1 and a_2 are random parameters, and ε is an error in measuring the value of the parameter, having a random value and a normal distribution.

2.2 Assessing the accuracy and reliability of predictions

An important milestone in predicting is the assessment of the accuracy and reliability of the predictions. [2]

The measure of accuracy of the prediction is the value of the error, which is determined by the difference between $\bar{y}_t$ the estimated and the y_t real value of the survey parameter.

This approach is possible only in two cases:

1. the determining period is known, it is finished and the researcher has the actual values of the parameter being analyzed.
2. a retrospective prediction is compiled, i.e. the values of the parameter for a period of time, for which we have real values, are

calculated. This is done in order to verify the developed prediction method.

In this case, all available information is divided into two parts in a ratio of 2/3 to 1/3. Some of the information (the first 2/3 of the time line) serves to create the prediction model. The second part of the information (the last 1/3 of the time line) serves to assess the accuracy of the prediction.

In this article, the two methods used for predicting are compared using Mean Squared Error (MSE) values and Tale's inaccuracy coefficients.

Mean Squared Error (MSE) –

$$(4) \quad S = \sqrt{\frac{\sum_{t=1}^n (y_t - \bar{y}_t)^2}{n}}$$

Tale's inaccuracy coefficient - determined as the ratio of the MSE to the square root of the real values [3,4] .

$$(5) \quad U = \sqrt{\frac{\sum_{t=1}^n (\bar{y}_t - y_t)^2}{\sum_{t=1}^n y_t^2}}$$

At U=0, we have a complete match of predicted and actual values.

At U=1, an MSE value comparable to the error obtained by applying the most common extrapolation methods is obtained.

At U>1, the estimated values manifest very large deviations from the actual ones and the mathematical model used for predicting must be rejected. The coefficient has no upper limit.

2.3 Prediction models

The least squares method (LSM) is one of the most common methods in performing a time series data regression analysis. The criterion, following which the model is created, is to minimize the sum of the squares of the error between the actual and the calculated value.

The neural network is a parallel processing system that has the ability to store and use experimental knowledge. The information in a neural network accumulates in the learning process, and the strength of neuronal connections is modeled with the weights of the relevant relationships that are used to store information. This article uses NARX (Nonlinear autoregressive with external input) networks. It can learn to predict one time series given past values of the same time series, the feedback input, and another time series called the external or exogenous time series.

2.3.1 Predicting the values of a parameter that is modified following a linear law

When extrapolating on the values of a parameter that is changed following linear law (1), the differences and errors between the methods of the LSM and the Neural Networks are minimal.

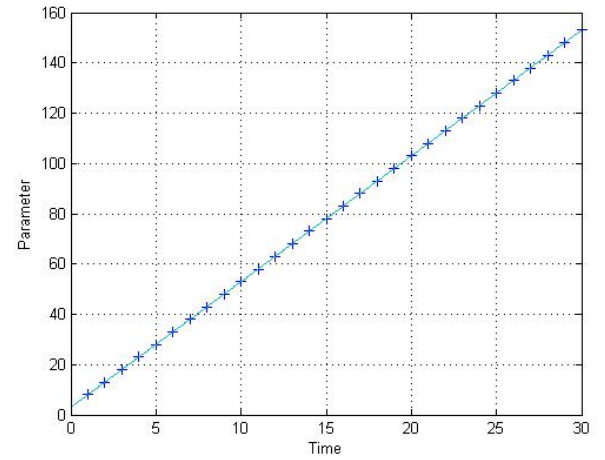


Fig. 1 Approximation of a parameter that is modified following a linear law

Determination of accuracy:

Mean Squared Error (MSE)
-LSM

S=1.3923

-Neural Networks

S=0.730198

Tale's inaccuracy coefficient
-LSM

U=3.1e-003

-Neural Networks

U=3.51e-004

2.3.2 Predicting the values of a parameter that is modified following a quadratic law

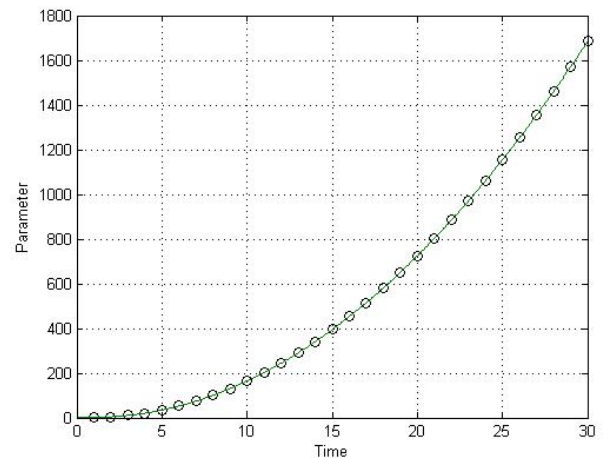


Fig. 2 Approximation of a parameter, which is modified following quadratic law, by the LSM

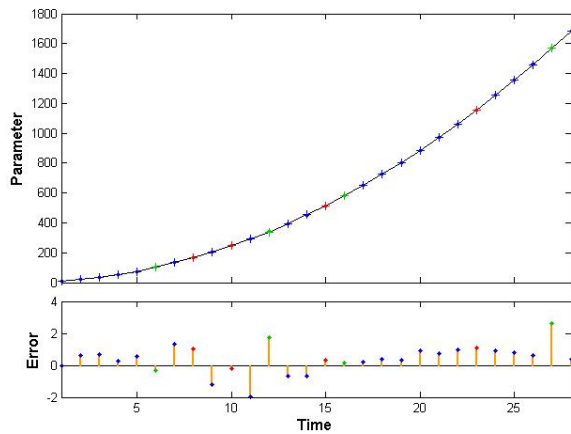


Fig. 3 Parameter approximation, modified following quadratic law, through Neural Networks

Determination of accuracy:

Mean Squared Error (MSE)

-LSM

$S=1.3923$

-Neural Networks

$S=0.693653$

Tale's inaccuracy coefficient

-LSM

$U=4.4293e-004$

-Neural Networks

$U=4.8375e-005$

2.3.3 Predicting the values of a parameter that is changed following exponential law

In the approximation of LSM 3rd and 4th degree polynomials are used. With higher degree polynomials, the error starts to grow.

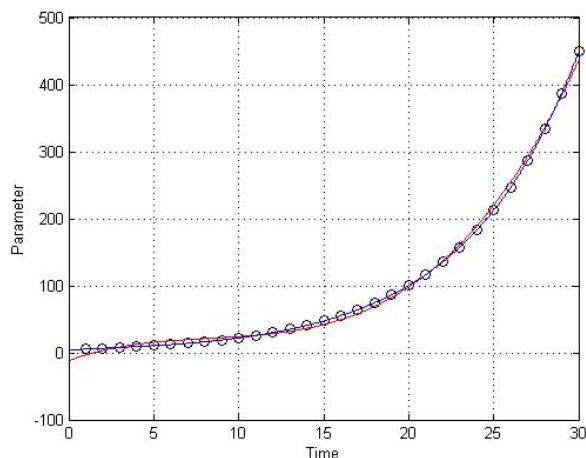


Fig. 4 Approximation of a parameter, which is modified following exponential law, by the MNC

Red - polynomial of 3rd degree

Blue - polynomial of 4th degree

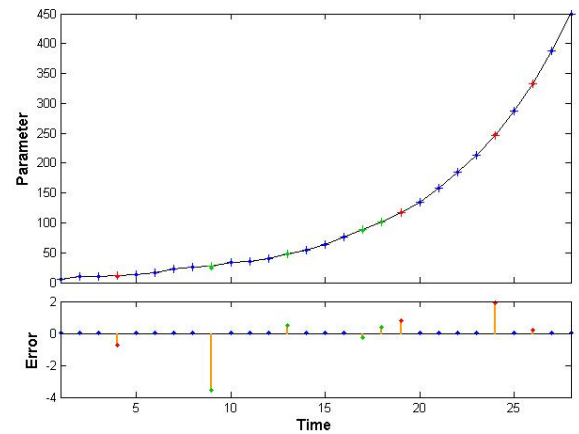


Fig. 5 Approximation of a parameter that changes following exponential law through Neural Networks

Determination of accuracy:

Mean Squared Error (MSE)

-LSM

$S_3=5.3557$

$S_4=1.5662$

-Neural Networks

$S=6.9036e-005$

Tale's inaccuracy coefficient

-LSM

$U_3=9.1e-003$

$U_4=2.7e-003$

-Neural Networks

$U=8.1804e-006$

3. Conclusion

The analysis of the prognostic results that are obtained using neural networks and the LSM method shows that with the use of the neural network apparatus, more accurate prediction can be achieved than with the classic LSM. When the character of the change of the examined parameter is described following a linear or quadratic law, the difference between the two methods under examination is minimal, but the neural networks manifest a smaller error. When the research parameter is described following exponential law, the difference in favor of neural networks is of the order of 10^2 - 10^3 times smaller error.

This in turn makes it possible to perform a much more accurate assessment of the condition of the aviation equipment and to reduce the probability of in-flight failure.

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FINITE ELEMENT ANALYSIS OF TORSIONAL-FLEXURAL BEHAVIOUR OF THIN-WALLED FRAME CONSIDERING JOINT WARPING CONDITIONS

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Abstract: Frames composed of thin-walled beam elements are frequently used as load-carrying systems in engineering practice. In this work the influence of different structural joint types on torsional moment transmission from column to beam is analysed. Two types of beam cross sections are considered, the I-beam cross section and the channel one. Four different structural joints are examined for both cross sectional types. Numerical simulations are undertaken using MSC. Nastran's shell model consisting of eight-noded flat elements. The results obtained are discussed through the test problems.

Keywords: FRAMES, THIN-WALLED BEAM, JOINTS, TORSION, WARPING

1. Introduction

Frames composed of thin-walled beam elements are frequently used as load-carrying systems in engineering practice. They are appealing because of their high stiffness-to-mass ratio, but such weight-optimised structures display a very complex structural behavior [1-2]. Load-carrying evaluations of such structures are usually carried out under the assumption of a simplified torsional-flexural behaviour of structural joints, completely ignoring the torsional-warping characteristics. Although such an approach simplified the analysis significantly, it fails to represent the real frame behaviour, because the joints of actual frames could exhibit a flexible warping behaviour falling in between the two extreme warping boundary condition cases: fully restrained and free warping conditions [3-4].

Analysis of thin-walled frames have shown that torsion applied to one member can be transmitted to unloaded one generating at the same time flexure in that member. In the case of solid frames and structures it is only the flexure that is produced in the second member. Relating to Morell [5] and Sharman [6], joint structure at the connecting point of two members affect magnitude and orientation of torsion transferred from column to beam. There are

two components of deformation in function of imposed torque: one due to St. Venant's torsion and another one due to the warping torsion.

The steel frame examined in this paper is composed of two thin-walled elements joined by the joint. Two types of beam cross-sections are considered: I-section and channel one. Dimensions of the frame and cross-section geometries are given in Fig. 1. The structure is clamped at both ends and loaded by a torque approximately at the middle point of a column. Joint types studied in this work are: unstiffened mitre joint, box joint, stiffened mitre joint and a combination of stiffened mitre and box joint, Fig 2.

The purpose of this work is to determine how the warping is transmitted due to joint type and to obtain the real frame behavior. In Morell's work [5] the influence of joint type on an unloaded member deformation due to three different joint types: box joint, mitre joint and stiffened mitre joint, respectively, was presented. It was shown that in the case of box joint the deformation of the unloaded member is mainly influenced by the warping, while in the case of stiffened mitre joint St. Venant's torsion was more dominant.

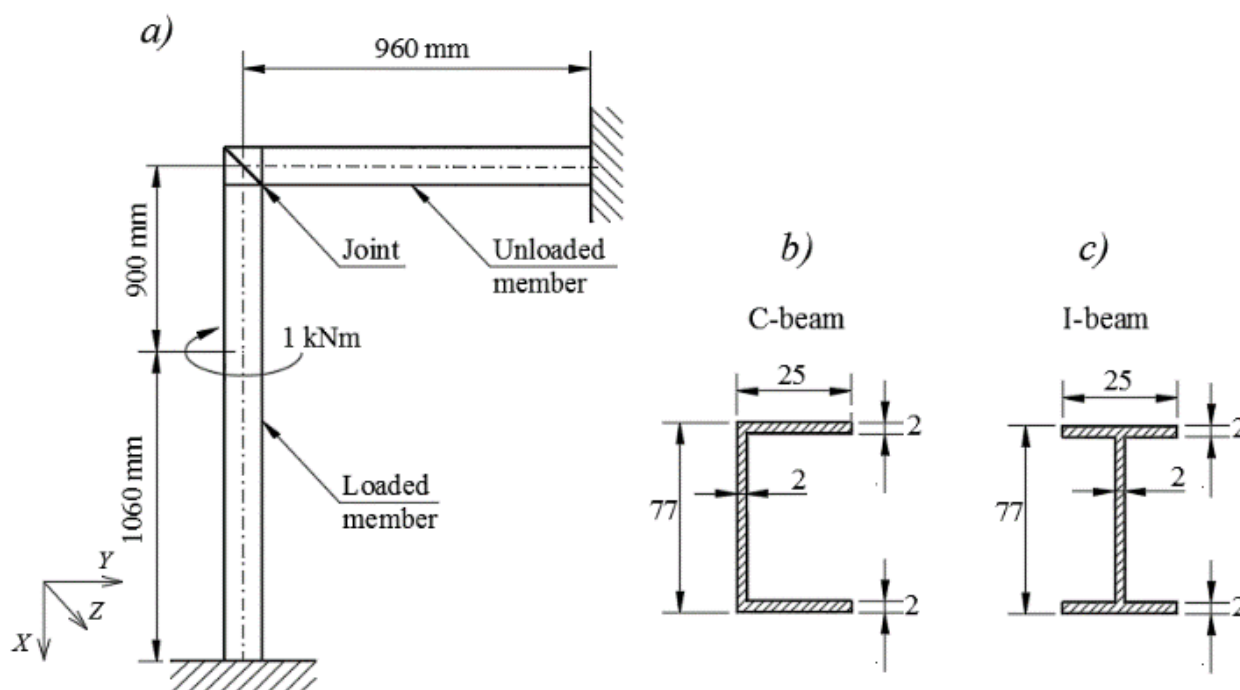


Fig. 1 Structure analyzed: a) L-frame; b) geometry of C-beam; c) geometry of I-beam

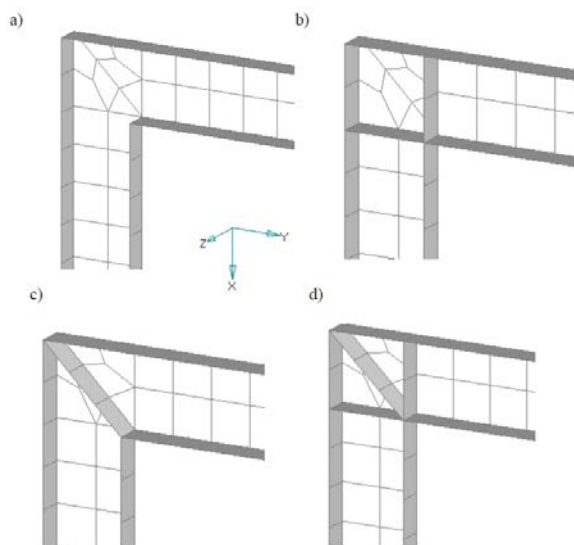


Fig. 2 Joint types: a) unstiffened mitre joint; b) box joint; c) stiffened mitre joint; d) box/stiffened mitre joint

2. Numerical analysis

Numerical simulations are undertaken using MSC. Nastran's shell model consisting of eight-noded flat elements. The results obtained in the finite element study are presented using diagram-forms: two for each joint type showing both cross-sections. As well, the results obtained for the channel-section are compared with those given by Morell [5]. As one can see, a good agreement has been established. Thereby, mesh quality is proved.

As announced, there are two diagrams for each case analyzed: first one representing the rotation about the Y-direction along the unloaded member, and the second one representing the rotation about the X-direction along the loaded member, always generating the similar curve trend.

2.1 Unstiffened mitre joint

Fig. 3 shows the rotation of the unloaded member about the Y-direction. As one can see, the rotation of the channel beam is mainly positive, while for the I-beam it is negative and reaches higher absolute values.

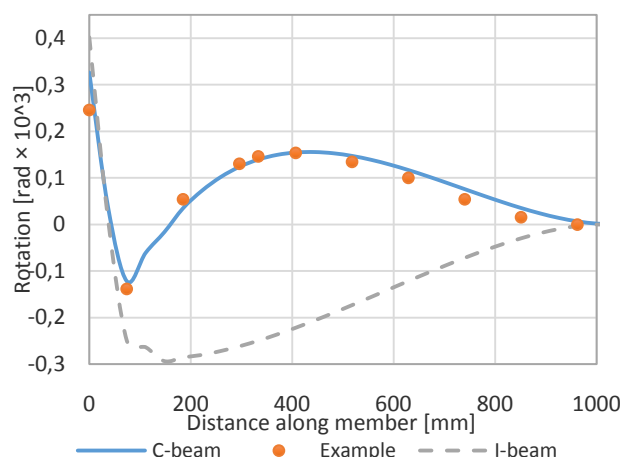
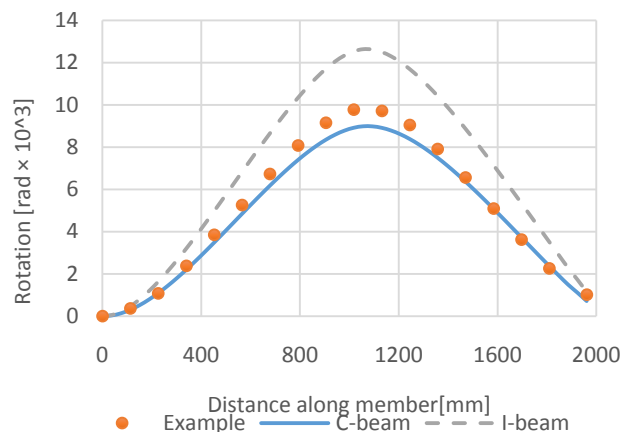


Fig. 3 Unstiffened mitre joint – rotation of the unloaded member

On the other hand, the rotation of the loaded member is positive with the highest value at the point where the torque is applied, Fig. 4. The results obtained for the channel-section are very close to

those reported by Morell and of lower values than those obtained



for the I-beam.

Fig. 4 Unstiffened mitre joint – rotation of the loaded member

2.2 Box joint

The box joint is a stiffer joint type than the mitre joint therefore causing different response of the unloaded member. In contrast to the unstiffened mitre joint, in this case the negative rotation about the Y-direction occurs, Fig. 5. The rotation of the loaded member is drawn in Fig. 6. As expected, the loaded member rotates in a positive direction of the X-axis, reaching lower values than those obtained for the mitre joint.

Again, higher deformation values are obtained in the case of I-beam for both loaded and unloaded members.

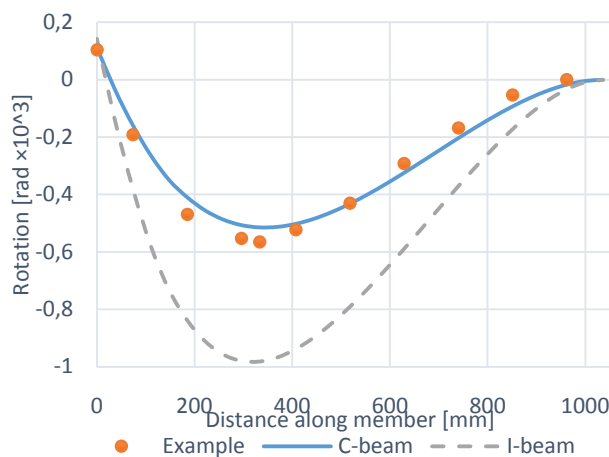


Fig. 5 Box joint – rotation of the unloaded member

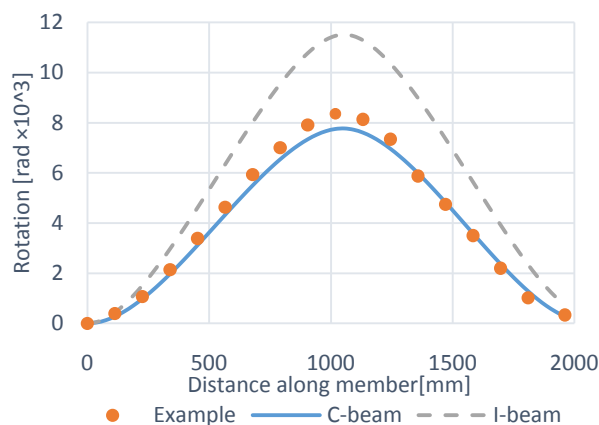


Fig. 6 Box joint – rotation of the loaded member

2.3 Stiffened mitre joint

Fig. 7 shows the rotation of the unloaded member at the frame with the stiffened mitre joint. In contrast to the preceding cases, the rotation of the unloaded I-member achieves lower values comparing to the channel section. The rotation of the loaded members is shown in Fig. 8.

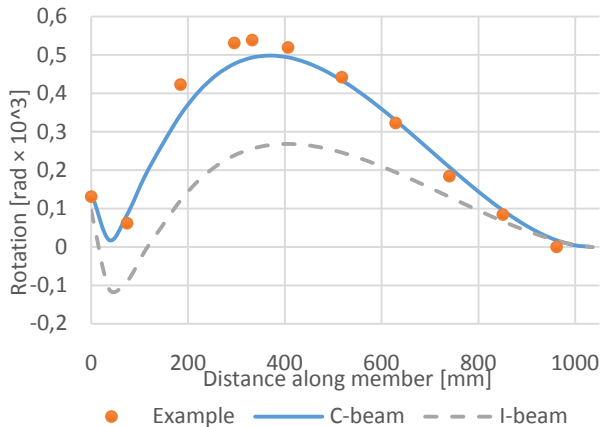


Fig. 7 Stiffened mitre joint – rotation of the unloaded member

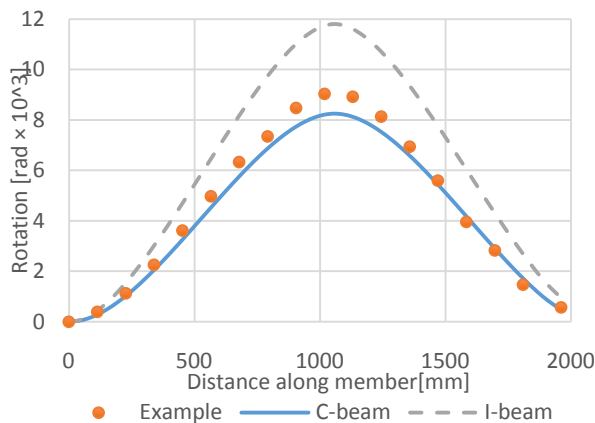


Fig. 8 Stiffened mitre joint – rotation of the loaded member

2.4 Box/stiffened mitre joint

Since the box-stiffened mitre joint is a combination of the two joint types gives similar response to that obtained for the box joint frame, Figs. 9 and 10.

However, it should be noticed that intensity of the rotation is smaller due to the stiffer structure.

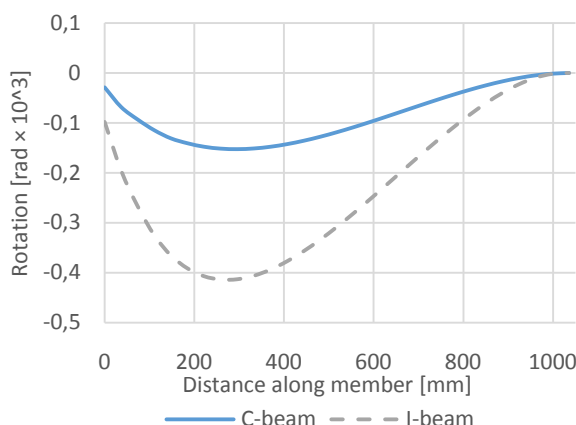


Fig. 9 Box/stiffened mitre joint – rotation of the unloaded member

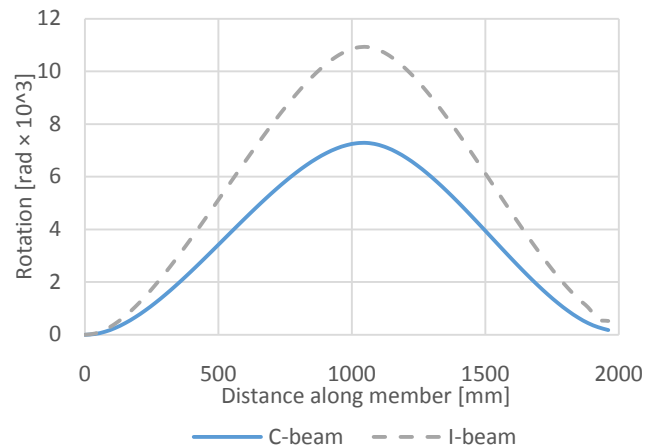


Fig. 10 Box/stiffened mitre joint – rotation of the loaded member

3. Conclusion

A numerical analysis, based on the finite element method, of several beam-to-column joint types has been presented. In this, a plate model consisting of eight-noded flat elements has been employed.

In all the cases a positive rotation has been obtained at loaded member, as it has been expected. The lowest values of rotation are obtained at the box/stiffened joint type. Analyzing frame composed of channel sections, positive rotations have been obtained at the unloaded member in the cases of mitre and stiffened mitre joints, while negative rotations have occurred at the other two joint types.

The topic of our further research is to examine warping transmission to unloaded member due to the joint type.

Acknowledgment

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OPTIMAL CONTROL OF QUARTER CAR VEHICLE SUSPENSIONS

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Abstract: this paper deals with the comparison of Control of quarter car vehicle suspension using Linear Quadratic Regulator (LQR) and Fuzzy Logic Controller (FLC) which are considered to control quarter car suspension and computer simulation is done on the nonlinear quarter-car model with actuator dynamics. The Linear Quadratic Regulator (LQR) and Linear Quadratic Gaussian (LQG) methods are the most used control approaches. LQR and FLC provide the possibility to emphasize quantifiable issues of vehicle suspensions like; ride comfort and road holding for varying external conditions.

Keywords: VEHICLE, SUSPENSION, NONLINEAR, LQR, FLC.

1. Introduction

The dynamics of vehicle suspensions is usually highly nonlinear. Therefore their control for active and semi-active should be nonlinear, e.g. gain scheduling. The LQR and LQG methods are the most used control approaches. Both methods use a state –space equation with a quadratic performance index and derive the optimal control law by solving a matrix Riccati equation, while LQG needs an additional design of Kalman filter. In reality, these active suspension systems are relatively complex, consisting of several nonlinear elements. "The more complex a system is, the more precision and significance (of the system's model) become mutually exclusive Zadeh 1973."

The control is being done usually by parameter optimisation of proposed control law, (Pajaziti, 1992). This is however difficult and especially tedious task requiring many iterations.

In recent years, advanced vehicle suspension concepts such as adaptive, semi-active and active suspensions have attracted increased attentions because of improving vehicle ride comfort and road handling performance. Such suspension systems using electromechanic or electrohydraulic components have been investigated and developed in the automobile industry (Toshio et al. 1990, Wallentowitz and Konik 1991). The other approach is new direct synthesis of nonlinear optimal control by (Vaculín et al., 2000).

There were some new control approaches applied to control design of active suspensions, such as the variable structure system control (Roukieh and Titli 1992), nonlinear control (Alleyne and Hendrik, 1992), optimal control (Venhovens, 1997), and (Likaj, 1998) etc. Besides that also other approaches exist like fuzzy logic control.

The model of the quarter-car active suspension system used in this paper with two degree of freedom is shown in Fig.1.

The model represents a single wheel of a car in which the wheel is connected to the quarter portion of the car body through an hydropneumatic suspension.

The equations of motion for this system are given as:

$$\begin{aligned} m_b \ddot{z}_b &= f_a - k_1(z_b - z_t) - c_s(\dot{z}_b - \dot{z}_t) \\ m_t \ddot{z}_t &= -f_a + k_1(z_b - z_t) + c_s(\dot{z}_b - \dot{z}_t) - k_2(z_t - z_r) \end{aligned} \quad (1)$$

2. Nonlinear dynamic control

The dynamics of the nonlinear system is generally described by the equations

$$\frac{dx}{dt} = f(x) + g(x)u \quad (2)$$

where $x(nx1)$ is the state and $u(mx1)$ is the control. If there exists the decomposition of the system dynamics

$$f(x) = A(x)x \quad (3)$$

which leads to the decomposed system

$$\frac{dx}{dt} = A(x)x + g(x)u \quad (4)$$

with some properties like controllability of couple $(A(x), g(x))$ in each state position x . Then for the quadratic performance index of the infinite horizon control problem

$$J = \int_0^{\infty} (x^T Q x + 2x^T S \cdot f_a + u^T R u) dt \quad (5)$$

$$u = -K(x)x \quad (6)$$

The state dependent gain matrix $K(x)$ is obtained as

$$K(x) = R^{-1}(S^T + B^T \cdot P) \quad (7)$$

where P is the solution of the Riccati equations.

$$-PA - A^T P + (PB + S)R^{-1}(B^T P + S^T) - Q = 0 \quad (8)$$

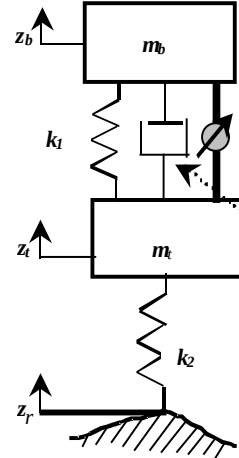


Fig.1 Quarter-car model

where:

- $z_b - z_t$ = body displacement
- $z_t - z_r$ = wheel displacement
- $\dot{z}_b - \dot{z}_t$ = susp. velocity
- $\dot{z}_b$ = absolute velocity of the body
- $\dot{z}_t$ = absolute velocity of the wheel
- z_b = body mass 200 kg
- z_t = wheel mass 33 kg
- k_1 = spring constant 9000N/m
- k_2 = spring constant 200000 N/m
- c_s = damping ratio 1600 Ns/m

3. Fuzzy Logic Controller

FLC has accelerated in recent years in many areas, including feedback control. A fuzzy logic approach for hydropneumatic suspension is presented by (Cai and Konik, 1993). By using empirical rules according to the designers knowledge and experience, which are represented linguistically with the conditional statements and resulting assertion, a FLC is developed and then compared with the optimal state feedback control method.

A fuzzy rule base has a very significant effect on the control strategy in a fuzzy controller, in other words it defines the strategy of the controller. To the active suspension system there are at least three main objectives, namely ride comfort, suspension travel and handling. The rule base can be tuned to improve each of the above objectives.

The fuzzy logic controller used in the active suspension has three inputs: body acceleration $\ddot{z}_b$, body velocity $\dot{z}_b$, body deflection velocity $\dot{z}_b - \dot{z}_t$ and one output: desired actuator force f_a . The control system itself consists of three steps: fuzzification, fuzzy inference machine and defuzzification. During the fuzzification process the real numbers (crisp) inputs will be converted into fuzzy values, where after fuzzy interference machine processes the input data and computes in cope with the rule base and database. The obtained outputs (fuzzy values) are converted into real numbers by the defuzzification step. Membership functions are chosen for the inputs and the output variables with the following variables: NV-negative very big, NB-negative big, NM-negative medium, NS-negative small, N-negative, ZE-zero, P-positive, PS-positive small, PM-positive medium, PB-positive big, PV-positive very big.

The fuzzy rule based system modeled by designer's knowledge and experience is shown in Table 1.

Rules of the controller have the following general form:

$$R_i : \text{IF } < \ddot{z}_b \text{ is } A_i \text{ AND } < \dot{z}_b \text{ is } B_i > \text{ AND } < \dot{z}_b - \dot{z}_t \text{ is } C_i, \quad (9) \\ \text{THEN } < f_a \text{ is } D_i > .$$

Where: A_i , B_i , C_i and D_i are labels of fuzzy sets representing the linguistic values of $\dot{z}_b - \dot{z}_t$, $\dot{z}_b$, z_b and f_a , which are characterised by their membership functions

$$-1 \leq \dot{z}_b - \dot{z}_t \leq 1; -1 \leq \dot{z}_b \leq 1; -4 \leq \ddot{z}_b \leq 4; -4000 \leq f_a \leq 4000 .$$

Table 1: Rule base.

$\ddot{z}_b$	$\dot{z}_b$	$\dot{z}_b - \dot{z}_t$	f_a
ZE	P	P	NS
ZE	P	ZE	NM
ZE	P	N	NB
ZE	ZE	P	PS
ZE	ZE	ZE	ZE
ZE	ZE	N	NS
ZE	N	P	PB
ZE	N	ZE	PM
ZE	N	N	PS
P or N	P	P	NM
P or N	P	ZE	NB
P or N	P	N	NV
P or N	ZE	P	PM
P or N	ZE	ZE	ZE
P or N	ZE	N	NM
P or N	N	P	PV
P or N	N	ZE	PB
P or N	N	N	PM

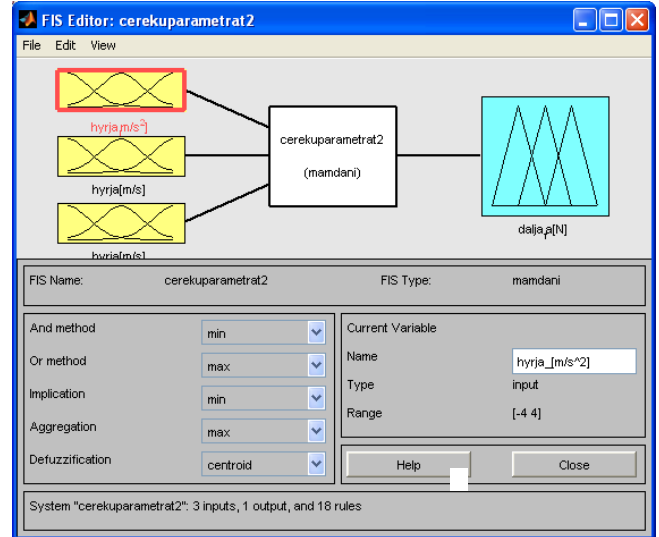
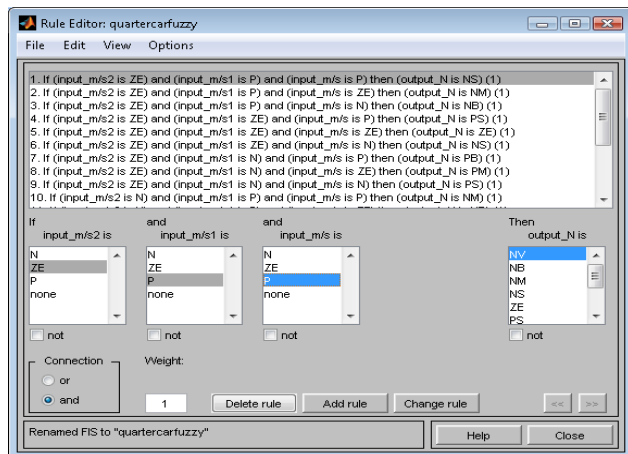


Fig.2 FIS Editor for Quarter-car model

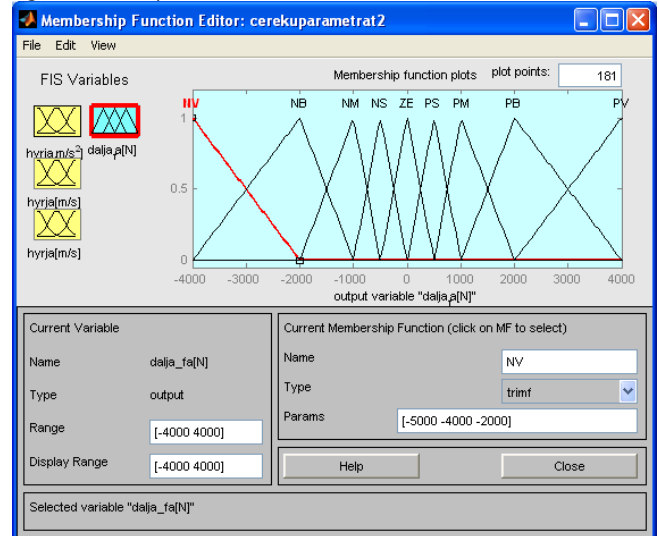


Fig.3 Membership Function Editor for Quarter-car model

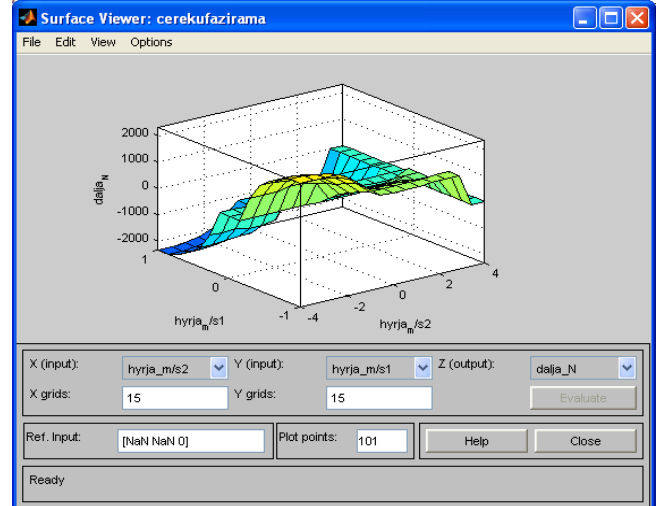


Fig.4 Surface Viewer for Quarter-car model

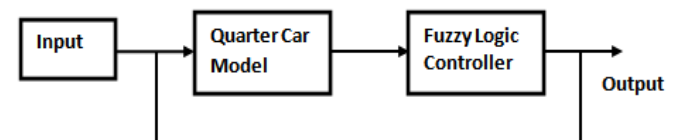


Fig. 5 Control scheme of quarter car model

4. Active Suspension control using Linear Quadratic Gaussian Control

The control system design is based on the theory of linear optimal control because Linear Quadratic Gaussian (LQG) offers the possibility to emphasize quantifiable issues like ride comfort or road holding very easily by altering the weighting factor of a quadratic criterion. The theory used assumes that the plant (vehicle model+road unevenness model) is excited by white noise that is Gaussian distributed. The term quadratic is related to a quadratic performance index. Minimization of this quadratic penalty function results in a feedback control law.

The object of linear optimal control theory is to specify an input vector $\underline{u}$ which drives a system to a specific target state in such a way that, during the process, a defined quadratic cost function J is minimized. Minimization of the performance criterion yields an optimal feedback law compromising control effort (actuator power) and control quality (ride comfort and road holding ability).

The quadratic cost function in general form is:

$$J = \int_0^T (\underline{x}^T Q \underline{x} + \underline{u}^T R \underline{u}) \cdot dx \quad (10)$$

where Q and R are weighting matrices, $\underline{x}$ is state vector and $\underline{u}$ control vector.

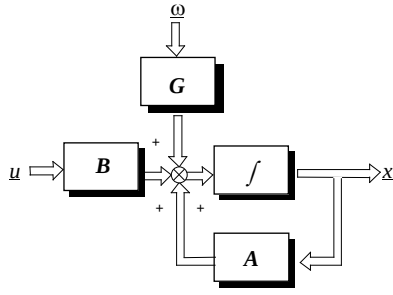


Fig. 6 Block diagram of the system in state space form

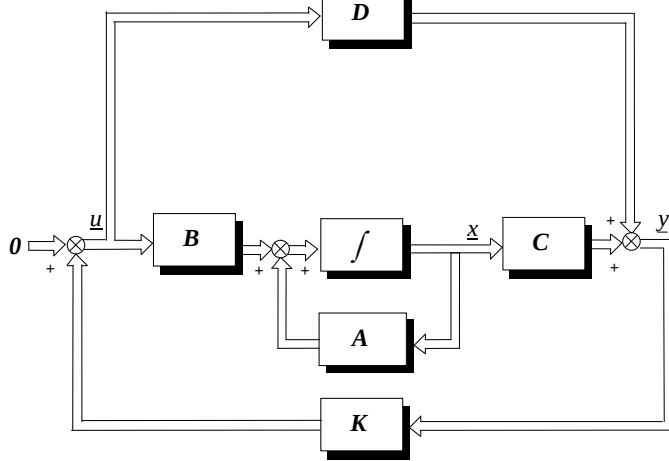


Fig. 7 Block diagram of the control system in state space form

In a real active or semi-active suspension system it will be of interests to examine the performance of the system under the assumption that only velocity signals are available for the feedback. Linear Quadratic Output Feedback (LQOF) will be used to determine the control feedback matrix. Limited state feedback is often used to minimize the number of states to be determined by measurements, but some states are very difficult to measure. The control structure can be selected through the output equation:

$$\underline{y} = C\underline{x} \quad (11)$$

Input vector $\underline{u}$ is proportionally related to the output vector $\underline{y}$ by the matrix K :

$$\underline{u} = K\underline{y} = KC\underline{x} \quad (12)$$

The combination of feedback law and the vehicle system gives a closed-loop state equation according to:

$$\dot{\underline{x}} = (A + BKC)\underline{x} \quad (13)$$

Fig. 7 shows the output feedback structure of the closed-loop system. The design of an optimal constant gain output feedback matrix K involves the selection of the weighting factors the choice of an initial feedback law and the selection of an initial condition. The solution K must be found using an iterative algorithm using a gradient search technique

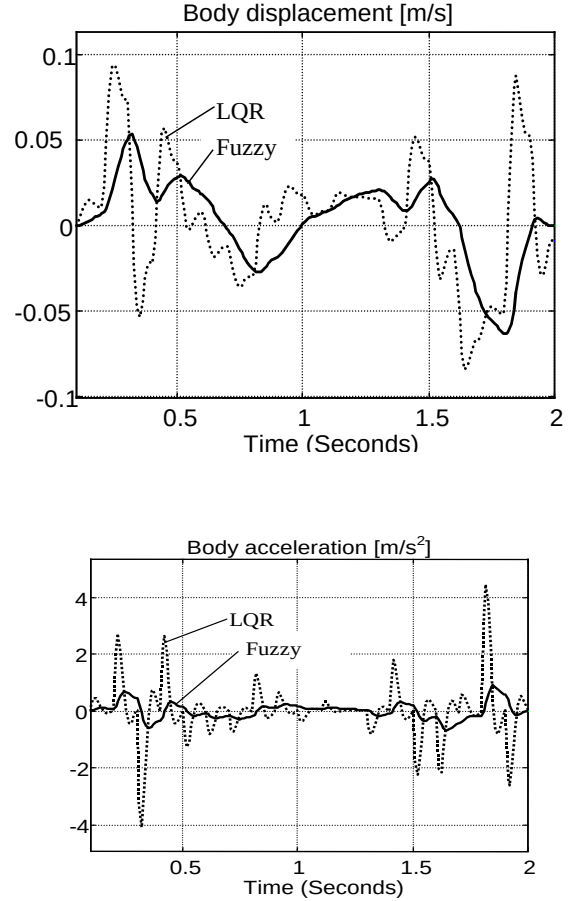


Fig. 8 Body Displacement and Acceleration of quarter car model

4. Conclusions

Both active suspension systems using LQR and FL Controllers can reduce vertical accelerations, and body displacements, Fig.8. So, the main properties: ride comfort and road holding were achieved for the quarter car model. For the design of an FLC, an accurate vehicle model is not needed, but it's a very difficult task to express the knowledge and experience in terms of fuzzy logic.

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THE EFFECTS OF TRANSPORT ON THE ECOSYSTEM AND HUMAN HEALTH

ВОЗДЕЙСТВИЕ ТРАНСПОРТА НА ЭКОСИСТЕМЫ И ЗДОРОВЬЕ ЧЕЛОВЕКА

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Abstract: The growth rates vehicles pose a significant threat to the physical and chemical status of the atmosphere and negatively impact on human health and viability of other living organisms. The ecological status of airspace in the cities of the modern world, is determined by numerous factors, among which the leading position is taken by motor vehicles, during operation of which, along with the exhaust gases, more than 200 chemical compounds are emitted into the atmosphere.

The paper describes the results of studies of motor vehicles on highways adjacent to the territory of Kutaisi, from ecological standpoint.

As a realistic way for solving the problems would be the use of alternative fuels, rational organization and management of traffic flow, and the large-scale introduction of electric cars and hybrid motor vehicles.

KEYWORDS : HARMFUL EXHAUSTS ; ECOLOGY ; HEALTH ; ALTERNATIVE FUEL.

1.Introduction

The current growth rates of vehicles pose a significant threat to the physical and chemical status of the atmosphere, since toxic compounds emitted during transportation and the radiated acoustic energy cause disruption of ecological balance of the atmosphere. The negative effect of transport implies its negative impact on the ecosystem and human health, which is caused by the existence of toxic impurities in combustion products, consumption of oxygen, the release of wear products into the environment, contamination of effluent waters, noise and vibration arising during the work.

Ecological status of airspace in the large cities of the contemporary world is determined by numerous factors, prominent among which is motor transport, during operation of which, along with the exhaust gases, more than 200 chemical compounds are emitted into the atmosphere. They include such compounds, which do not affect negatively the human body (nitrogen, water steam, oxygen), although the most part is represented by toxic substances negatively affecting as the human body, so plant and animal life.

Asphyxiating gas (carbon dioxide CO₂) is not only production of fuel combustion in the engine's cylinder. It is a colorless, tasteless, odorless, and poorly water soluble gas, and it arises as a result of incomplete combustion of carbon under conditions of the lack of oxygen. Carbon dioxide taken into the organism together with the inspiratory air binds to hemoglobin and creates pink-color compound, causes lack of oxygen in the blood and strains normal respiration, due to which it is called asphyxiating gas. Asphyxiating gas causes dizziness, headache, coughing, a person loses the ability to sense, and often proved lethal.

Of nitrogen compounds in the airspace of highways, we mostly find monoxide (NO) and dioxide (NO₂). Nitrogen monoxide is a colorless gas and oxidized until dioxide (NO₂), which has dark yellow color, and is by 7-times more toxic than monoxide. Nitrogen dioxide impairs eyesight and particularly effects on people (especially on children) suffering from asthma and bronchitis.

Activity of low-molecular gaseous hydrocarbons in the combustion products is manifested in a narcotic effect on the human organism, and evokes a state of euphoria. As to polycyclic aromatic hydrocarbons, they are carcinogenic – cause lung cancer and central

nervous system disorder. Among them, Benzo(α)pyrene - C₂₀H₁₂, is characterized by highest activity. Nitrogen oxides, under the photochemical effect of sunlight, react with hydrocarbon compounds and create poisonous mist, which strongly effects on the tissues, plant and animal life, the mucous membrane and respiratory organs.

Sulphur anhydride is a colorless gas having bad smell, whose even small concentration (20-30 mg/m³) causes irritation of the mucous membrane of eyes and respiratory organs and human poisoning within minutes. A long-term effect of the compound of sulphur (SO₂) and carbon (CO) oxides causes impairment of the genetic function.

Of solid particles released into the atmosphere, the most carcinogenic are plumbic compounds, the amount of which is considerable when using ethylated petrol. Intake of plumbic compounds into the human body causes headache, fatigue, normal sleep disorder, and lowering enzymatic activity of proteins. Plumbic compounds are supplied to all parts of the organism through the blood, then they are deposited in the bone system and return back into the blood. Signs of the disease are manifested, when the concentration of plumbic compounds in the blood is 200-400 mg/l. In the child's organism, even the presence of its small concentration may prevent mental development of the child. Intake of plumbic compounds into the human body is also possible in the form of lead accumulated in the plants growing on the territory adjacent to highways.

Dust is an important source of environmental pollution, the impact of which causes various diseases. In particular, the effect of dust particles causes the irritation of the mucous membrane of respiratory organs, and leads to manifestation of conjunctiva and dermatosis.

Special mention should be made of the release of soot together with combustion products, which a black finely divided substance (sizes 0,19-0,54 mcm), and arises as a result of fuel incomplete combustion or thermal breakdown. In addition to fact that soot particles are toxic, the different-type carcinogenic substances are absorbed on their surface, and then are deposited in respiratory tracheae and bronchi.

It is important to mention that a three-fourfold increase in maximum permissible standard of tropospheric ozone and its long-term effect on the human body lead to irreversible changes in respiratory organs. According to experts, each lost percent of tropospheric ozone causes 150 thousand additional cataract cases, and incidence of skin cancer is rising by 2,6%.

Continuous effect of the polluted environment negatively affects the human body, and causes various serious diseases that is manifested in the increased incidence of diseases and the mortality rate. Life in such environment has especially negatively affects children. It causes reductions in IQ among them, memory impairment, they frequently fall ill and their learning achievements are low. For example, IQ among children living in the environment polluted by exhaust gases is by 20% lower in comparison with children, who are less affected by polluted air.

2. Preconditions and means for resolving the problem

The results of studies we carried out in Kutais can be cited for assessing the above stated facts. Because of the contraction of the industrial sector, the main source of contamination of the atmospheric air is road transport. A decrease in the quality and quantity of the air basin is caused by the sharp increase in the number of vehicles, nonstationary distribution of transport flows, relatively low quality of consumed liquid fuel, congestion of highways and so on. The carried out studies revealed that the concentration of lead, nitrogen dioxide, carbon acid, benzene and dust in the city's atmospheric air exceed maximum permissible level. In addition, air pollution is proportional to growing intensity of the number of vehicles. It has been established that by essential growing incidence in the city, there are characterized such diseases, as pneumonia, allergy, bronchial asthma, eye diseases, cancer and cardiovascular diseases.

Table 1: The action effect of the composition (g/m³) of impurities in the air on human health

No	The action effect	CO	NO ₂	SO ₂
1	The effect is subtle within hours.	115	15	6
2	In 2-3 hours, manifestation of signs of poisoning or irritation of the mucous membrane	115-575	20	130
3	Poisoning in 30 minutes	2300-3500	100	210-400
4	Short-term impact is life threatening	5700	150	1600

Numerous studies have revealed the essential role of road transport in pollution of the territories adjacent to highways, from which special emphasis should be placed on heavy metals: lead, zinc, chromium, cadmium, mercury, copper, tin and others, which are widely used in manufacturing industry, energy sector and transport. Heavy metals are released into environment mostly as the combustion products, they are accumulated in the soil and actively included in the ecological chain "chain-water-plant-product", and ended up in the human body and causing numerous diseases.

Sedimentation of heavy metals in the human body significantly affects development of the plant world, since their compounds are maximally intensely accumulated by herbaceous crops, especially by: salads, sorrel, spinach, table beet, corn stover and seed, walnut, pea, etc. Protein content is low in forage grass. Due to the morphological changes, stone fruits contain low a small amount of sugar and vitamins, agricultural productivity is declining and so on. For example, the presence of mercury in the soil accelerates drying of the plants, prevents photosynthesis process and causes disruption of activity. Lead and cadmium taken into the human body cause infarction, severe damage of the circulatory system, malignant tumors and so on.

Based on the above stated, it is important to study the agro-ecological state of the territories adjacent to the main highways, for which it is necessary to determine the accumulation dynamics of heavy metals in the agricultural products, as well as their distribution by the sections of the areas.

It is interesting that the presence of heavy metals in herbage of the plants can be also seen as a result of visual surveillance, since the existence of a certain amount of different chemical elements in them leads to obtaining special coloring, that is the formation of the pathology. For example:

- in the presence of copper, the plant leaves have dark green coloring, short and thick roots;
- iron content causes dark green coloring of leaves, and slower growth of aerial parts of plants is observed;
- in case of lead content, the plant leaves have dark green color, and relatively old leaves are bent, roots are short and have brown coloring;
- in the presence of zinc, in the ends of leaves, there is observed a plant disease – chlorism, during which leaves and shoots loose green coloring. In the leaf mass, there occurs dying of a group of cells of the entire organ or its part;
- in case of cadmium content, leaves are bent, shoots have reddish coloring and the development of roots is restricted.

3. Conclusion

The aim of our research was to study the agro-ecological situation in the territories adjacent to the main highways of Kutaisi City. In particular, the distribution of heavy metals on the territory near highway by the sections of the areas, and the accumulation dynamics of heavy metals in the agricultural products, dependent on traffic intensity and composition. The content of heavy metals in the agricultural products was determined by using the atomic absorption analysis, but the composition of heavy metals in the soils near the highway was determined by using XRF analyzer.

The studies carried out have revealed as follows:

- on the both sides of the carriageway, at 30 m from the road, lead content is growing and at the distance of 150 m, it is within the permissible limits;

- nickel content exceeds permissible level, but the content of heavy metals (Cu, Zn, Mn) in the taken objects is the permissible limits;

- near the road, normal development-growth of plants and quality characteristics of the products are impaired, agricultural productive is decreased; sugar and vitamin contents are low in stone fruits;

- agricultural crops exhibit contrasting relationships to heavy and toxic elements. For example, in larger amount of lead content is observed in corn stover than in a seed. A large amount of zinc is contained by corn stover walnut leaves.

- It should be noted that the arable layer (0-20 cm) in the territories adjacent to highways of Kutaisi contains a wide range of radionuclides, which are actively included in the ecological chain ("soil-water-plant-product") and are taken into the human body that causes numerous diseases.

If we take into account that the central highways cross arable lands, obtaining of environmentally safe agricultural products is impossible without taking radical measures. In practical terms, the promising way to address the mentioned problems consists in the use of alternative fuel, rational organization and management of traffic flows, widespread application of electric and hybrid vehicles.

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OPTIMIZATION OF PUBLIC TRANSPORT ROUTING

ОПТИМИЗАЦИЯ СОСТАВЛЕНИЯ МАРШРУТОВ ОБЩЕСТВЕННОГО ТРАНСПОРТА

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Abstract: The paper describes the urban passenger transport system which is a set of interdependent subsystems: «city», «transport», «passengers». The urban passenger transport performance indicators have been determined for all system participants. The objective functions of an optimization problem of urban passenger transport are given in general terms. The optimization criterion for traffic routing of urban passenger transport has been determined, which takes account of mutual influence of the interests of all system participants has been determined. The passenger traffic flow density on the studying road section, has been suggested as such optimization criterion. The formulation of an optimization problem of urban passenger transport have been defined as well.

KEYWORDS: PASSENGER TRANSPORT; ROUTING; EFFECTIVENESS; OPTIMIZATION, TRANSPORT SYSTEM.

1. Introduction

Passenger transport is among the most important sectors of sustainable livelihood in cities, the functioning of which affects the quality of life of people, efficiency in the economic sectors of cities and the possibility of using their city-planning and the social and economic potential.

This results from the process of dynamic social and economic development of cities, which has resulted in creating new facilities and the attraction zones for passenger flows, such as business, trade, entertaining and sports centers, changes in the structure of resettlement of residents in connection with the emergence of new zones of the active housing construction.

Concomitant with the increase of the level of automobilization of the population, road load in transport has also increased, one of essential parts of which is passenger transport.

All this predetermines the need for optimizing the spontaneously developed system of urban passenger transport (UPT) which does not compatible with present-day needs.

2. Preconditions and means for resolving the problem

Effective solution to this problem is the use of the decision support systems in the field of vehicle routing [1]. However, automation of tasks related to this sector calls for research input for the purpose of obtaining effective algorithms suitable for use in practice.

According to [2,3], in its simplified form the UPT system is presented in the form of three mutually influencing subsystems: "city", "transport", "passengers" (Fig. 1).

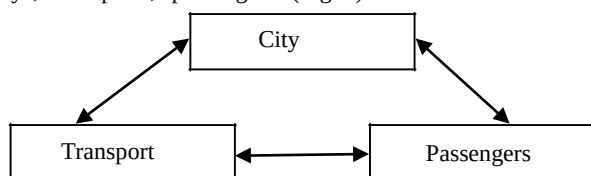


Fig. 1.

The subsystem "city" includes such elements as "industry", "housing construction", "street-road network", as well as service and

management of these elements. The basic requirement to be met by the "City" subsystem "City" for the operation of UPT.

systemis ensuring uninterrupted transportation of passengers. The "Transport" subsystem includes the organizations providing passenger traffic. For the "Passengers" subsystem, the effectiveness of the functioning of the transport system is determined by quality of satisfaction of demand for transportations.

Thus, it is evident that the interests of the participants of the UPT system considerably differ from each other. Recently, private carriers have come onto the UPT market. Therefore, the problem of UPT optimization has become more complex in a competitive environment.

Functioning of the UPT system is directly associated with its effectiveness. The effectiveness for the UPT is completely determined by the needs of its participants, which have to be taken into account at the analysis stage

From the point of view of the city administration, the effectiveness indicators could be as follows:

- meeting demands of the public for transportations;
- economic efficiency of the municipal transport organizations (the maximization of their profit);
- the effectiveness of road traffic organization;
- the absence of the conflicts of interest of the municipal and private transport operators developing into the conflicts.

From the point of view of the transport organizations, the basic indicator of the effectiveness is the maximization of profit from transportation activities.

From the point of view of the passengers, as the final consumer soft transport services, the effectiveness indicators could be as follows:

- the minimization of travel time;
- the minimization of travel cost (including possible stopovers);
- improving the travel comfortableness (through the type of vehicle and the level of its filling).

Determination of a single criterion of the effectiveness for passengers is significantly complicated by various motivation when making decision on movement and its mode, that is the concept of optimality of specific passenger considerably differs from criterion of optimality of the population in general.

As the integrating efficiency indicators of the UPT system for the population, the following criteria can be determined:

- the minimum cumulative waiting time of all passengers, who, with certain probability, go from starting points of departure to the destination;
- the minimum travel time from any starting point of departure to any destination;
- the minimum number of stopovers when moving from any starting point of departure to the required destination, and so on.

It is obvious that the efficiency indicators, from the points of view of the UPT system participants, are contradictory. So, for example, reduction of waiting time of passengers has clear links with the increase in a number of the motive power on the route, and, consequently, with the decline of its loading and the economic benefit. On the other hand, the commitment to increased profitability of the transport organizations may lead to the abandonment by the population of transportations and to the emergence of the competing organizations. Thus, the assessment of the efficiency indicators should be carried out taking into account the needs of all participants of the UPT system [4].

Turning to formal description of the UPT system optimization problem, it is possible to highlight several basic criteria of the effectiveness, in a general view presented in the form of purposive functions:

$$(1) \quad T_p = T_1 + T_2 + T_3 + T_4 \rightarrow \min$$

$$(2) \quad C_p = \sum_{Q_p}^n Q_d \cdot T \rightarrow \max$$

$$(3) \quad P_{to} = Q_p \cdot T - E \rightarrow \max$$

where T_p – timespent by passengers for movement; T_1 – timespent for approaching to the stopping point; T_2 – vehicle waiting time; T_3 – travel time; T_4 – timespent for movement to destination; Q_p – number of passengers; C – travel cost, including the possible stopovers; Q_d – number of travels/stopovers per day; T – passenger transport tariff; S – profit of the transport organizations; E – operating costs of the transport organizations.

Formal description of the UPT system is applied in the decision support systems making in the field of transport routing: design of route network of the locality, determining the type and the number of the motive power on routes, optimization of the existing route schemes, and so on. At the same time, the issues of optimization should be considered from the positions of all participants of the system of passenger traffic. Their interests are often contradictory, but optimization of the UPT system has also to consider and balance the needs of all participants of UPT.

The classic version of a vehicle routing problem not always covers all features of practical problems routing, specifics and the formulation of which are given in Tab. 1.

Currently, there are known many methods for the vehicle routing problem. As stated earlier, the vehicle routing problem is a generalization of the well-known travelling salesman problem, in which it is necessary to arrange at once several loop routes passing through a certain common top (depot). These problems belong to class of the problems of combinatorial optimization, and are complex ones.

3. Conclusion

There is considered the classic problem of vehicle routing, its varieties and solution methods. On the basis of the analysis of vehicle routing problems, there have been determined additional

restrictions, which must be taken into account in optimization of route schemes for UPT. As an optimization criterion for the UPT system, it is offered to use passenger traffic density on the particular section of the road.

Varities of vehicle routing problems

Table 1.

Problem	Formulation
Vehicle routing problem with account for vehicle carrying capacity	There is set the value $q > 0$ – carrying capacity of each vehicle, and a set $Q = \{q_1, q_2, \dots, q_n\}$, where q_i defines the volume of cargo in each top of v_i
Vehicle routing problem with the limitation of the number of knots on the routes	There is set the value $d > 0$ – the maximum number of tops required for visiting on each route.
Vehicle routing problem for several depots $P_{to} =$	The rout may start in any possible depot, but it must be ended where it starts. There is determined a set $D = \{d_1, d_2, \dots, d_k\}$ of the tops of depot.
Vehicle routing problem with graded delivery	It is permitted to visit the route knots not by one, but by several vehicles
Stochastic vehicle routing problem	Some parameters of problem (the number and the requests of customers, and so on) may appear to be random, set by stochastic observations.

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LINER SHIPPING NETWORKS AND PORTS CONNECTIVITY IN THE BLACK SEA REGION

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Abstract: The development of feeder networks in modern liner shipping has undergone significant changes during the last two decades. The hub-feeder systems and short sea shipping networks have largely expanded in the Black Sea and the Mediterranean regions due to fluctuating containerized cargo volumes. The present article analyses the feeder networks structure in the Black Sea region, examines the liner shipping connectivity based on the liner shipping connectivity index (LSCI) and further outlines the current trend of regional cargo transportation network expansion. The liner shipping connectivity index reflects the long-term objectives of liner operators for maximizing revenue via extensive market coverage. Despite the negative effect of the economic crisis and excess supply on the market a distinct trend towards increased service frequency and expanded geographical coverage are observed.

Keywords: LINER SHIPPING NETWORK, FEEDER LINES, LINER SHIPPING CONNECTIVITY INDEX, HUB-FEEDER SYSTEM

1. Introduction

The present article analyses the development of feeder networks in the Black Sea region. The hub-feeder systems and short sea shipping networks have largely expanded in the Black Sea and the Mediterranean regions due to fluctuating containerized cargo volumes. The status of liner shipping connectivity measured by the liner shipping connectivity index (LSCI) further outlines the current trend of regional cargo transportation network expansion. The examined data prove that the feeder network in the region has intensified its services due to the lower regionalization of the ports and lack of reliable hinterland links. LSCI reflects the long-term objectives of liner operators for reducing costs and maximizing revenue via extensive market coverage. Despite the negative effect of the economic crisis and excess supply on the market a distinct trend towards increased service frequency and expanded geographical coverage are observed.

2. Development of liner shipping networks – factors and trends

Liner shipping networks design is influenced by the strategic goals of liner shipping companies which are based on shippers' demand for certain services. As such, the location of a port or a region within the global liner shipping network is determined by the density of trade flows to and from a specific port or region [9]. The structure of the liner shipping networks, the number of vessels deployed and the frequency of service are based on the capacity and characteristics of the ports and cargo volumes. Based on these determinants, the service frequency (including the fixed days/hours of the week for departure/arrival), loading capacity of the transport equipment used, number of port calls per roundtrip and stops at intermediate terminals (transshipment/relay) are all determined [1].

Factors related to ports include: the specifics of the hinterland access, the specifics and capacity of the port infrastructure and superstructure, the characteristics of access to the berths/piers and also the geographical location of the ports in the region. As concerns national and international policies the factors include regulations related to cabotage sailing, customs formalities, international and regional regulations for the transport corridors, type of port management. From a market point of view the port operator model, cooperation between port operators, concentration level between liner operators, market strategy of liner companies, etc. are also decisive. The land access to the ports and the developed logistical chains, reliability of hinterland transport and pertaining costs are also of importance. The higher density of liner shipping networks allows for lower transshipment ratios, deployment of larger ships and higher level of capacity utilization. Nevertheless, additional operations for containers handling at relay terminals affect the quality of the service in terms of time integrity. There is a

standing trade-off between the supplementary costs and the higher revenue from higher capacity utilization. Furthermore, the regional feeder services design is based on the structure of the company's main liner routes. The quality issues are resolved via different strategies: increase of sailing frequencies, reduced time of shipping, higher reliability of services.

Another tendency predominant in liner shipping networks development is port regionalization. Port regionalization is characterized by strong functional interdependency and even joint development of a specific load centre and logistics platforms in the hinterland [6]. The main problems associated with regionalization include limitations to land expansion, draft requirements at berths and approaching channels, availability of investment financing, etc. Figure 1 displays the container port systems in Europe and its multiport gateway regions as of 2007. The position of the Black Sea region allows for respective access to hinterlands along with the established transport corridors. Among the major winners are the Spanish Med ports (from 4% in 1993 to 7.5% in 2008) and the Black Sea ports - from virtually no traffic to a market share of 1.9% in 2008 [4]. Intermodality is the driving factor for feeder networks expansion and cooperation in transshipments, development of consolidation centers, warehousing, etc.

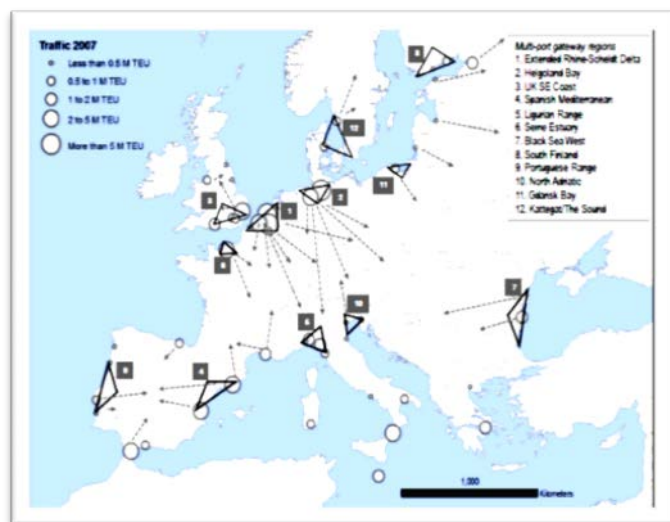


Figure 1. The European container port system and its multi-port gateways regions [6]

The point-to-point network is the traditional layout of liner shipping networks emphasizing on regionalization of services with low level of connection to other markets. In order to achieve better connectivity with outside markets intermediate ports are developed as hubs. The latter is the underlying factor for the creation of the hub-and-spokes system. Thus the respective port regions gain competitiveness via higher level of connectivity. However, due to

the cargo flow concentration the port development strategies undergo significant changes in the form of new approaches of port management. The latter gives way to increased investment via shareholding in port ownership and stevedoring activities. The increased cargo flows density gradually leads to geographical expansion of hinterland facilities and land connections and eventually of adding new ports in the already existing services. In the long run, the market share of certain hub ports grows significantly which allows for the liner operators offering direct services having the comparative advantage of decreased port stay. The described process is in fact the trigger for development of new regional ports which will enhance the local area connectivity and the implementation of other feeder networks.

3. Liner Shipping Connectivity Index and implications for the Black Sea region

Liner Shipping Connectivity Index (LSCI) is developed by UNCTAD in 2004 [7]. LSCI aims at capturing a country's level of integration into the existing liner shipping network by measuring liner shipping connectivity [6]. The LSCI is based on several components [4]:

- number of companies providing shipping services from/to a country's ports;
- size of the largest ship deployed from/to a country's port (TEU capacity);
- number of liner services connecting one country's ports to other countries;
- number of ships deployed on services from/to the country's ports;
- container carrying capacity of the vessels providing services from/to the country's ports (TEU).

The volume of maritime trade depends on the costs of transportation and the available access to shipping services and vice versa. Connectivity depends on the port infrastructure, location, demand and trade facilitation measures. Figure 2 presents the values of the LSCI for 2016 for the top 15 countries in the world. These countries have dynamic trade relations and large volume of exports.

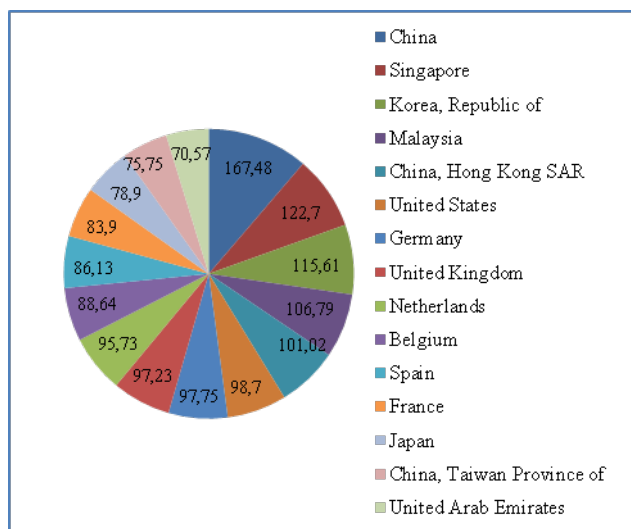


Figure 2. Liner Shipping Connectivity Index – top 15 countries in 2016 [12]

A higher value of the index demonstrates better access to port and hinterland facilities and ensures for more frequent connections between ports. LSCI is regarded both as a value of connection levels in shipping and as a means for facilitating trade. The structure of the LSCI allows for quantifying the strategic goals of liner operators for achieving larger market shares and wider geographical

coverage. The countries that have the highest LSCI values are actively involved in trade. The latter includes larger volume of exports and transshipments at liner shipping hubs. On the other hand, the share of direct links between countries within liner shipping networks is considerably low thus higher number of transshipments are planned. The design of the traditional hub-and-spokes networks in liner shipping has certain limitations, namely with respect to the number of hubs in a network and other technological factors that allow for efficient service. The transshipment markets' role encompasses maritime connections between mainline areas and regional port systems.

The traditional network layout is based on the "hub-and-spoke" system whereas the Mediterranean, Southeast Asia and the Caribbean are being the most important regions. Within the Black Sea region the container ports are both competing with each other and with adjacent port regions to increase their transshipment traffic. In 2006 UNCTAD secretariat has also developed an index for measuring bilateral connectivity between countries. The bilateral connectivity is derived from the assessment of the availability of direct connections between two countries basis the shortest possible link. The lower the value of the index of bilateral connectivity, the larger the number of transshipments are needed. This index measures country's integration in the global shipping networks including liner shipping. The types of connections between the countries are ranked according to the availability of direct connections and the necessary number of transshipments between two countries. Table 1 presents the bilateral connectivity index of the countries in the Black Sea region.

Table 1. Bilateral connectivity index for the Black Sea region in 2016 [12]

PARTNER ECONOMY	Bulgaria	Georgia	Romania	Russia	Turkey	Ukraine
Bulgaria	-	0,25	0,26	0,27	0,28	0,26
Georgia	0,25	-	0,26	0,27	0,28	0,26
Romania	0,26	0,26	-	0,43	0,45	0,42
Russia	0,27	0,27	0,43	-	0,52	0,46
Turkey	0,28	0,28	0,45	0,52	-	0,47
Ukraine	0,26	0,26	0,42	0,46	0,47	-

4. Black Sea region feeder networks development and connectivity

During the last decade the LSCI has marked a steady growth although not at a high pace. It is mainly due to the tendency to deploy larger ships (for economies of scale), decrease the number of deployed vessels, lower the liner services frequency, etc. Liner shipping is by default a capital intensive industry. Following the economic crisis in 2008 and its effect on the transportation of finished goods the liner companies sustained significant losses. The rationale behind the new strategies of liner operators lies within the several possible strategic scenarios: restructuring of liner services as networks, withdrawal and scrapping of vessels, flexibility in terms of slot numbers, improvement the rate of utilization, decreasing overheads.

The sequence and the number of port calls in a feeder liner network have its specifics. The assigned vessels may call the ports in a different than geographical rotation or call some of the port twice during the full voyage cycle. Due to the lack of post-crisis economic recovery liner shipping operations still suffer from strong imbalances between demand and supply. Feeder services, however, have undergone a different path of development which led to increase of port number, increase of number of deployed vessels which allowed for increased turnover and higher frequency of services. The structure and development of the feeder lines in the Black Sea region is presented in Table 2. All major liner operators have introduced additional services within/via Black Sea, increasing the number of port of calls and the frequency during the last five years [see 8].

Table 2. Feeder networks in the Black Sea region in 2017 [own elaboration]

Liner operator	Feeder service rotation	Number and capacity of container ships	Number of ports	Round voyage duration (days)
Maersk	Ambarli – Bourgas – Varna – Ambarli (Z39 EMES Bourgas Service)	1 vessel 1155 TEU	3	5
	Damietta – Port Said – Ambarli – Constanza – Odessa – Chernomorsk – Novorossiysk – Constanza – Ambarli – Port Said – Ashdod	4 vessels 6800 TEU	8	26
MSC	Gioia Tauro – Piraeus – Batumi – Odessa – Constanza – Bourgas – Gioia Tauro	2 vessels 1400 TEU	6	14
ZIM	Cagliari – Varna – Constanza – Cagliari (W Med Black Sea – WBS)	3 vessels 1600 TEU	3	17
	Piraeus – Ambarli – Novorossiysk – Constanza – Varna – Ambarli – Piraeus (Black Sea Shuttle – BSH)	2 vessels 1700 TEU	5	14
Arkas Line	Marport – Bourgas – Varna – Marport	1 vessel 900 TEU	3	7
	Marport – Varna – Constanza – Marport – Gemlik – Piraeus – Cagliari – Gemlik	4 vessels 1400 TEU	6	14
CMA CGM	Malta – Piraeus – Istanbul – Poti – Novorossiysk – Ambarli – Piraeus – Malta (Black Sea 1)	2 vessels 100 –1200 TEU	6	14
	Malta – Ambarli – Odessa – Constanza – Varna – Ambarli – Piraeus – Malta (Black Sea 3)	2 vessels 900–1200 TEU	6	14

The adjustment between supply and demand is achieved through the change of the number of ships deployed. Presently, due to the on-going decrease of demand the change of supply is a vital component of liner companies' strategy. One of the options is slow steaming thus considerable savings in voyage costs can be achieved. However, the latter can result in increase of transit times (rescheduling) and loss of market share to other transport modes' competitors especially for sensitive goods. As for ships withdrawal the main long-term considerations are the environmental benefits from non-deployment of older ships. In a logistics world confronted with mounting reliability and capacity issues, routing flexibility is a keystone for the logistics attractiveness of a region [9]. The inter-connections among several gateways give the opportunity of better routing options and more alternatives for logistics companies. Successful port development is therefore based on complete utilization of logistical options with other transport modes.

The Black Sea container terminals of Romania, Ukraine, Russia, Georgia and Bulgaria handled 2,46 mln. TEU in 2016, including empty containers and excluding transshipment [10]. The number of containers loaded amounted to 1,785 mln. TEU that is an increase with 9.63% as compared with year 2015. All container ports reported increase in throughput except for the ports in Georgia (Figure 3).

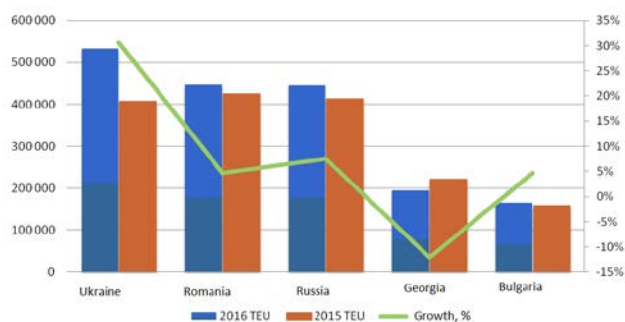


Figure 3. Container throughput of Black Sea region in 2015-2016, TEU loaded [10]

Imports and exports of containers in the region accounted for 51.37% and 48.63% respectively. The percentage of empty containers handled was three times lower than that of loaded containers. The exports from Bulgaria and Romania showed insignificant changes in 2016 unlike the ports in Georgia where a decrease by 14.93% is reported. The imports into the region grew by 6.95% in average mainly due to the increase of imports in Ukraine, Russia and Georgia. The countries' shares in terminal handling of loaded containers in 2016 are as follows: Romania – 24.99%, Russia – 24.92%, Ukraine – 29.87%, Georgia – 10.93%, Bulgaria – 9.29%. The leading positions of major liner companies is preserved (Figure 4) - Maersk Line (24,21%), MSC (20.44%), CMA CGM (10.47%), Arkas (10,16 %) and ZIM (8,10%).

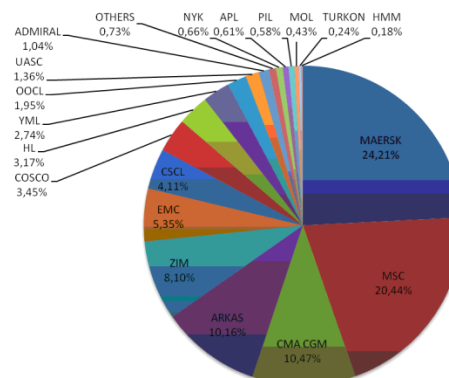


Figure 4. Shares of Black Sea lines in the region (2016) [10]

In terms of port regionalization the Black Sea region is divided into three multi-port gateway sub-regions - Black Sea West (Burgas, Varna, Constantza), Black Sea North (Odessa, Ilyichievsk, Yuzhnyi, Mariupol) and Black Sea East (Poti and Batumi). and one separate gateway (Novorossiysk). The ports of Constanza, Odessa, Ilychevsk, Yuzhny and Novorossiysk are called directly by shipping lines. During the last fifteen years the size of the vessels, visiting these ports, grew to 8000 TEU whereas the maximum size is about 9000 TEU due to the navigational restrictions of the Bosphorus strait. The smaller ports in the Black sea region are called by feeder vessels and the ports of Istanbul, Piraeus, Damietta, Port Said, Gioia Tauro, Malta, etc. are used for transshipment. This shift occurred after the crisis in 2008 whereas the transshipment operations in the region declined in volume. Presently direct and feeder calls are almost evenly distributed within the network. The largest container vessels are handled in the port of Constantza. One of the major factors is the considerable investment of leading port operators. The container terminals of Ukraine, Romania, Russia and Bulgaria demonstrated a growth of 30.66%, 4.71%, 7.52% and 4.65% respectively (Figure 5).

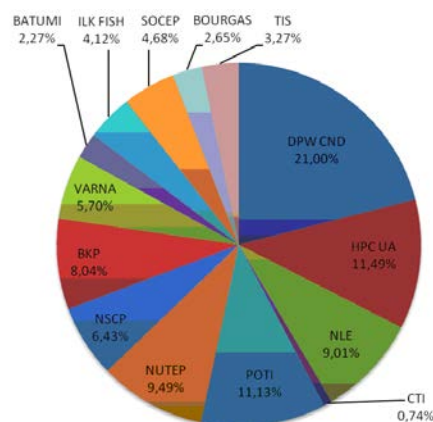


Figure 5. Share of Black Sea terminals in 2016 [10]

Terminal productivity plays an important role in the future development of container terminals in the Black Sea region, where operators in both Ukraine and Russia such as Odessa and Novorossiysk are trying to attract both transshipment and

import/export business [2]. The number of ports within the regional feeder networks have increased but with no definite model of cargo concentration. This is also due to the fact the traffic and cargo volumes increased in transshipment ports, i.e. in Istanbul and Piraeus. The ports of Varna and Bourgas have been competing with the port of Constanza during the last two decades, also Odessa has gained advantage to Ilychevsk. The technological level of the Black Sea hinterland is far from serious advances, which, combined with the lack of efficient modal shifts, further prevents concentration of cargo flows in the ports.

Due to the lack of cargo concentration in Black Sea region ports the maritime links still play an important role but impede the development of hinterland logistical centers and the realization of scale economies also on inland services. Containers for the more distant hinterland benefit from a port's strong local cargo base as local containers often provide the critical mass for allowing frequent deepsea liner services [5]. The sub-region of Black Sea West (Constanza) has a potential to develop a strong hinterland region with developed intermodal services for the Central European Countries, South Germany, Austria, etc. The main consideration of liner operators in the region is the minimization of operational cost (liner services, inland transportation) and maximization of the quality of service by customer-oriented approach while having direct calls as much as feeder calls. Feeder shipping lines in the Black Sea region are a growing segment for connectivity in Europe. Local or immediate hinterlands remain the backbone of ports' cargo bases [5]. The requirements for reliability and capacity issues makes the flexibility in cargo routing the major factor for the regions logistical efficiency. Hinterland links to several multi-port gateways allows for diversity in routing options and higher flexibility for all logistics companies.

5. Conclusion

Despite the fact that the container market is in general becoming more concentrated in Europe, the Black Sea region still remains a secondary market benefiting presently by the higher level of regional connectivity. Furthermore, as the intermodal networks are vital for the development of the EU port system, a significant level of cargo flows concentration is required to achieve efficient modal shifts. There is a serious potential that the larger ports in the Black Sea region attain higher concentration and benefit from economies of scale (both of maritime and inland modes) and of the increased frequency of liner port calls. Important impetus for smaller ports, located closer to larger ones, are the existing hinterland links of the latter.

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TECHNOLOGICAL ASPECTS OF EXTENSION OF TRANSPORT OPERATION ON RAIL-LINES IN RECONSTRUCTION

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Abstract: *High quality of operational concepts in railway transport represents one of the basic premises of functional public transport system and public transport services. In this area the systematic timetable engineering plays an important role. Advanced timetable engineering brings a strong contribution for an effective use of infrastructure capacity. This systematic approach is very important, especially when the new railway service is being introduced on such railway line, which is in the state of reconstruction with numerous restrictions. The article demonstrates this approach on the example of the introduction of new express trains Prague - Linz in the timetable 2016/17.*

KEYWORDS: RAILWAY TRANSPORT, PUBLIC TRAFFIC, RAILWAY TECHNOLOGY, TIMETABLING, FBS

1 Introduction

In the Czech Republic, over a period of more than 20 years, intensive renewal of railway infrastructure, primarily transit railway corridors, has taken place. One of these cases is IV. transit corridor leading from Děčín via Prague to the border with Austria in the direction of Linz. Between Prague and České Budějovice, the corridor is already completed at 75% of its length. The Ministry of Transport, as the orderer of long-distance trains, decided to order new express trains between Prague and České Budějovice in the Timetable 2016/17, which will be a new additional passenger service to the current fast trains. Between Prague and České Budějovice, there is motorway D3 in construction, so it is also not yet completed and the new express trains have a travel time comparable to that of individual transport.

The task was to prepare such an operational concept on the railway line, to make the most of the modernized infrastructure for the new trains, the trains of existing trains did not deteriorate and the technological impacts on the sections in the reconstruction (eg cruising in single track sections or sections under the construction) were minimal.

2 Prerequisites for solving the rail capacity and timetable problem

The timetable is a basic instrument for organizing railway transport. Though, it represents supply of connections in network for passengers. Generally, timetables can be divided into fixed-interval (periodic) and commercial (non-periodic).

The way from the basic idea of transport concept to final daily operation is long and complicated – from the transport planning with regards to present infrastructure parameters through timetable planning to the simulation of the transport concept. Within the stage of transport planning the transport relations (OD-Matrix) and estimated Modal-Split of railway passenger transport have to be determined followed by the line network scheme defining the lines, period of services and capacity of operating vehicles. These two phases generate the background for a rough draft of operational concept. Finally, this proposal of operational concept has to be verified by tool for timetable planning.

The problems of the new operational concept on the corridor line Prague - České Budějovice can be defined by three topics.

The first was the capacity of the line itself - line sections before the reconstruction are in many places only single-track with limited possibilities of train crossing. There are also some

double-track sections under reconstruction, which have to be operated as only single-track. The capacity of the line is further limited by the fact, that in the Czech Republic the speed of the trains by working places on the tracks is reduced to 50 km/h and for stations to 40 km/h (with regard to the provisional state of the signalling equipment).

The second problematic topic was defined by the constraints of the transport concept. Classical long-distance fast trains (train category R) are operated in a basic interval of 120 minutes, and for most of the working day it is completed for 60 minutes interval. The long distance trains R are reaching the complete IPT (interval periodic timetable) node in Tábor in the minute 00, the wider IPT node in Veselí nad Lužnicí at minute 30 and the wider IPT node in České Budějovice in the minute 00. The suburban regional transport service at Prague is operated in a basic interval 30 minutes between Prague and Benešov. At the nearest agglomeration section between Prague and Strančice the interval is concentrated in peak hours of working days to 15 minutes. The paths for long-distance fast trains are in the timetable so designed, to avoid overtaking regional trains in the section between Prague and Benešov, i.e. to avoid the loss of time for passengers in suburban transport. From this constraint it follows logically, that for the new express trains (train category Ex), the only path which could be used between Prague and Benešov is shifted exactly 30 minutes to the current fast trains. Thus, the entire timetable interval scheme of the Ex and R trains with regional trains had only such a time-manipulation space, to avoid disturbing current IPT nodes while avoiding overtaking regional trains. The conditions for the timetable construction of the path for new express trains were such, that a path with the smallest technological conflicts had to be found, which at the same time fulfilled the time conditions for passing trains on the border with Austria (for reaching transfer connections in station Linz). Although only 8 pairs of new express trains per day were introduced, a virtually periodical timetable scheme with Ex path in every hour must be found. This is due to the fact, that the Ex trains were introduced on the principle of a 4-hour period Prague - České Budějovice - Linz, supplemented by one express connection Prague - České Budějovice - Český Krumlov (UNESCO city with a tourist attendance of more than 1.3 mil persons per year) and 3 pairs of express trains Prague - České Budějovice in peak hours of working days.

The third problematic topic concerns to the vehicles, which are necessary for newly established express trains. The new operational concept was based on using of new passenger seating cars with modern locomotives type 380 ČD (Czech Railways)

and velocity of 160 km/h. There were 6 locomotives and 6 car-sets needed to ensure the project. However, a new restrictive condition was embedded by preparing the project, namely that with regard to the number of vehicles, that ČD could release for the project only 4 locomotives of the type 380 and only 4 car-sets for the speed of 160 km/h allowing international traffic. For the remaining trains, two older locomotives type 362 were released, with maximum speed of 140 km/h and two modernized car-sets for domestic operation. The preparation of the vehicle circulation plans had to be planned separately and designed so, that both types of sets could be correctly maintained.

3 Suggested solution for new express train paths

Proposal of operational concept should be verified by tool for timetable planning.

Inputs for this verification should be represented by infrastructure parameters, e.g. track station lay-out and location, velocity and propensity profile, curve radii and tunnel profiles. Speed-traction-effort curve, distribution of traction effort, tonnage of train and the stopping time at the stations are required for the running time calculation.

Faculty of Transportation Sciences at the Czech Technical University (CTU in Prague) use the software FBS (iRFP Dresden – Germany) since 1999. CTU in Prague has adapted tool FBS to Czech operational conditions.

FBS is a programme family for railway conception, which has been developed since 1993. Naturally, it combines the opportunities of today's computer technology with scientific calculations and the knowledge of daily railway operation. FBS represents an efficient tool concerning creation of timetables and utilization of obtained data.

The timetable programme currently consists of the following programmes:

- FBS-Dispatcher (survey of files)
- Integrated planning program iPLAN
- Station Database Editor BSV
- Train type and h'code Editor ZNV
- Engine Database Editor TFZ

FBS is available in a wide range of functions as well as in versions for industrial purposes and for research and teaching purposes.

Basic object management is performed in iPlan programm, which integrates other program modules.

More complex technological tasks are dealt for example by work with a scheduled timetable across multiple lines.

FBS defines an optimised interaction between infrastructure, rolling stock and operation.

All possible schemes of train crossings have been verified as part of the search for acceptable variants. Under the terms of the periodic timetable, a solution that is symmetrical by minute 00 has always been sought.

The timetable constructional principle of the express train path was:

- 1) Examine the shortest travel time on infrastructure conditions with all constraints due to the reconstruction
- 2) Time binding to a time position agreed for passing trains on the border with Austria

3) From the above to derive the latest possible arrival from Prague to České Budějovice (from Prague) and for this time to find the closest path, realizable periodically and symmetrically

4) Overlapping of the time scheme of express paths (Ex trains) with the scheme of fast trains paths (R trains) and identification of technological collisions

5) Solving the collisions primarily by adjusting the fast train (R) paths so, that the constraints of the existing connections in the IPT nodes are respected - the aim of the step was to make as few changes as possible for existing trains and linkages

6) Minute fine-tuning of express (Ex) and fast trains (R) paths in the Prague - Benešov section, within the exact time spacing of 30 minutes for collision-free timetable construction of suburban regional transport

In the search for variants, it was always proceed first theoretically, by examining the mathematical conditions of the edge time lengths (in this case, the edge between the IPT nodes was replaced by an imaginary edge between the crossing stations) in the presence of both periodical segments in 1-hour period, by applying the edge equation over the sums of 30 min within one segment and over the sums of 15 min within a combination of both segments.

Under the constraints, in co-ordination with the Austrian partners, it was possible to find such solution, that led to the acceleration of trains on the Austrian side (due to the introduction of the two-segment operation between Pregarten-Linz), which in addition to shortening the travel time itself leads to a comfortable transfer link at Linz to Salzburg, Zurich and Vienna) and to extending of time for changing trains from approximately 8 to approximately 20-25 minutes (which has a positive effect on the reliability of long-distance journeys).

4 Results

From the point of view of the resulting combinations, it was finally possible to find and create such a timetable variant in the section Prague - České Budějovice, that in the single track section before reconstruction only the express trains (in Střeziměř) are crossing and all other train crossings (express / express, express / fast train, fast train / fast train) are realized on already completed double-track sections.

This one crossing is also evident from the model tachograph of the express train. From the tachograph of the ride are also visible all speed restrictions on the sections in the reconstruction. The tachograph is for direction Prague - České Budějovice, the 380 ČD locomotive and the 250-ton car set:

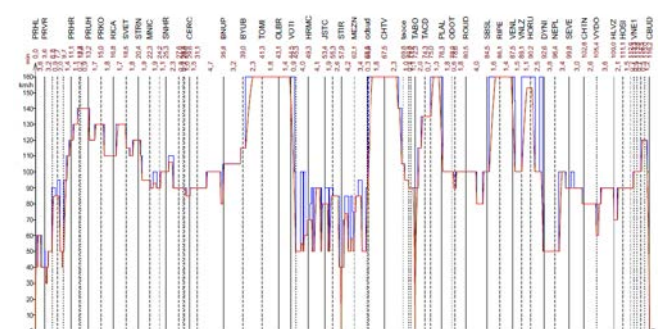


Fig. 1 tachograph of Ex train Prague - České Budějovice

From the point of view of reached travel times, the straightening looks as follows:

- travel time of fast trains (R) in periodic path Prague - České Budějovice in timetable 2015/16: 2 hour 23 min

- travel time of fast trains (R) in periodic path Prague - České Budějovice in timetable 2016/17 (by solved timetable conflicts with Ex trains): 2 hour 20-25 min

- travel time of new introduced express trains (Ex) in periodic path Prague - České Budějovice in timetable 2016/17: 1 hour 58 min

Even more interesting is the result achieved in the relation Prague - Linz.

In the timetable 2015/16, the Prague - Linz connection was made with fast trains (R) which continued to Linz from train Prague - České Budějovice, in the amount of 2.5 pairs a day (in one direction were 3 connections, the other 2 and the one ending in České Budějovice). Travel time Prague - Linz was 4 hours 50 min.

In the timetable 2016/17 the connection between Prague and Linz is provided by express trains, where between České Budějovice - Linz the already existing fast train paths were used. At the Austrian side, the Pregarten - Linz service was modified to two-segment operational concept and the express train use the higher segment path. The total balance of time savings is 25 minutes on the Czech territory between Prague - České Budějovice (Ex path), 8 minutes on the Czech territory (removal of the locomotive overpass in České Budějovice) and 12 minutes on the Austrian territory (influence of two-segment service Pregarten - Linz). The total time savings achieved 45 minutes and the resulting travel time of the Prague - Linz train is currently 4 hours 5 minutes.

5 Conclusion

This paper has presented, what timetable solutions could be achieved by appropriate technological combinations on the railway infrastructure, that is undergoing reconstruction, but it already enables higher transport attractiveness. All technological processes and variants have been reviewed in FBS. The state of construction of the 4th railway corridor between Prague - České Budějovice allowed, in conjunction with other follow - up measures of operational and technological nature, the introduction of a new express train segment, which led to shorter travel times not only in the relation itself, but also in the international relation Prague - Linz.

From the point of view of travel times, there was found such solution, which by introducing new express trains (Ex) did not damage existing fast train segment (R), including its transfer links. The average travel speed of fast trains (R) Prague - České Budějovice is 73.7 km/h. The average travel speed of the newly established express trains (Ex) Prague - České Budějovice is 87.5 km/h. Between Prague and České Budějovice, there is not yet a motorway D3 completed. The current travel time by individual transport is so comparable with the travel time of the newly introduced Express trains. This is the reason, why newly introduced trains have become a very attractive and sought after connection.

With further construction works, the constraints for train paths will also change and the technological solution founded for timetable 2016/17 is only temporary. However, we believe, that applying the same procedures a methods will result in a further

shortening of travel times of long distance trains (both categories Ex and R) as soon as infrastructure capabilities allow it, naturally without impacting on existing interconnections and IPT nodes of lower service segments.

Advanced timetable engineering brings a strong contribution for an effective use of infrastructure capacity – it's possible to say, where the current limits and bottlenecks of the infrastructure are – using these support tools is possible to enumerate, what the most important precautions in operation and investment in relation to capacity, reliability and safety are. This effectiveness is particularly fundamental by investment-consuming railway infrastructure. Practical application of these tools makes necessary link between theory and praxis.

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NEW SILK ROAD: COMARATIVE ANALYSIS AND WAYS FOR DEVELOPING ALTERNATIVE ROUTS

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Abstract: *This research work is devoted to the trends for further development of the New Silk Road. In the framework of the study, the authors have analyzed the export and import of all potential participant countries of the New Silk Road, examined the Northern, Central and Southern corridors. They have also identified alternative directions for transportation of goods from China through the countries of Central Asia to Russia and Europe. At the same time, according to the calculations carried out to assess the volumes of transit cargo flows on the alternative routes offered by the central and southern international transport corridors, the authors have highlighted the strategic role of Iran in the distribution of cargo flows.*

KEY TERMS: NEW SILK ROAD, TRANSPORT CORRIDORS, LOGISTICS CENTER, EXPORT. IMPORT.

The interest and active participation of the governments in the formation of new international transport routes and associated transport corridors is aimed to diversify and strengthen economies, maximize transit potential, stimulate the development of transport and communications within countries and to get *direct* access to the world markets. The need to form the "*Economic belt of the Silk Road*" is justified with the importance of building an economic cooperation, which can become one of the elements of the node that consolidates commodity flows from China, India, Southeast and Central Asia to Europe and in the opposite direction, which will, subsequently, lead to the integrating processes among the economies of all participating countries and intensification of political dialogues between them.

The concept of the "New Silk Road" includes the projects "The Economic belt of the Silk Road" and the "Silk Road of the XXI century", which assume the creation of an extensive infrastructure network along the way from the western borders of China to the countries of Central Asia and from Iran to Europe.

"Economic belt of the Silk Road", according to various estimates, includes more than 40 countries. Through the concept of the "New Silk Road," China is trying to expand its influence in this territory. Along with the geo-political goals, China expects serious economic outcomes. Henceforth, it is known that during the last years the growth rates of China's economy were the lowest [6], and consequently, China needs new, cheaper and innovative ways of development. China actively cooperates with the largest countries participating in the New Silk Road i.e. Russia, Iran and Kazakhstan.

The strategic importance of the "New Silk Road" is associated with the development and growth of international supply chains over the past 30 years. Nowadays large companies tend to place separate phases of their production in other countries, which allows to increase the level of efficiency of the organizational logistic chains. Therefore, these companies organize production in countries which have access to channels of inexpensive transportation, and labour resources. Operating under such conditions, China became the center of global production. Over the past ten years, the average annual growth of foreign trade turnover rate in China has been 25%. Most of the exported goods are transported from China by sea. However, it has recently become difficult to organize the services on time due to congestion in ports, which necessitates the organization of transportation by railway. While dealing with exports from China to Europe, freight transport by railway has shorter transit times than by sea. For example, the time of cargo transportation by sea from China's industrial ports to Europe is 35 days, while the freight transportation by railway is 18 days. The increase in the volume of railway freight will lead to industrial development of the countries of the "Economic belt of the Silk Road", as producers will have the opportunity to diversify the supply chain, which will become a source of investment in the economies of these countries. The new Silk Road will open up new markets and will significantly reduce transportation costs by using the latest technology of logistics and cargo transportation. It can

also be assumed that the implementation of this program will lead to a stabilization of the political situation and the reduction of conflicts in the countries of the "Economic belt of the Silk Road."

The project "New Silk Road" requires significant financial resources, the volume of which will reach eight trillion US dollars by 2020. The modern Silk Road will become the largest project in the economic history. It will pass through the territories of countries in which 70% of the world's population live, and which produce about 55% of world GDP [6].

Each country that can potentially become a participant in the New Silk Road project must make its contribution in the form of appropriate infrastructure or financial investments. Undoubtedly, this project will be a decisive step on the path of developing and restoring the production potential, creating new promising industries and jobs in countries located along the entire length of this path.

Historically, along the entire length of the Silk Road, road transport has been relatively poorly developed, and more attention has been paid to railway communications, since the distances were large, and the bulk cargoes dominated in the domestic trade. Before the Second World War, 89% of the total cargo was transported by railway, while road freight services were used to transport goods to the railway and were used for short distances, accounting for only 3% of the total cargo volume [3]. Within the framework of the "New Silk Road" three corridors have been formed: the Northern, Central and Southern, which stretch from China to Europe.

Findings of the study

Based on the results of this study, we propose ways to improve the presented routes by using alternative modes of cargo transportation. The study is based on the development of rail transport corridors using intermodal transport. Despite the fact that there are a number of alternatives for the development of this scenario, we have examined and analyzed the indicators and opportunities of all countries that can potentially become participants in the New Silk Road. During the analysis, volumes of export and import in tons have been considered, and only goods that can be transported by railways and highways have been taken into account. The calculations do not include precious stones, perishable goods and plants, as well as gas and oil transported by pipeline.

The results of the analysis [5] show that among the countries potentials of which have been examined, China is the main exporter exporting more than 120 million tons of goods to the countries of the Central Asia, the Caucasus and Europe. The second country with a similar potential is France with 112 million tons, then Germany with almost 103 million tons of goods. One of the largest, if not the largest, importer of Chinese products is Russia, which imports almost 10 million tons of goods from China and exports 43 million tons of goods to China, not considering oil and gas. Among the examined countries, Germany is the main importer, and this country imports almost 131 million tons of goods from the countries of potential participants of the New Silk Road.

Belgium ranks second with imports of more than 127 million tons, followed by France with more than 119 million tons of goods.

Transportation of goods from China, Central and South-East Asia to Europe is carried out by three alternatives of international transport corridors: northern, central and southern. For a comparative analysis and evaluation of the economic feasibility of using alternative options for international transport corridors of the New Silk Road, we will present their structure and analyze the volumes of cargo flows, which will also allow us to economically justify the choice of the logistics center for cargo distribution between the South-Europe and North-South corridors.

The Northern International Transport Corridor has two alternative routes:

- Route 1N: China - Kazakhstan - Russia-Belarus-Poland - Germany - Belgium - France-England;
- Route 2N: China - Russia - Belarus - Poland - Germany - Belgium - France - England.

Although, this corridor passes fewer cross-border points, it operates in adverse weather conditions, as it mainly uses Trans-Siberian Railways, which need upgrading.

The Central International Transport Corridor has the following alternative routes:

- Route 1C: China - Kazakhstan - (Kyrgyzstan) - Uzbekistan - Turkmenistan - Iran - Armenia - Georgia - Bulgaria - Romania - Hungary - Austria - Germany - Belgium - France-England;
- Route 2C: China - Kazakhstan - Turkmenistan - Iran - Armenia - Georgia - Bulgaria - Romania - Hungary - Austria - Germany - Belgium - France-England;
- Route 3C: China - Kazakhstan - (Kyrgyzstan) - Uzbekistan - Turkmenistan - Iran - Azerbaijan - Georgia - Bulgaria - Romania - Hungary - Austria - Germany - Belgium - France-England;
- Route 4C: China - Kazakhstan - Turkmenistan - Iran - Azerbaijan - Georgia - Bulgaria - Romania - Hungary - Austria - Germany - Belgium - France-England.

The Southern International Transport Corridor has the following alternative routes:

- Route 1S: China - Myanmar - India - Pakistan - Iran - Turkey - Bulgaria - Romania - Hungary - Austria - Germany - France - England;
- Route 2S: China - Myanmar - India - Pakistan - Iran - Azerbaijan - Russia - Belarus - Poland - Germany - France-England;
- Route 3S: China-Myanmar-India-Pakistan-Iran-Armenia-Georgia (Poti) -Bulgaria-Russia-France-England.

One of the main logistics centers of the "New Silk Road" is Iran, where the Central and South international transport corridors form a junction. The goods of Central, South-East Asia, India, South Korea, Vietnam and other countries transported to Western and Northern Europe can be distributed in this logistics center between the corridors "South-Europe" and "North-South". With the sponsorship of the Chinese investment company, one of the segments of the "New Silk Road" which is connecting China with Iran has already been exploited. It passes through China, Kazakhstan, Turkmenistan and Iran. For the speedy implementation of the project, China is ready to allocate interest-free loans to improve the infrastructure of potential member countries, including Iran. Iran and India signed an agreement to modernize the Chabahar port (Iran's largest maritime port after Bendery Abbas). For these purposes India has invested U \$500 million, out of which US\$ 345 million has been directed towards the construction of a railway in Zahedan, located on the border with Pakistan and Afghanistan (41 km distance), and the rest of money will be spent to purchase port equipment for the Chabahara.

The calculations carried out to assess the volumes of transit cargo flows on the alternative routes presented by the central and southern international transport corridors show that Iran plays a strategic role in the distribution of freight traffic, since the largest transit volumes pass through Iran. According to the data (2015), the annual volume of cargo flows of alternative routes 1C and 3C could reach 142 million tons and 143 million tons, respectively.

Taking into account the volume of cargo flows of the Southern International Transport Corridor, the expected annual volume of

cargo flows through Iran will increase by 13% reaching about 160 million tons.

In the route 3C of the Central International Transport Corridor, Azerbaijan and Georgia are trying to take an active part. At the moment, the Baku-Tbilisi-Kars railway (which will be exploited by the end of 2017) and Kazvin-Resht-Astara (which will be exploited by the end of 2018) are being built bypassing Armenia. The construction of the Armenia-Iran railway (Gagarin-Kamo-Martuni-Jermuk-Kapan-Meghri-Merand) is planned within the corridor "North-South" in route 1C of the Central International Transport Corridor. As a result of the construction of this railway, Armenia will be connected not only with the neighboring Iran via railways but it could also use the railroad to reach the Persian Gulf and to other neighboring regions and states. It could also join the railway corridor within the "New Silk Road ". The calculations show that the transportation of 20 containers along the route Iran-Armenia-Georgia is 10.3% cheaper than the route Iran-Azerbaijan-Georgia. Henceforth, the construction of the railway from Armenia to Iran has a strategic importance and is economically justified.

Armenia has three railway corridors (Armenia-Georgia, Armenia-Turkey, Armenia-Azerbaijan), however, under the current political situation, only the Armenia-Georgia corridor operates. However, this corridor restricts the integration of the Armenian railways into the regional railway transport system because of the non-functioning of the railway corridor connecting Georgia-Abkhazia. The railway corridor of Samtredia-Ochamchiri-Sukhum-Adler provided railway communication between Armenia and Russia. It should be noted that with the use of the Georgian-Abkhaz railway, Armenia will be able to resume cargo transportation to Russia via this railway and join the "New Silk Road" along the corridor "North-South". Currently, cargoes from Armenia to Russia are mainly transported through the Georgian port of Poti or by road, which increases transportation costs.

As a result of the construction of the Armenia-Iran railway and the completion of the construction of the highway within the North-South corridor, the 1C route can successfully compete with the 3C route of the Central International Transport Corridor "New Silk Road", as the volumes of exports and imports of Armenia and Azerbaijan slightly differ.

Armenia is competitive, since Azerbaijan has no serious advantages in terms of export and import of goods. The only advantage of the neighboring Azerbaijan is the infrastructure. Thus, in order to provide competitive advantages, Armenia should make appropriate investments or stimulate foreign direct investments into the development of the suggested route.

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DRIVER ASSISTANCE SYSTEMS IN VEHICLES USING AUGMENTED REALITY – BENEFITS AND CHALLENGES

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Abstract: *The issues related to road safety and the complexity of the driving task present a continuously increasing burden for the driver. In order to support this task, the existing on-board systems in vehicles primarily display visual messages, forcing drivers to move their eyes from the road. This paper presents a survey of studies related to perception and cognitive attention of drivers when this information is presented on the windshield (Head-Up Displays). Past research has suggested that this technology is considered as a possible solution for reducing the time and frequency of drivers moving their eyes of traffic. However, this technology brings its own challenges that are discussed in this paper. Augmented Reality concept is also presented because this solution adds new challenges to the technology as the risk of occlusion of real objects that are relevant to the traffic as well as phenomena like perception tunneling and cognitive capture.*

Keywords: DRIVER ASSISTANCE SYSTEMS, HEAD-UP DISPLAYS, AUGMENTED REALITY, 3D VISUALIZATION, ROAD SAFETY.

1. Introduction

Driver Assistance Systems in the automotive industry have been developing for several years, with a final goal to improve the safety of the driver and the passengers, but also to improve the performance, efficiency and comfort through ICT. The activity of operating a motor vehicle is highly complex. Partially, that is because of the high time limitations needed for the human to notice, percept, process information before making a decision, and act appropriately. This activity is happening in an environment of traffic filled with unpredictable situations. In such an environment, displaying appropriate information, like step-by-step navigation instructions, information about the road conditions, accidents or work on road, distance to the vehicle in front, danger from rockslides and similar information can be highly useful as information in support of the decision making and preparation for appropriate action. Issues of the ergonomic design aspect for these solutions are focused on determining the most appropriate ways for ensuring efficient and effective cooperation between human and the system in context of that that the driving activity is of primary importance. The efficiency, or on the contrary, the negative effects of the aspect of road safety while using these systems is mainly depended of the compatibility of their interfaces, the way of dialog, surrounding and functional ability of the drivers [1].

The European Commission in its document the European Statement of Principles on Human Machine Interface for In-Vehicle Information and Communication Systems presents the framework recommendations and principles that need to be fulfilled when developing these components, as well as the basic safety aspects that need to be followed. The document lists the key European directives and international standards that provide the framework for the manufacturers and suppliers of such equipment to be able to plan their development and implementation [2]. Geham (2005) states that in order to increase safety of the driver and passengers it is more important for the vehicles through the systems for active safety to avoid accidents compared to the minimizing effects of the accidents through the systems for passive safety. The systems for driver assistance aim to increase the safety and/or comfort and to assist the driver to focus on the driving activity.

Regarding the perception, it has been concluded before long time that the driving performance are in tight correlation with the

ability for visual perception and visual strategy. Lot of authors agree to the fact that the perceptive visual channel is of paramount importance for the driving activity [3,4]. It is estimated that up to 90% of the needed information for seamless completion of this task are communicated through the visual channel. The existing systems in vehicles are mainly presenting visual messages: in a form of text messages, pictograms and/or graphic maps on displays integrated in the dashboard. When the driver needs to operate these systems, he has to move his view from the road for several seconds. The probability for an accident increases with the duration of the time the driver is not watching on the road [3, 4, 5]. Studies determine that the key duration of sight of the road while driving is 2 seconds [6]. In wider perspective, any integrated display in the vehicle can be assessed as visual cost that can be quantified in a number of occurrences and duration in order to get an information from the system [7].

Because there is a void or distance between the physical spaces (for example the road and the vehicle interior) and the virtual ICT spaces (for example the integrated display in the vehicle), the user has to spend time and cognitive effort to adjust from one space to the other. This void is referred as cognitive distance between the physical and the computer world [6]. Two separate components exist that consist the cognitive distance. The first component is the cognitive effort needed in order for the driver to move his/her attention from the physical to the computer environment and to locate the appropriate information in that space: moving the view from the road to the display. The second component is the needed effort to return back from the computer environment to the physical world and to implement the gained information in the current activity like using the systems for GPS navigation, glance from the ICT map to the road and the real environment and making a decision regarding the maneuvering and driving of the vehicle. The increased effort for completion of each of the components that make the cognitive distance result in increased total result of the cognitive distance. Going into details, if the user has to switch between spaces often the effect of the cognitive distance is even bigger. This is significant for people with cognitive disabilities, people that complete activities that are in tight regard to the time duration, or activities that have big cognitive load. This is especially important for older drivers that often have weak cognitive system as result of their age [6].

In this regard, the concern of the human factor is how to define criteria for efficient recommendations for support in the design of the systems for driver assistance in vehicles with displaying visual messages without the need to distract the attention of the driver from the driving activity [8]. This should also take into consideration the major road safety issues knowing that the number of systems implemented in vehicles is getting bigger each year [9, 10].

2. Head-Up Displays and Augmented Reality in Automotive Industry

The way information is displayed on the windshield of vehicles or the Head Up Display (HUD) can be one of the solutions for presenting information from the driver assistance system because they are already proven concept for reducing the time and frequency of sight off road while driving [11]. The HUD system is defined as see-through display that presents data without the need of the user to change the usual viewpoint.

Augmented reality (AR) is a concept in which the presented information to the windshield of the vehicle correspond to the elements in the physical world or the real objects in the traffic environment. This concept presents information at the right place where the need for that information originates. With that the number of glances off road in order for the driver to obtain visual information is reduced.

Historically, the HUD systems have been first introduced in fighter jets where the information were shown in the field of view of the pilot. In the automotive industry, for the first time they are introduced by General Motors in 1988 in Oldsmobile Cutlass Supreme. Although, the HUD systems are not a new concept, their sales is not according to the expectations. That is mainly due to different issues with the technology, like the used light sources and optical solutions. Today, there is a significant increase in the demand for these systems from the car manufacturers following the constant improvements in the used ICT.

Only 2% of the vehicles sold in 2012 had a HUD system. Nevertheless, it is expected that by 2020 this percent will reach up to 9. Japan has the highest percentage of vehicles with HUD system in 2010, but it is expected that Europe will become leader in this segment by 2020 [35]. In further, the HUD technology in combination with AR offers potential to overcome the existing issues for displaying visual information for drivers compared to the traditional displays.

One of the key advantages that is expected to be achieved from the increased focal distance of the HUD systems is the reduction of the need to adjust when switching the views and the reduced need for additional adjustment of the driver's eye focus when returning the view to the road. It is expected that the biggest benefit from this feature will be to the older drivers [6], because they have limited range of adoption and they will not have to glance through the lower part of the view field of their glasses in order to read out an information from the dashboard [15].

In addition to that, HUD gains much more attention because it reduces the time needed for adaption of the driver's focus [12], it increases the time of sight on road by reducing the time needed to look at the dashboard and the other systems in the vehicle interior [13, 14].

The time needed for driver's reaction in an emergency is shorter when using these systems compared to the traditional displays. In addition, the speed control is more consistent [4, 6]. These systems enable the driver to spend more time on scanning the traffic, faster response times in unpredictable situations in the traffic, earlier detection of danger, lower mental stress for the drivers, easier use for beginners in traffic [17], lower number of mistakes, shorter times compared to the use of traditional systems for information displaying in vehicles [18] as well as increased understanding of the surrounding of the vehicle especially in conditions of bad visibility

[16]. Altogether, bigger number of drivers feel safer when driving a vehicle equipped with HUD system [19].

The advantages in aspect of better understanding of the situation in the traffic can influence on the probability of the driver to successfully notice an event in critical time [15]. Therefore, it is expected that in the future the HUD systems will become important equipment for most part of the drivers.

However, these systems are also criticized, for example the measured times for scanning of the traffic are valid only in situations with lower load of obligations for the driver and they cannot be generalized for all conditions [15]. Furthermore, these systems can have negative effect if the information projected on the windshield occludes some of the real objects from the traffic scene [20]. This effect is in conjunction to the level of filling up of the field of view as result of the information displayed by the system and the contrast between the displayed information and the real environment in the background [15].

Some of the shortcomings of the previously described system can be overcome with the concept of augmented reality (AR). AR is enriching the three-dimensional world by adding computer generated virtual objects into the user surrounding [28]. This concept has recently been further developed in the context of the automotive industry, enabling registration of the projected information on to the windshield and the real world that the user is looking at [16, 29]. The combination of object or locations and the appropriate information allow condensation of information and enrichment of the perception. This way of information presentation uses new, implicit schemes of presentation that present a lower mental load for the user while interpretation. Especially the information regarding the spatial relations to the surrounding of the vehicle have the capacity to be transferred in AR.

A decade ago, researchers have started investigating and evaluating the concepts for visualization based on AR using mobile platforms or driving simulators based on projectors [30, 31, 32]. The fact that information can be related to the location of the object of interest introduces new possibilities for fast and efficient presentation of information. In the same time, it generated new challenges.

Compared to the HUD systems, the presentation of information in AR has several shortcomings like for example the risk of occlusion of objects of interest in the traffic scene, and the phenomena like perception tunnel and cognitive capture.

In the next part of the paper several displays based on HUD-AR are presented and their functions are analyzed from the aspect of operating a vehicle.

3. Analysis of the existing systems for driver assistance based on the HUD-AR technology

Having in mind the advantages of the systems and in order to test the effects, different types of HUD-AR displays have been analyzed from the aspect of several of their functions for driver assistance.

3.1. Lane Departure

While testing the AR systems that present safe corridor for lane departure when driving in order to provide the driver with the ability to safely overtake a vehicle in front of, the researchers have noticed a significant improvement in two positive aspects: bigger number of the drivers used the braking pedal to lower the speed, which in general is a positive indicator from the aspect of safety; all drivers operated the vehicle and braked in a similar way, according to the instructions of the desired path. Nevertheless, the behavior of the drivers in adverse situations have not been investigated, that is when the vehicle is in the dead spot or when overtaken by a faster vehicle. Furthermore, this study shows that in situations of lane departure, AAR systems have the tendency to make the drivers glance at the side rear view mirror later compared to the drivers not

using such a system, because the visual attention of the driver is firstly occupied by the AR display on the road (Figure 1.). After they interpret this AR information, the drivers checked the side mirror to prepare for lane departure.



Fig. 1 Driver Assistance System for lane departure

(Source: <http://cdn.bmwblog.com/wp-content/uploads/head-up-display-augmented-reality-04.jpg>).

Keeping the desired path of the vehicle while driving can be especially difficult for unexperienced drivers and/or in bad weather conditions when the visibility is lower. The concept of augmented reality enables outlining of the road edge with a virtual element assisting the driver in the task of maneuvering the vehicle (Figure 2, Figure 3). By displaying a path for driving in augmented reality, the maintaining of the vehicle in the desired path of motion can be achieved while lowering the deviations from the desired trajectory [19].



Fig. 2 Driver Assistance System for lane keeping

(Source: <http://continental-head-up-display.com/ar-hud/#arhudfeatures>).



Fig. 3 Driver Assistance System for lane keeping

(Source: <http://www.wired.com/2010/03/gm-next-gen-heads-up-display>).

3.2. Detection of critical events on the road

Drivers must be careful on the vehicles around them, the dangers on the road, the desired path, pedestrians and traffic signs and all of that while driving the vehicle, controlling its speed and direction. All these tasks increase the physical and the mental

workload, which is especially dangerous for older drivers and drivers with lower reflexes. Hence, an alarm that would warn the driver for an eminent danger on the road can assist in minimizing the workload of the driver and decrease the number of accidents. The fact that a critical event can be presented on the windshield can assist the driver in detecting the dangerous events (Figure 4, Figure 5). Compared to traditional systems for driver assistance, HUD-AR systems lower the time needed for detection of an event up to 100ms [34].



Fig. 4 Driver Assistance System for obstacle detection on the road

(Source: <http://continental-head-up-display.com/ar-hud/#arhudfeatures>).



Fig. 5 Driver Assistance System for critical events detection

(Source: <http://continental-head-up-display.com/ar-hud/#arhudfeatures>).

3.3. Night Vision

The systems for displaying information with AR can significantly improve the visualization in dark, emphasizing the location of pedestrians and other obstacles on the road, enabling drivers to efficiently transfer information that is instantly understandable [32, 35].

Night vision systems are known from time ago and for the first time were used in the military industry. In the automotive industry, this type of systems was introduced for the first time in a serial production model by Mercedes-Benz in 2011. This system shows an image on display placed in the instrument panel of the vehicle. That means that the driver needs to move the eyes from the road, to interpret the image on the display, to return the view on the road and to implement the information gained from the system. The systems for night vision using AR present the very same information but this time directly on the windshield and with that significantly lowering the workload of the driver and decreasing the time needed for processing of the information and taking action (Figure 6).



Fig. 6 Driver Assistance System for night vision

(Source: <http://w-info.blogspot.mk/2013/05/hud-head-up-displays-windshield.html>).

3.4. Navigation

The concept for projecting navigational instructions and guiding through space directly on the windshield using HUD or AR has been researched for several years now. The main goal of the researchers is to investigate if this way of informing the driver makes the decision making process easier for the driver that is navigating through different traffic conditions and complex road infrastructures. The use of navigation systems based on GPS that presents information on display results in divided attention, meaning the driver needs to focus the view at the display with navigational instructions and the road ahead at the same time. In addition, a significant cognitive effort is needed to interpret the computer-generated streets on the navigational system and connecting them to the real streets in 3D perspective of the driver.



Fig. 7 Driver Assistance System for navigation

(Source: <https://www.the4cast.com/2013/09/pioneer-launches-navigate-head-display-hud-future-satellite-navigation>).

Projecting information in AR can be used to minimize the issue of visual distraction. The distraction and the cognitive effort can be mitigated through overlapping the navigational information with the real world directly on the windshield. In that way, the system assists the driver and enables him/her to focus the attention only on one location and easily interpret virtual information in efficient navigational instructions.

Some navigation solution based on AR [36], use the complete surface of the windshield to project navigational information like the destination or the distance to it in combination with the heading of movement that the driver needs to follow.

Some researchers develop similar system for driver assistance where instead of standard navigational instruction the solution uses so called virtual cable. This solution uses a volumetric display to create a 3D image and overlay it to the view of the real world through the windshield.



Fig. 8 Driver Assistance System for navigation

(Source: <http://www.ohgizmo.com/2007/12/17/virtual-cable-provides-better-in-car-navigation>).

However, because the virtual image of the AR is by definition connected to the reality or the road infrastructure, the potential for anticipation with this type of display while navigating through space is less efficient compared to the existing displays of the navigation devices. They inform the driver for the next steps necessary to undertake much earlier than the AR based devices that provide this information after the location is in the field of view of the driver. To overcome this problem, some researches [6] develop device based on AR that allows anticipation of the next steps even when the appropriate infrastructure is still not in the field of view of the driver. In this original concept, the AR information is overlapped in the upper portion of the real street and continues with the display of the streets that come ahead and what the driver needs to follow even they are still not in the driver's field of view (Figure 8).

While testing this device, the authors have notices that older drivers liked the fact that AR allows them to see at the same time the navigational instructions and the real street. They have also mentioned that this enables them to easily notice the pedestrians crossing the streets. As expected, AR reduces separation of the attention and the cognitive load for older drivers that have difficulties using the navigation devices and most of them have lower cognitive functions.



Fig. 9 Driver Assistance System for navigation

(Source: Seung Jun Kim, Anind K. Dey [6]).

However, it was noticed that in cases when the visualization informs before time about the needed activities like the needed turn in a street, some drivers made mistakes and turned earlier, before they have arrived at the appropriate intersection. Other drivers have commented that when the visualization have instructed them to drive straight (by presenting a lighted path moving upward on the

windshield) they thought that they can continue to drive straight no matter the real condition of the traffic scene and the signals at the traffic lights.

4. Conclusion

Besides the fact that the HUD systems are present since the 80s, they are still not a usual way of displaying visual information in the automotive industry. Studies have shown that HUD displays have bigger potential, but they have lower acceptance level from drivers. One of the possible reasons for that why HUD systems are still not well established is the fact that so far the focus was on their development as technology, and not on adjusting to the needs of their use by drivers. The design principals of the classic 2D displays are not applicable any more in full for this way of presentation, because of the different habits of movement of the visualized objects. Further research is needed in the area of determining the combination of design principals that provide best results for a certain driving activity especially for HUD and AR.

Based on that perspective, the review presented in this paper shows that HUD-AR visual displays have great potential from the aspect of driver assistance in the way of increasing the perception and decreasing the work load, but with caution to the design principles and implementation of information to the windshield. In addition, it is necessary to make additional studies in real conditions and not with the use of driving simulator in order to get better understanding of the acceptance level of the driver for the HUD systems and to get understanding of that where drivers like to receive the information.

Further research should be conducted on the aspect of human factors in order to fully understand the ways of optimization of the huge technological advantages of the HUD-AR concept in the automotive industry with a final goal to increase the road safety.

Understanding the challenges that these systems are bringing and their effect to the road safety in the everyday use in traffic should become part of the capacities of the other stakeholders (police, departments for motor vehicles, insurance experts, prosecutors and others) involved in the process of keeping the roads safe.

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THE EVALUATION OF TRANSFER TIME IN PUBLIC PASSENGER TRANSPORT

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Abstract: The segment of public passenger transport is a part of the everyday activities of the population. His task is to ensuring for the population commuting to work, at free time activity, shopping etc. The passengers must sometimes during of transport process to change of transport mode. The change is carried in the traffic hub, where the passenger can change the means of transport of the same transport mode or different transport modes. It is important to ensure continuity of public transport in the traffic hub. The current situation in the field of solving the problem has lack, not yet been to developed a complex assessment methodology. In practice this means, that all transfer times between different modes of transport are set from estimations coordinators integrated transport system. The changes of transfer times are performed operatively. In the contribution is set a new methodology of continuity public passenger transport in traffic hub.

.Keywords: PUBLIC TRANSPORT, TRANSPORT HUB, PASSENGER TRANSPORT

1. Introduction

The transportation process is a sequence of consecutive sub-operations, which the passenger must during transportation take part. Passengers in many cases forced crossing passage the same or a different way of transportation. Crossing passage is negative for passenger. The optimal architectural arrangement and optimal setting time of continuity traffic line in traffic hub will significantly contribute to increase the attractiveness of public transport and help reduce growing share of individual transport.

The current situation in the field of solving the problem has lack, not yet been to developed a complex assessment methodology. In practice this means, that all transfer times between different modes of transport are set from estimations coordinators integrated transport system. The changes of transfer times are performed operatively. In the contribution is set a new methodology of continuity public passenger transport in traffic hub.

2. Characteristics of the transport chain

The transport chain in passenger transport can be characterized as a series of continuously sequential material and time actions. Appropriate optimization of partial operations can contribute to the creation of a functional transport system in public passenger transport. [1]

Appropriately chosen methodology of quantifying time elements can reveal the bottlenecks of the shipping process, which need to be modified in order to improve and make public transport more attractive. [1]

In a passenger transport system is a transport element an object that is not divided into smaller parts during the transport process. The transport requirements are imposed on the movement of persons, that is to say the object of transport is the passenger. [2]

All passenger transport systems can be characterized:

- places of arrival, exit and transfer of passengers - by transport hubs,
- sections between pairs of transport nodes, úsekmi medzi dvojicami dopravných uzlov, which are always overcome by the only means of transport,
- the common goal of fast, safe, convenient and reliable transportation [3].

3. The evaluation of the connections in the traffic junction

Traffic and transport processes that affect the linkage of the connections in the transport hub consist of the evaluation of partial indicators. Partial indicators can be divided into:

- time indicators of continuity evaluation,
- spatial arrangement of doped node.

Time indicators of follow-up evaluation

A temporal link connection processes the links between the train, bus and public transport. The result of the analysis is the number of joints, the interval between connections, the suitability and the inaccuracy of connections, and so on. [2]

Frequency connection (Fc) – an indicator that expresses the number of target, starting and direct connections of each type of public passenger transport (PPT) at the traffic hub. The formula for calculating this pointer is:

$$F_c = \sum_{i=1}^n F_i^{target} + \sum_{i=1}^n F_i^{start} + \sum_{i=1}^n F_i^{direct} \quad (1)$$

[Number of public passenger transport connections]

where:

F_c	number of connections PPT
$\sum_{i=1}^n F_i^{target}$	total number of target links PPT
$\sum_{i=1}^n F_i^{start}$	total number of starting links PPT
$\sum_{i=1}^n F_i^{direct}$	total number of direct links PPT
F_1, F_2, F_n	connections of PPT [-].

Interval between connections $\Delta(T)$ – expresses a difference $\Delta(T)$ arrivals or departures of connections PPT, i.e. denotes the difference between the arrival or departure of the second connection (Connection 2) PPT from/to the transport junction and the first connection (Connection 1) PPT form/to the transport junction (fig. 1). In the same way, it continues until the last PPT connection that has arrived or left the transport junction.

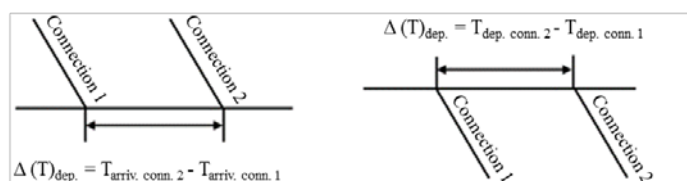


Fig. 1 – Graphical representation of the interval between connections

After determining the interval between individual connections, it is possible to determine the **average interval between connections** ($\bar{I}$). The calculation formula is:

$$\bar{I} = \frac{\Delta(T_{1,2}) + \Delta(T_{2,3}) + \dots + \Delta(T_{n-1,n})}{n-1} [\text{min.}] \quad (2)$$

where:

$\bar{I}$ average interval between connections PPT [min.],
 $\Delta(T_{1,2}), \dots, \Delta(T_{n-1,n})$ interval between incoming or outgoing connections PPT [min.],
 n total number of connections PPT [-].

A **suitable connection** is considered to be the connection that departs for the minimum transfer time and the set maximum transmission time according to the PPT type.

$$T_{\text{departure}} - T_{\text{arrival}} > T; T \in T \text{ min.}, \infty \text{ min.} > \quad (3)$$

An **inappropriate connection** is considered to be the connection that leaves before the minimum transfer time and after the specified maximum transfer time.

$$T_{\text{departure}} - T_{\text{arrival}} \leq T; T \in (0 \text{ min.}, T \text{ min.}) > \quad (4)$$

where:

$T_{\text{departure}}$ time of departure PPT [min.],
 T_{arrival} time of arrival PPT [min.],
 T maximum transmission time [min.].

The **direct link** is the connection which, upon arrival at the transport node stops for the exit and the arrival of the passengers and leaves in one of the directions that are there.

Spatial arrangement of the transport junction

The need for relocation is one of the basic human needs. In many cases, the passenger is forced to change the means of transport of the same or different type of transport. The transport vehicle is changed in the transport node. The construction configuration of the transport hub should therefore comply with certain principles based on the legislative regulation of the European Union and national legislation. [4]

Building element in a transport junction	Measures
Parking spaces	location close to the entrance hall, a sufficient number of parking spaces for people with SHD card (severe health disability)
Access roads	connection of public spaces in the transport junction with the shortest way, alternative access routes for SHD, indication by visual means
Cashes for ticket sales	the sales area is separated by transparent glass, customization for people with SHD card, acoustic devices for better communication
Platforms	separating the danger zone by a visual and tactile indicator, the smallest platform width is 90 cm.
Other building elements	visual information devices and radio equipment for actual transport information,

4. The proposed assessment methodology of linking connections

The proposed methodology is based on:

- using network analysis,
- the calculation of partial indicator (modules).

Using network analysis

Network analysis (NA) - Is a special way of mathematically displaying a time or technological sequence of partial operations where the basic element is a **network graph**. It serves as a graphical representation of individual partial operations and links between them. [5]

The generated network graph is both edge and vertices rated:

- **evaluating the edges in the graph** – the edges in the network graph are formed by orientated connections between the individual vertices (the operations of the passenger in the transition at the transport junction) and represent the access paths in the transport junction. Evaluating the graphs in the chart is the time ("t") that is needed to overcome the access roads to the passengers.
- **evaluating the vertices in the graph** – the vertices in the network chart are the carriers of the information on the duration of the individual activities at the transfer of the passenger at the transport hub (purchase of travel documents, exit from the vehicle, etc.).

Calculation of partial indicators – modules

This part of the methodology defines the partial operations of the passing traveler, which serve to evaluate the edges and the vertices of the traffic node network graph.

Evaluating network chart vertices

The vertices in the network chart carry the information on the duration of the individual activities at the transfer of the passenger at the transport junction. Partial indicators are:

- exit time from the vehicle,
- time of walking down the stairs,
- time transport of passengers by escalator,
- time of passenger transport in the lift,
- passenger time on mobile walkways,
- time required purchasing travel documents.

Exit time from the vehicle

The factors that affect the time of the passengers coming out of the vehicle are:

- **the time of opening the door on the vehicle „ t_{od} “** - it is determined by measuring according to the design of the trigger mechanism and method for controlling doors,
- **coefficient of design of the door on the vehicle „ C_{dd} “** - the design of a door on a public passenger transport vehicle (their design width) greatly affects the number, speed, time of entry and arrival of.
- **loading the door on the vehicle „ L_{dv} “** - the load on the vehicle is the ratio of the number of passengers outgoing to the number of doors on the vehicle. The more the door is on the vehicle, the faster (in shorter time) the passengers will get out because they are more evenly split in the door. On the contrary, with fewer doors on the vehicle, the time of exit is longer due to the increased use of individual doors on the vehicle.

- **platform edge coefficient „ C_{pe} “** - this coefficient is determined on the basis of the platform edge design. The platform edge design is level where the edge of the platform is at the level of the floor of the vehicle from where the occupants will stand and the level of the platform where the edge of the platform is not at the floor of the vehicle. [4]
- **Baggage handling coefficient „ C_{gh} “**- the luggage coefficient depends on its size, weight and volume.

The resulting relationship for calculating the time required to exit the vehicle is:

$$T_{lv} = t_{od} + \sum_{i=1}^n O_p * \sum_{i=1}^{L_{dv}} T_{epi} * C_{dd} * C_{pe} * C_{bh} \quad [s] \quad (5)$$

where:

T_{lv}	time required to leave the vehicle [s],
t_{od}	time of opening the doors on the vehicle according to their design [s],
O_p	number of outgoing passengers [number of passengers].
T_{epi}	unit time of exit by type of passenger [s],
C_{dv}	door's coefficient on the vehicle [-],
L_{dv}	loading the door on the vehicle [-],
C_{pe}	coefficient of design of the platform edge [-],
C_{bh}	baggage handling coefficient [-].

Time of walking down the stairs

The time required to walk the stairs is to be divided into:

- walk down the stairs,
- walk up the stairs.

The reason for dividing the time needed for the walking passengers on the stairs downward and upward steps are the fact that the speed of downward walkers is faster than the upward speed. The relationship for calculating the time of the passage of passengers on the stairs is:

$$T_{ws} = \frac{N_s}{\phi_{ws_i}} * C_{bh} \quad [s] \quad (6)$$

where:

T_{sch}	walking time on stairs [s],
N_s	number of stairs down or up [-],
ϕ_{ws_i}	walking speed [m.s ⁻¹]
C_{bh}	coefficient baggage handling [-].

Time transport of passengers by escalator

The total transport time depends on the individual design of the escalator at the traffic junction, i.e. it conveyed speed and the escalator length.

In the case of calculating the total time of passenger transport to the escalator, it is necessary to calculate the number of passengers traveling simultaneously at the escalator.

Calculation of the passenger's time to the escalator:

- 1. passenger - t_1
- 2. passenger - $t_1 + t_i$
- 3. passenger - $t_1 + 2 * t_i$
- n – th passenger - $t_1 + n * t_i$

The time of the first passenger's journey ("t₁") to the escalator is determined by:

$$t_1 = \frac{L}{p_s} \quad [s] \quad (7)$$

where:

t_1	time of one passenger's journey [s],
L	length of the escalator [m],
p_s	passenger speed [m.s ⁻¹].

In the case of the time of each other passenger's journey ("t_i"), account must be taken of the time of the first passenger's transport and the time of another passenger's transport. The relationship and calculation of the time of another passenger's journey is:

$$t_i = \frac{2 * L_s}{p_s} \quad [s] \quad (8)$$

Time of passenger transport in the lift

The total transit time in the lift is dependent on the individual design solution used in the transport junction.

Time up passengers from the lift begins to run after the lifts stop on the relevant floor, it can be determined by:

$$T_{pgoi} = t_{od} + \frac{\sum_{i=1}^n T_{pgoi} * N_p}{C_{de}} \quad [s] \quad (9)$$

where:

T_{pgoi}	the unit time for the passengers to get out of the lift [s],
t_{od}	time of opening the lift door [s],
N_p	number of outgoing passengers [number of outgoing passengers],
C_{de}	the construction of the door to the elevator [-].

The time at which passengers can enter the lift begins to run from the moment when all the passengers arrive can be determined by the relationship:

$$T_{ep} = \frac{\sum_{i=1}^n T_{EP_i} * N_p}{C_{rdvv}} + t_{cld} \quad [s] \quad (10)$$

where:

T_{epi}	unit time of passengers entering the lift [s],
T_{cld}	time to close the lift door [s],

The total calculation time of transferring the passenger in the lift can be determined according to the relationship:

$$T_l = T_{pgoi} + T_{ep} + \frac{d}{v} \quad [s] \quad (11)$$

where:

T_l	total transit time in the lift [s],
d	distance travelled by lift [m],
v	conveyed lift speed [m.s ⁻¹].

Passenger time on mobile walkways

The mobile walkway is suitable for mass transit of people in shopping centers and transport hubs. In general, it is possible to determine the time of transport according to the relationship:

$$T_{mw} = \frac{L}{v} + N_{pc} \quad [s] \quad (12)$$

where:

T_{mw}	total time on mobile walkways [s],
L	path of the mobile walkways [m],
v	transport speed of the mobile walkway [m.s ⁻¹].

Time required purchasing travel documents

The place where a traveler can buy the necessary travel documents for his / her journey is a typical example of the THO (Theory of Mass Management). Places for the sale of travel documents consist of service lines and may consist of one or more service lines.

The basic THO model will be $M / M / n / \infty$ system in which n nodes are available or vending machines for the sale of travel documents. We assume that customer arrivals are described by a Poisson division with the λ frequency and the length of service time of one service line has an exponential distribution with an average operator time of $1/\mu$. All lines are mutually equal and equally powerful. Serving passengers are in the order in which they entered the system.

The total time spent in the system, i.e. the average total time spent in the system is the sum of the average time spent waiting in the queue for the service and the time of the operator:

$$E(R) = \frac{\pi}{n*\mu - \lambda} + \frac{1}{\mu} = \frac{\frac{\rho^n}{n!} * \frac{1}{1 - \frac{\lambda}{n*\mu}} p_0}{n*\mu - \lambda} + \frac{1}{\mu} \quad [min.] \quad (13)$$

Edge evaluation in the network graph

Edges in the network graph are formed oriented link between the individual peaks (passenger operations at crossing the transport junction) and represent access roads to transport junction.

Time walking along the access road

Access roads should connect all public spaces at the traffic junction as quickly as possible. Another module for assessing linkages in public passenger transport is to determine the time needed to overcome these distances.

The relationship for calculating the walk access road is:

$$T_{wr} = \frac{d}{\varnothing v_{ws_i}} * C_{bh} \quad [s] \quad (14)$$

where:

T_{wr}	walking time on access roads [s],
d	distance that passengers must overcome [m],
$\varnothing v_{ws_i}$	the average walking speed by type of traveler [m.s ⁻¹],
C_{bh}	coefficient baggage handling [-].

In the case of a passenger coming out of a means of transport, the distance from the farthest door to the vehicle from which the passenger may exit can be counted. In this case, the relationship for walking time calculation will look like this:

$$T_{wr} = \frac{d_{max}}{\varnothing v_{ws_i}} * C_{bh} \quad [s] \quad (15)$$

where:

d_{max}	the maximum distance that passengers must overcome after leaving the means of transport [m].
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The result of the application of a network graph at the transport junction and the calculation of individual time slots is to make a comprehensive assessment of linkage in public passenger transport for all combinations of edges and peaks that may occur.

Comparing calculations

The last part of the methodology compares the transit times of the passengers, which are determined on the basis of the network analysis of the transport node (time needed for the transfer) and the intersection interval between the connections. Based on the comparison, the following are set:

- appropriate connection,
- inappropriate connection,
- direct connection.

For a **appropriate connection** according to the relation (3), we consider the connection which leaves after the minimum transfer time and within the determined maximum transfer time according to the type of PPT.

For an **inappropriate connection** according to the relation (4) we consider the connection that leaves before the minimum transfer time and after the determined maximum transfer time.

The direct link is the link that upon arrival at the transport hub stops for loading and unloading passengers and goes to one of the directions that are out there mouths.

Conclusion

The presented methodology is based on a comprehensive analysis of the transport hub on the technical-construction site and the arrangement of the individual elements affecting the passengers' transition times. The proposed solution is based on the real situation, yet it provides a methodology suitable for different transport nodes with the potential to implement an integrated transport system.

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A STUDY OF THE INFLUENCE OF CONTROL VALVE STROKE CHANGE ON THE CONSEQUENT WEAR ON FUEL FLOW RATE

Изследване влиянието на промяната на хода на управляващия клапан вследствие износване

върху цикловата порция гориво

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Abstract: In the process of operation, there are changes in the injector with hydro-electromagnetic control of the nozzle needle. These changes are due to a wear on all components of the fuel system. Essential to the wear rate of the nozzle elements, excluding the clearing degree of the fuel and the extent of its cleaning prior to entering the high-pressure system of fuel system, are the operating pressure of the fuel, the number of sprays, the thermal load, the speed and the accelerations of the movable elements. The valve wear on the control valve changes the stroke of the ball valve. This variation results in an increase in the output flow from the control chamber, which increases the speed and the maximum stroke of the control piston and the flow fuel rate respectively. The ball valve stroke increasing respectively increases the distance between the core of the electromagnet and the coil. The increased distance between the coil and the core also has a significant effect on the hydraulic characteristics of the nozzle.

KEY WORDS: VALVE SEAT, WEARING OUT, ELECTROMAGNETIC GAP, HYDRAULIC CHARACTERISTICS

1. Introduction

The fuel injection systems is a key sub-system for direct-injected internal combustion engines as its operation controls to a large extent both the mixture formation and the combustion processes. In particular, in compression ignition engines the fuel metering accuracy, the required injection rate time-profile and the uniform fuel spray spreading in the combustion chamber are strictly governed by the injection system behavior. The achievement of these complex tasks is mandatory in order to fulfill the current automotive market design targets in terms of fuel conversion efficiency, combustion noise control and pollutant emissions level.

The way to achieve all these requirements is to carry out a multiphase injection of the fuel.

The main disadvantage of the nozzles with hydro-mechanical control of the nozzle needle is that it is unable to change the characteristics and timing of the fuel supply, as well as to perform multi-phase fuel supply. This limits the fuel economy reducing opportunities and the toxic substances amount.

This disadvantage is corrected using hydroelectromagnetic control needle of nozzle.

This type of injector is able to accurately manage the fuel supply, but it considerably loads all elements of the injector design.

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$$(1) S = \pi d h, \text{ m}^2, \text{ where}$$

$$(2) d = 2R \cos \frac{\alpha}{2}$$

In which S is the area of the throttle bore, h - the stroke of the ball valve, d - the diameter of the ball valve, a - the angle of the inclination of the valve seat

When increasing the diameter, it is also necessary to increase the compressive force F_k of the ball valve.

This force causes a greater load in the control valve elements. Accordingly, reliability is reduced. [4]

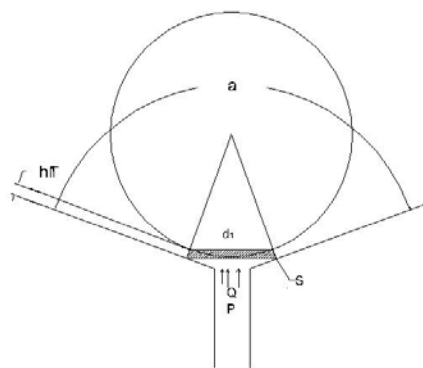


Fig. 1 Changing in speed defined by the diameter of the ball valve

This is the mechanism of the valve seat wearing out, as a major influencing factor are the modes in which there is a larger number and a long duration of the control pulses.

This wearing increases the stroke of the nozzle needle, thus multiplying the cross-section, increasing the actual fuel flow rate of fuel injected into the cylinder.

The change of the control valve stroke is followed by a change in the distance between the core and the electromagnetic coil.

When the valve seat is worn out, the control valve sinks down with it and the electromagnetic core, which increases the magnetic clearance h_k between the core and the coil (Fig.2). This change reduces the speed of core attraction, as well as the magnitude of the fuel flow rate, which, in turn, compensates the impact of the increased stroke of the control ball valve.

The purpose of this study is to determine the influence of the control valve wearing on the injection process.

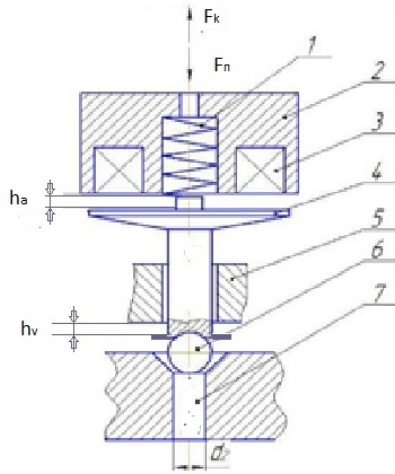


Fig. 2 General appearance of the solenoid:

1 - spring; 2 - core; 3 - coil; 4 - core; 5 - nut; 6 - ball valve; 7 - valve seat, h_a - electromagnetic gap, h_v - ball valve stroke

2. Discussion and results

The study of the effect of the control valve stroke magnitude on the hydraulic characteristics of the electromagnetic injector was carried out by an experimental installation for research purposes of common rail fuel systems in a laboratory in the Department of Engines and Automotive Engineering at the University of Rousse.

The subject of the study is a magnetic injector with ball control valve Bosch series 0445110.

The realization of the study is possible because the structure of the object allows changing the stroke of control ball valve and the magnitude of the electromagnetic gap between the coil and the armature of the solenoid. This enables making all the attempts on the same electromagnetic injector Bosch.

The standard magnitude of the electromagnetic gap must be a 0.08 mm, determining the fuel flow rate formation. By smaller electromagnetic gap values, the fuel flow rate increases. With greater gap, the fuel flow rate decreases, and the actual injection moment is displaced by the angle of rotation of the crankshaft.

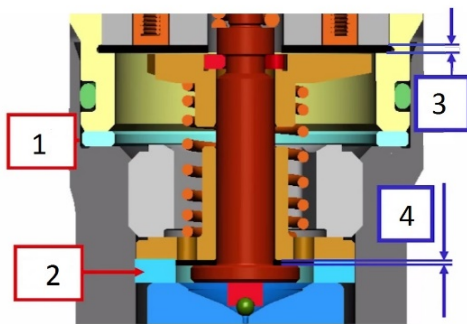


fig. 3 Diagram of the solenoid valve

1 - Electromagnetic gap washer, 2 - Ball valve washer, 3 - Electromagnetic gap, 4 - Ball valve stroke.

Implementation of the injection process occurs as a result of the following pressure difference in the fuel chamber under the nozzle needle and the control chamber. When the electromagnet coil is triggered, the ball valve is lifted. At this moment the pressure in the control chamber drops. After the trigger impulse stops, the ball valve closes quickly, causing wearing on the valve seat. With prolonged use, the ball valve stroke increases as a result of wearing

on the valve seat. In this way the ball valve changes its stroke. This further disturbs the density of the ball valve to the valve seat. [2] These changes lead to an increase in the speed and the stroke of the control piston, respectively, of the nozzle needle, which starts wearing more intensely in its sealing surface to the nozzle.

The quantitative relationship between the magnitude of electromagnetic gap and the injection characteristics is examined by altering the thickness of the adjustable washer between the injector body and the electromagnet coil.

The values of the control pulses and the working pressure are experimentally selected according to the capabilities of the test equipment.

In fig. 4 and 5 show the results of the hydraulic characteristics according to the magnitude of the electromagnetic gap in the control valve.

Figures 6 ÷ 13 show the graphs of the results obtained in the modification of the hydraulic characteristics of the electromagnetic injector by modeling the wearing by the change in the control ball valve stroke,

These changes are observed when the stroke increases by 0.025 mm and 0.04 mm in comparison with the usual values of stroke, with a control impulse duration of 0.4 ÷ 0.8 ms and a fuel pressure of 30 ÷ 60 Mpa

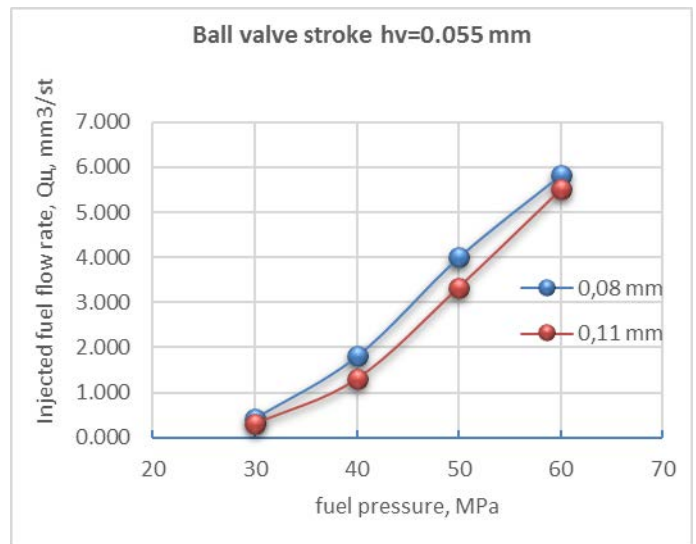


Fig. 4 Alteration of the fuel flow rate defined by magnitude of electromagnetic gap $h_{coil} = 0.08 \div 0.11$ in control valve at fuel pressure $P_a = 30 \div 60$ MPa.

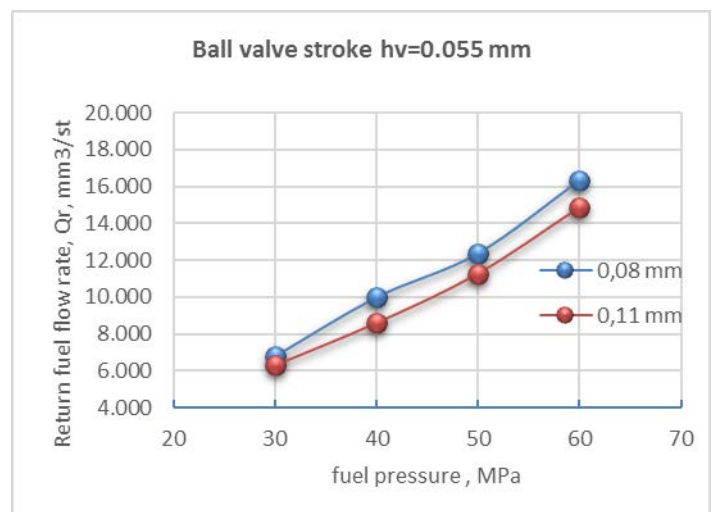


Fig. 5 Alteration of the return fuel flow rate defined by the magnitude of the electromagnetic gap $h_{coil} = 0.08 \div 0.11$ mm in the control valve and the fuel pressure $P_a = 30 \div 60$ MPa

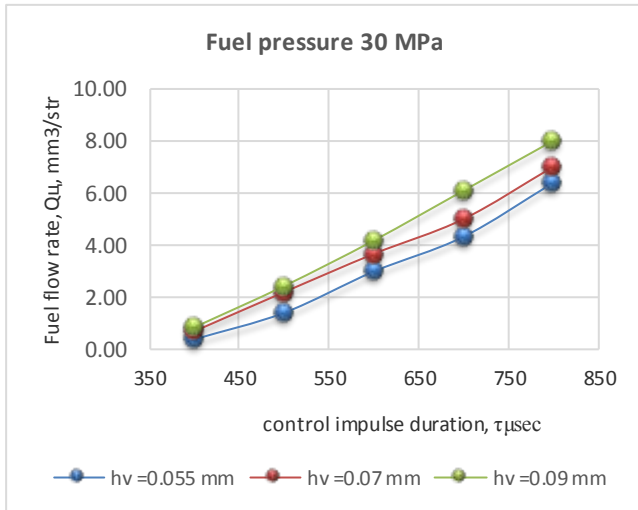


Fig. 6 Alteration of the fuel flow rate defined by the stroke of the control ball valve $h_v = 0.055 \div 0.09$ mm

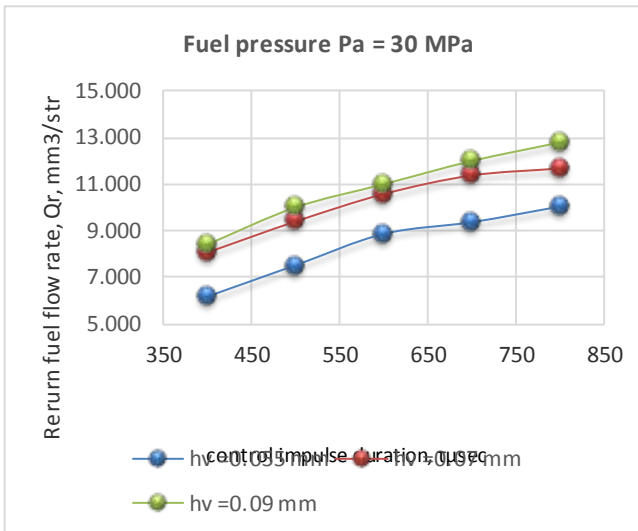


Fig. 7 Alteration of the returned fuel flow rate defined by the stroke of the control ball valve $h_v = 0.055 \div 0.09$ mm

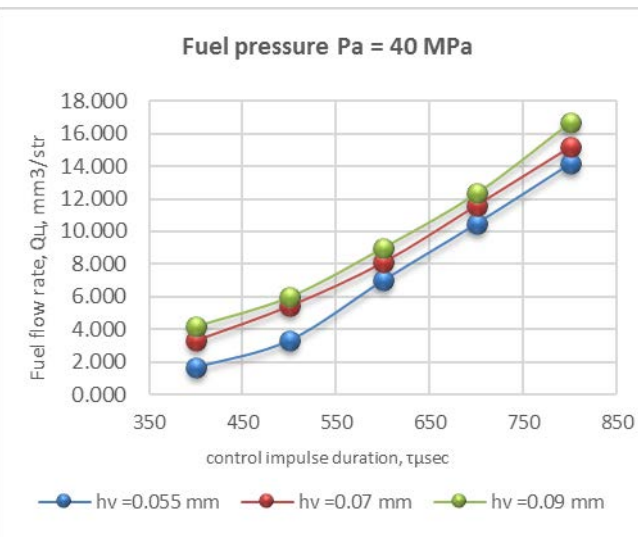


Fig. 8 Alteration of the fuel flow rate defined by the stroke of the control ball valve $h_v = 0.055 \div 0.09$ mm

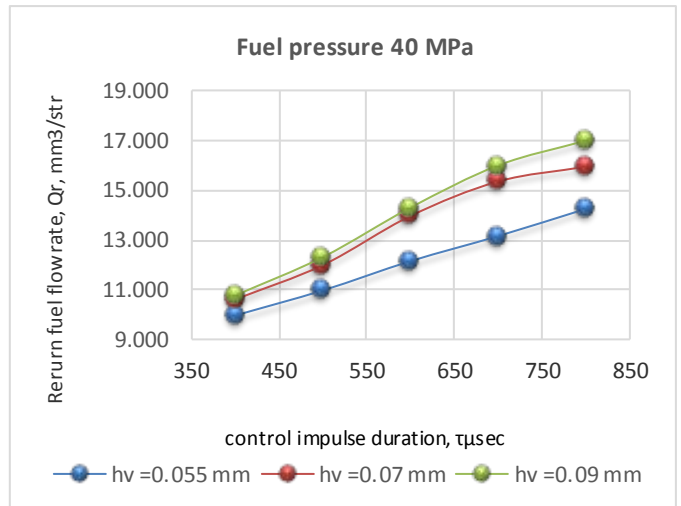


Fig. 9 Alteration of the returned fuel flow rate defined by the stroke of the control ball valve $h_v = 0.055 \div 0.09$ mm

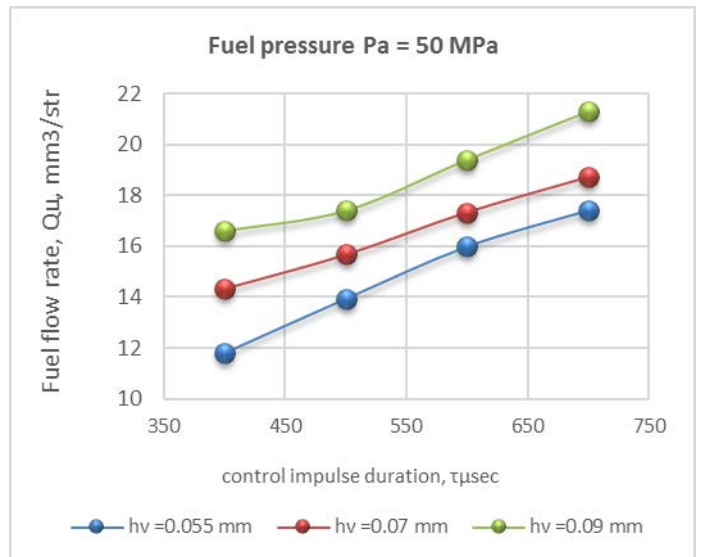


Fig. 10 Alteration of the fuel flow rate defined by the stroke of the control ball valve $h_v = 0.055 \div 0.09$ mm

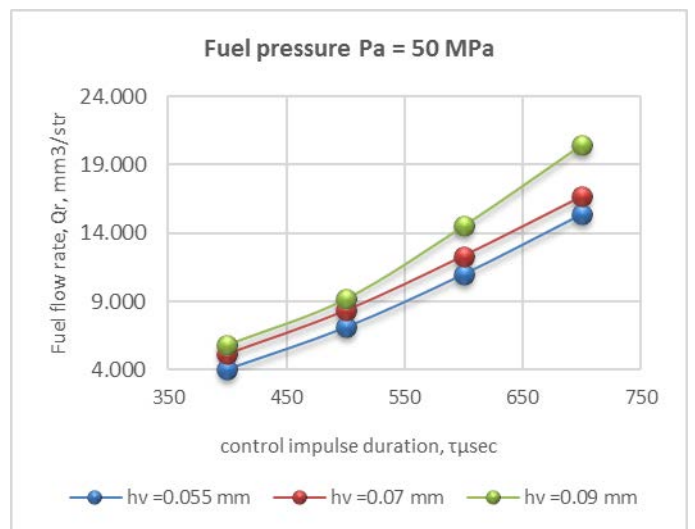


Fig. 11 Alteration of the returned fuel flow rate defined by the stroke of the control ball valve $h_v = 0.055 \div 0.09$ mm

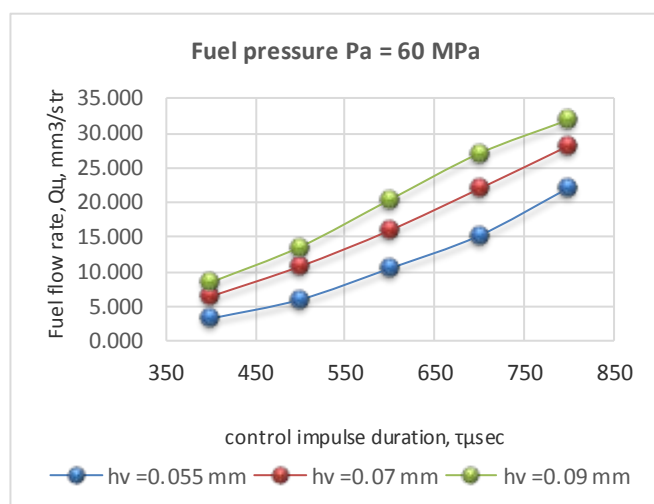


Fig. 12 Alteration of the fuel flow rate defined by the stroke of the control ball valve $h_v = 0.055 \div 0.09$ mm

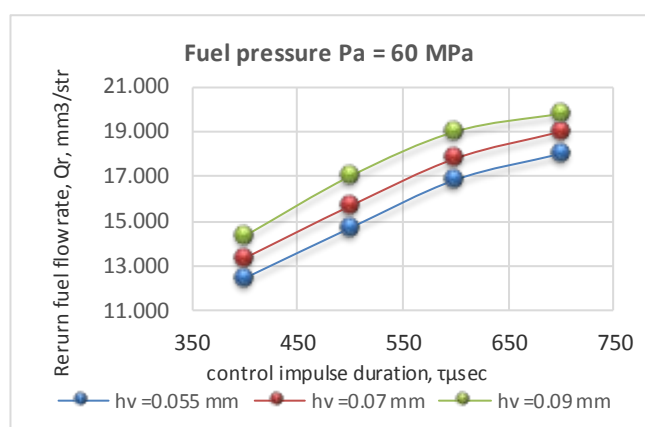


Fig. 13 Alteration of the returned fuel flow rate defined by the stroke of the control ball valve $h_v = 0.055 \div 0.09$ mm

3. Conclusions

The following conclusions can be made from the experiment.

1. In the modeling of the change of the electromagnetic gap by 37% or the increase of the stroke by 0.025 mm a decrease in the fuel flow rate was found about 19%.
2. In the modeling of the change of control ball valve stroke by 27 % or 0.025 mm, an increase of the fuel flow rate was found about 19%, as the increase of return fuel flow rate was about 18%.
3. In the modeling of the ball valve stroke by 63% or 0.04 mm, an increase of the fuel flow rate was found about 21 %, as the increase of the return fuel flow rate was found about 17 %

4. As a result of wearing in the control ball valve, the fuel flow rate Q_c , mm³ as well as the return fuel flow rate, mm³, is increased.
5. The measurement results obtained confirm the effect of the increased electromagnetic gap on the hydraulic characteristics of the injector.
6. Result of the increasing of the control ball valve stroke is the increasing of the electromagnetic gap between the core and the electromagnet coil.

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The report has been reviewed.