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TRAFFIC INFORMATION INTERFACE DEVELOPMENT IN ROUTE CHOICE DECISION

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In this paper, a method has been developed based on historic traffic data (vehicle speed), which helps the commuters to choose routes by their intelligence knowing the traffic conditions in Google maps. Data has been collected on basis of video analysis from several segments between Tuker Bazar and Bandar Bazar route. For each of the video footage, a reference length has been recorded with measurement tape for use in video analysis. Software has been also developed based on Java language to get the traffic information from historic data, which shows the output as images consisting of traffic speed details on the available routes by giving day and time limit as inputs. The developed models provide useful insights and helpful for the policy makers that can lead to the reduction of traffic congestion and increase the scope of intelligence of the road users, at least for the underdeveloped or developing country where navigation is still unavailable.

Keywords: traffic speed, speed interface, route choice, Google maps, Java, Kinovea

1. Introduction

Traffic congestion is a notable transportation related problems in Bangladesh. This problem is becoming a prominent problem in Sylhet city, the fifth populous city in Bangladesh (BBS, 2011) with a population more than 0.6 million and an area of only 26.5 km^2. This city is facing rapid urbanization problem because of large amount of people's migration with unimproved transportation facilities (Haque, 2008), the leading reason behind rapid increase in congestion. Tuker Bazar to Bandar Bazar is one of the busiest and congestive routes in Sylhet city.

The urban transport issues of mobility, congestion, safety and environmental aspects are becoming increasingly important and critical while the rapid urbanization process, high vehicular population growth, inadequate transportation facilities and policies, varied traffic mix with an over concentration of non-motorized vehicles, absence of dependable public transport system and inadequate traffic management practices have created a significant worsening of traffic and environmental problems in the major urban areas (Haque, 2011).

Generally people choose routes from alternatives with the knowledge of experience on that specific road condition on a specific time range. The capacity of the roadways is not sufficient to transport all car drivers without delay, especially in the rush hours when there are enormous traffic jams. Therefore, a method has been developed in this paper based on historical traffic data, which helps the drivers or commuters to learn the traffic flow condition of specific time span, and, thus, helps to choose routes by their intelligence knowing the traffic conditions. An overview has been proposed to show the traffic data and traffic condition in basis of vehicle speed.

2. Literature Review

Traffic information collection and providing it to the commuters for their route choice is an important part of intelligent transportation system. Vast researches are being made on this sector worldwide. Tong et al. (2006) described an integrated GPS-GIS methodology for traffic information data extraction. The spatial characteristics for the highways of interest were developed using a GIS based on the Franklin County DOQQ with a high resolution of 0.5 ft. (0.15 m). Linear referencing, which is used by highway professionals to express a location as a distance from a known starting point in a given direction, was also used in the GIS. Chen et al. (2010) proposed path observation generation algorithm, supplemented to a path probability measurement in their paper to generate path observations from GPS data. By applying to real trips, they showed the viability of the algorithm and analyzed some characteristics of the algorithm in order to explore any possibility of improving it. Tatomir et al. (2009) discussed the problem of dynamic routing in their paper. They adapted the ABC algorithm and were able to compute the shortest path in time taking into account travel time predictions along road segments. They combined it with historical data from ANWB containing speed measurements along the freeways in the Netherlands. Anwar and Chowdhury (2007) presented a complete Transport Information System that facilitates the travellers to choose their comfortable transport, reduce ravel time by guiding them to travel through a shortest path to go their desired destination. Abbass (2010) used image processing to estimate car speed, given a sequence of real-time video of traffic images. The images are converted to monochrome images then edges are extracted and then quantified the resulting images to classify the objects and find the cars, after detecting the cars, they can be tracked in different frames and their speed can be estimated by calculating the position of the car object in different frames and compare it to a ground truth. His research used a different approach to estimate speed, rather than using a reference object to estimate speed, the MATLAB function is used and different relationships between the objects that are extracted from the image itself.

Mehrubeoglu and McLauchlan (2009) used optical flow patterns and blob analysis for vehicle detection and tracking. Yu et al. (2002) describes an algorithm that estimates traffic density and average speed from Skycam MPEG compressed images. Kimsey (2010) showed time and distance analysis to calculate speed of a patrol car from a videos tape of 29.97 frames per second in which a still picture is recorded every 0.0333 seconds.

Gathering inspiration from Google traffic map, in this paper an interface for traffic information (speed) is being tried to be developed. Google maps shows traffic information by collecting GPS enabled handset data to help the commuters make their choice to choose the route or change their current route for any kind of incident such as congestion, traffic flow volume etc. In this context, Java language based software has developed, which will show the traffic condition (via traffic speed) on Google maps, which will be a guideline for the developing countries where navigation is still unavailable.

3. Methodology

A traffic information interface based on vehicle speed has been developed for easier route choice decisions as well as a software output based on Java language. Tuker Bazar to Bandar Bazar route has been chosen. Three roads are used mainly to travel this route which is via Medical road, Police line road and Amberkhana and have fifteen road segments. Existing roadway of this route are shown on Figure 1.

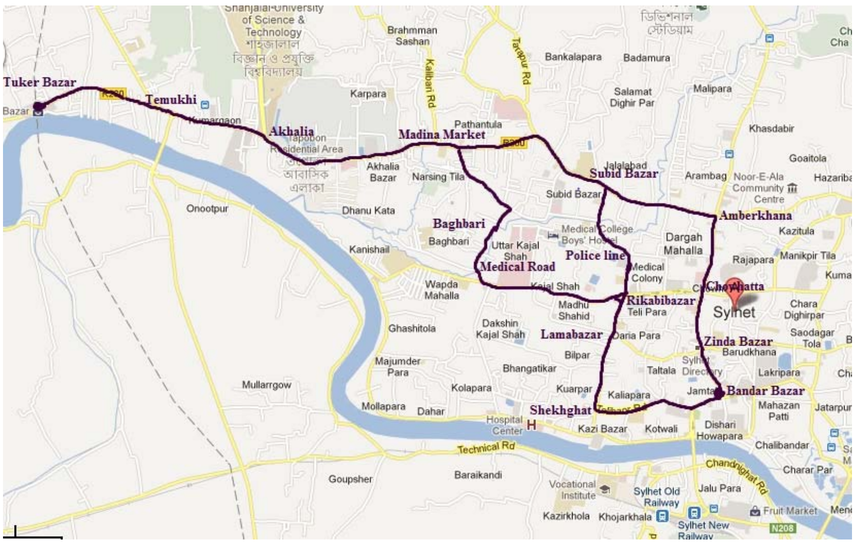

Figure 1. Study area (Source: http://maps.google.com/)

At first, stations are selected to collect the video footages. On each station video of 15 minutes for each hour is made keeping the road perpendicular to the video camera. Several video footages are collected from each road segments available from Tuker Bazar to Bandar Bazar. Hourly data have been taken from 9:00 AM to 10:00 AM and 4:00 PM to 5:00 PM of Sunday only. For each of the video footage, a reference measurement length has been recorded with measurement tape for use in video analysis. The recorded videos are analyzed with the help of biomechanical video analyzing software named Kinovea. Video footages are calibrated by the reference measurement that was recorded during data collection. The video footages are of 29.97 Frames per second. The videos are made of slow motion to detect frame by frame images to realize the movements of vehicles in time. Then from an easy velocity calculation (V = D/t) the speed is measured (Kimsey, 2010). Using this speed variation data, an interface has been developed which will show the traffic condition with speed limits by denoting different colours. Software has been developed based on Java language to get the output more easily to the commuters.

4. Data Analysis

Traffic speed has been calculated from collected video footages by the software named Kinoviea and the speeds were found automatically from the software. Then this speed was calculated by video analysis calculation and have been compared both findings. In this paper only Sunday and 9:00AM-10:00AM and 4:00PM-5:00PM have been taken as the busiest day and time of the week.

An example has been shown here how the traffic speed of a specific route has been calculated. The example video footage was taken at Shahjalal University Gate area of Sylhet-Sunamgonj Highway Road. A reference measurement of 9.39 meters between two billboard poles has been taken. A CNG taxi was just about to cross the first pole from the right side when it was found, Frame no: 363 and Time: 0:00:12:07 that means 12.07 seconds (Figure 2). When the taxi was about to cross the left sided second pole crossing 9.39 meters the calculated Frame no: 391 and Time: 0:00:13:01 that means 13.01 seconds (Figure 3).

Figure 2. Taxi about to cross first pole

Figure 3. Taxi about to cross second pole

Now using conventional formula,

Distance Travelled by the CNG Taxi,

$D = 9.39$ meters

Time to cross the above mentioned distance,

$t = (13.01 – 12.07) = 0.94$ seconds

So, Speed of the CNG Taxi,

$V = D/t = 9.39 / 0.94$

$= 9.9894$ meter per second

$= 35.96$ kilometre per hour

≈ 36 km/h

And from the same vehicle, from Kinovea output, it was found 36.22 km/h ≈ 36 km/h. Figure 4 shows the software output.

Figure 4. Taxi speed from Kinovea

Hence the speed limit have been taken of that road is between 30 km/h to 40 km/h.
This way all the roads traffic speed of two specific time limits and a day has been calculated and shown in Table 1.

Table 1. Speed details for Sunday 9:00AM-10:00AM and 4:00PM-5:00PM (km/h)

Road Segment	**9:00AM-10:00AM**	**4:00PM-5:00PM**
Tuker Bazar-Temukhi	40-50	40-50
Temukhi-Akhalia	50-60	40-50
Akhalia-Madina market	30-40	30-40
Madina market-Baghbari	10-20	20-30
Baghbari-Medical	20-30	20-30
Medical-Rikabibazar	20-30	10-20
Rikabibazar-Lamabazar	20-30	10-20
Lamabazar-Shekhghat	30-40	20-30
Shekhghat-Bandar Bazar	30-40	20-30
Madina market-Subid Bazar	30-40	20-30
Subid Bazar-Rikabibazar	30-40	20-30
Subid Bazar-Amberkhana	20-30	0-10
Ambarkhana-Chouhatta	20-30	0-10
Chouhatta-Zinda Bazar	20-30	0-10
Zinda Bazar-Bandar Bazar	20-30	0-10

5. Model Development

The motive to collect the speed of traffic vehicles is to make them available to the commuters so that they can make choice which route to be selected when generating a trip. For this reason an interface development is required by which travellers can learn about the traffic condition on the routes available. An interface has been developed, a small Java based software to show the traffic condition on a specific day in a time limit. By this software a commuter can input the DAY and TIME LIMIT and the output will show an image consisting of traffic speed details on the routes available from Tuker Bazar to Bandar Bazar. The colours to express the speed limits are as follows in Table 2.

Table 2. Colours defining the speed limits

Colour	**Speed(km/h)**
	0-10
	10-20
	20-30
	30-40
	40-50
	50-60

The outputs of the software for these two time limits 9:00am-10:00am and 4:00pm-5:00pm of Sunday are given below:

Figure 5. Speed limit details (Sunday, 9:00am-10:00am) on map for the routes from Tuker Bazar to Bandar Bazar

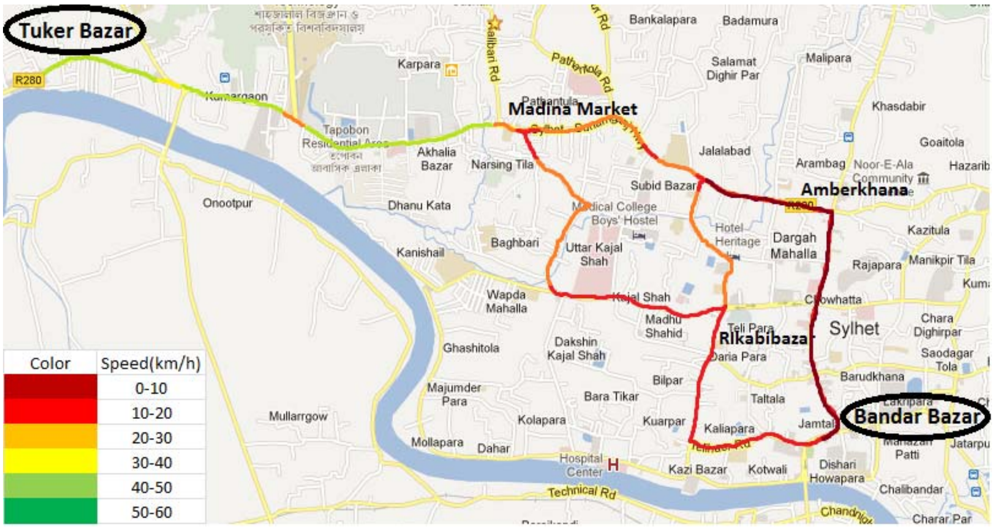

Figure 6. Speed limit details (Sunday, 4:00pm-5:00pm) on map for the routes from Tuker Bazar to Bandar Bazar

It was found that can be seen on Figure 5 that almost all the routes have moderate flow, but medical road is comparatively with smooth flow than other two routes; and Figure 6 shows that Medical road or Police line road is better to be chosen as Amberkhana link is with traffic congestion. This helps a commuter to choose the routes before starting his journey with this information. The developed software can be used in computer and mobile phones to collect traffic information by commuters.

6. Conclusions

A conceptual method in Google maps for showing traffic information based on vehicle speed and a Java based software to get the output more easier to the commuters have been developed in this study. First, vehicle speed has been calculated from both Kinovea and conventional formula and a speed range has been denoted with different colours. Second, a Java based software has been developed to find the output of traffic condition in Google maps by giving input “DAY” and “TIME LIMIT”, which can be used in computer as well as commuters mobile phone. In a developing country like Bangladesh has not yet been introduced to any advanced technology such as sensors, speed detecting camera and many powerful software and their database to collect traffic information and reach them to travellers in real time, navigation etc., although traffic congestion is a major concern in this country.

There were so many limitations and disadvantages by doing this research. The most highlighting problems were that collecting so many video footages with normal video camera is difficult and time consuming. With this developed method it is not possible to provide real time traffic information whether only historic data is available. It would be better if it is possible to use speed detecting devices like sensors or speed cameras to collect the traffic speed data. For limited time and due to many reasons all the traffic speed data for other days could not be collected. This may be expanded by taking data of 24 hours, at least morning to night of whole week as well as whole month. In Bangladesh, setting up traffic sensors, camera or other technical devices traffic information's can be collected in near future. And a route user will be able to know about traffic condition even before starting his journey. But still the developed method is an attempt to collect the speed data of routes, which might be helpful if it is well developed, regularly updated and available to people.

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WEIGHT-IN-MOTION ESTIMATION BASED ON RECONSTRUCTION OF TYRE FOOTPRINT'S GEOMETRY BY GROUP OF FIBRE OPTIC SENSORS

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The problem of measuring road vehicle's weight-in-motion (WIM) is important for overload enforcement, road maintenance planning and cargo fleet managing, control of the legal use of the transport infrastructure, road surface protection from the early destruction and for the safety on the roads. The fibre-optic sensors (FOS) functionality is based on the changes in the parameters of the optical signal due to the deformation of the optical fibre under the weight of the crossing vehicle. A fibre-optic sensor responds to the deformation, therefore for WIM measurements it is necessary to estimate the impact area of a wheel on the working surface of the sensor called tyre footprint. This information is used further for the estimation of the vehicle wheel's speed, contact width, length, and, finally, axle's weight while in motion. Recorded signals from a truck passing over a group of FOS with various speeds and known weight are used as an input data. The results of the several laboratory and field experiments with FOS, e.g. load characteristics according to the temperature, contact surface width and loading speed impact, are provided here. The method of initial signal deconvolution on symmetric and asymmetric components provides the chance to approximate geometric size of tyre surface footprint as well as calculate weight on each wheel separately. The examples of the estimation of a truck speed, tyre contact surface footprint parameters using FOS signals are discussed in this article.

Keywords: transport telematics, weigh-in-motion, fibre-optic sensor, tyre footprint

1. Introduction

The worldwide problems and costs associated with the road vehicles overloaded axles are being tackled with the introduction of the new weigh-in-motion (WIM) technologies. WIM offers a fast and accurate measurement of the actual weights of the trucks when entering and leaving the road infrastructure facilities. Unlike the static weighbridges, WIM systems are capable of measuring vehicles travelling at a reduced or normal traffic speeds and do not require the vehicle to come to a stop. This makes the weighing process more efficient, and in the case of the commercial vehicle allows the trucks under the weight limit to bypass the enforcement.

There are four major types of sensors that have been used today for a number of applications comprising the traffic data collection and overloaded truck enforcement: piezoelectric sensors, bending plates, load cells and fibre-optic sensors (McCall & Vodrazka, 1997; Teral, 1998). The fibre-optic sensors (FOS), whose working principle is based on the change of the optical signal parameters due to the optic fibre deformation under the weight of the crossing road vehicle (Batenko & etc., 2011; Malla & etc., 2008), have gained popularity in the last decade.

Analysis of the WIM current trends indicates that optical sensors are more reliable and durable in comparison to the strain gauge and piezoelectric sensors. Currently the two FOS types based on two main principles are being used:

- Bragg grating (the change of diffraction in a channel under deformations);
- The fibre optical properties (transparency, frequency, phase and polarization) change during the deformations.

A lot of recent investigations are devoted to the peculiarities of the construction and applications of the sensors, using different physical properties. The data presented in this publication have been received using SENSOR LINE PUR experimental sensors (SENSORLINE GmbH., 2010) based on the change of the transparency (the intensity of the light signal) during the deformation.

2. Axles Weighing-in-Motion Principles

The fibre optic weight sensor is the cable consisting of a photoconductive polymer fibres coated with a thin light-reflective layer (Fig. 1(b)). A light conductor is created in such a way that the light cannot escape. If one directs a beam of light to one end of the cable, it will come out from the other end and in this case the cable can be twisted in any manner. To measure the force acting on the cable, the amplitude technology is more appropriated for the measurements based on measuring of the optical path intensity, which changes while pushing on the light conductor along its points.

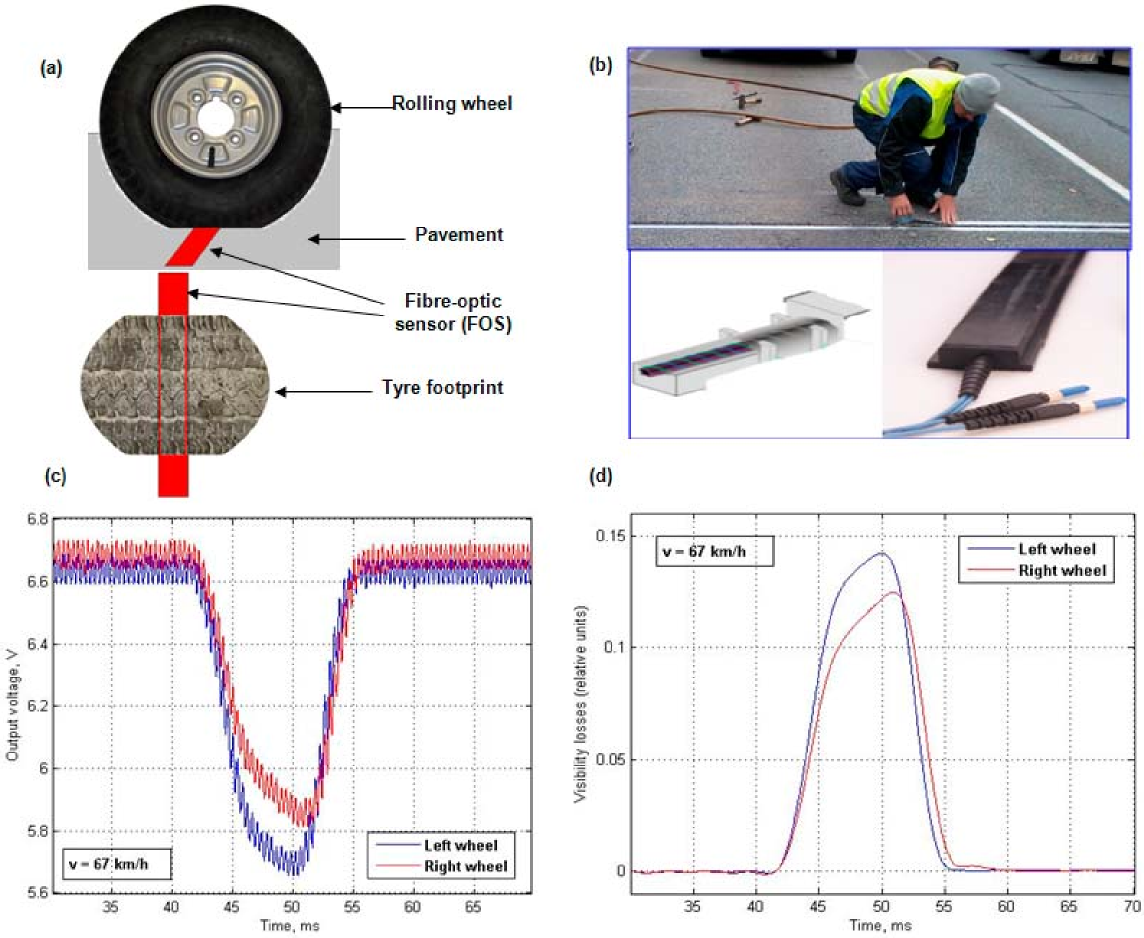

Figure 1. (a) Fibre optic sensor's position against the wheel and tyre footprint, (b) SENSORLINE PUR installation and construction of the sensor, (c) FOS output voltage, (d) Visibility losses as the function of pressure after pre-processing (filtering)

At these points the deflection of a light conductor and reflective coating occurs, that is why the conditions of light reflection inside are changed, and some of it escapes. The greater the load the less light comes from the second end of the light conductor. Therefore the sensor has the unusual characteristic for those, familiar with the strain gauges: the greater the load the lower the output is. Apart from the fact that it is reversed and in addition to this it is non-linear.

In order to avoid the inaccuracy of zero load level we need to exclude the high frequency components from the voltage signal at the output of the sensor's transducer by filtering, as well as to recalculate the voltage signal $\boldsymbol{U(t)}$ (Fig. 1(c)) into the relative visibility losses signal $\boldsymbol{V(t)}$ (Fig. 1(d)), directly related to the weight pressure on the FOS surface. It can be done by the transformation (1):

$$V(t) = \frac{U_0 - U(t)}{U_0}, \qquad (1)$$

where U_0 is the voltage of sensor's output with zero loads. The signal transformation to the relative visibility losses signal $V(t)$ gives the possibility to compare signals for different measurements in different conditions.

Fibre optic load-measuring cables are placed in the gap across the road, filled with resilient rubber (Fig. 1(b)). The gap width is 30 mm. Since the sensor width is smaller than the tyre footprint on the surface, the sensor takes only part of the axle weight. Two methods are used in the existing systems to calculate the total weight of the axle (Malla & etc., 2008; McCall & Vodrazka, 1997): the Basic Method and the Area Method. The following formula is used to calculate the total weight of the axis using the Basic Method:

$$W_{ha} = A_t \cdot P_t , \tag{2}$$

where W_{ha} – weight on half-axle, A_t – area of the tyre footprint, $P_t \sim V(t)$ – air pressure inside the tyre and, according to Newton's 3rd law, it is proportional to the axle weight.

As we can see the exact values of the formula factors are unknown. The area of the tyre footprint is calculated roughly by the length of the output voltage impulse, which, in its turn, depends on the vehicle speed. The Area Method uses the assumption that the area under the recorded impulse curve line, in other words – the integral, characterizes the load on the axle. To calculate the integral, the curve line is approximated by the trapezoid. In this case the smaller the integral – the greater the load. This method does not require knowing the tyre pressure, but it requires the time-consuming on-site calibration. Also, it has to be kept in mind that the time of the tyre crossing the sensor is too small to get an electrical signal of high quality for its further mathematical processing. We use the Area method only for the tyre footprint area definition in (2), but the pressure is measured from the signal amplitude.

3. Experimental Vehicle Parameters

There was the set of measurement experiments with the roadside FOS sensors on April, 2012 in Riga, Latvia. Loaded truck (Fig. 2) was preliminary weighed on the weighbridge with the accuracy < 1%.

Figure 2. Experimental truck "Volvo FH12" with full load *36900 kg*

Table 1. The reference static axle weights

Date: 20.04.2012 (Air Temperature +12ºC)					
Reference axle weight (tons):	**7.296**	**12.619**	**5.509**	**5.641**	**5.844**

Reference weights of the separate axles are given in the Table 1. The output signals from FOS sensors for truck speeds 70 km/h and 90 km/h are demonstrated on Figure 3. It is evident that the signals for the different speeds have been changing by amplitude and the proportion of amplitudes does not fit the axle weights (Fig. 3).

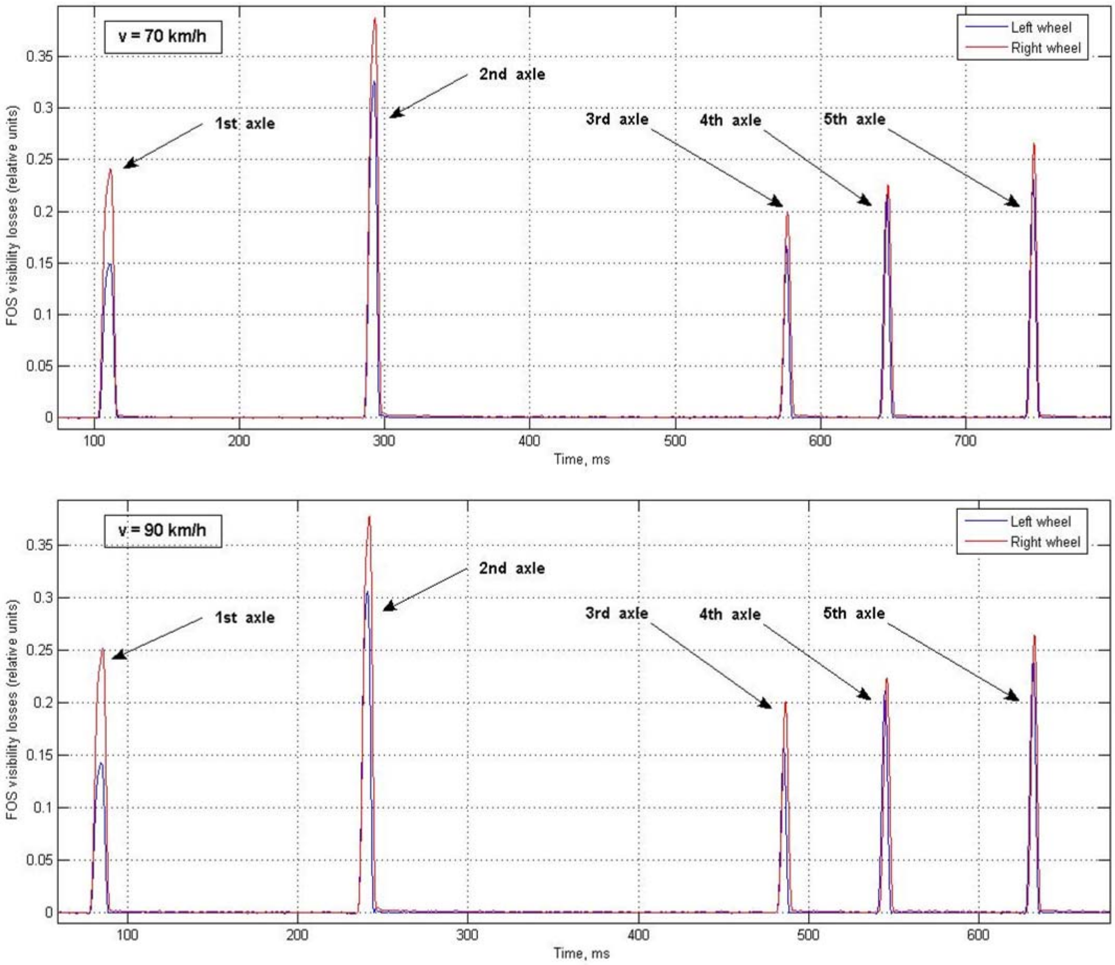

Figure 3. Examples of FOS signals of experimental truck for vehicle speeds 70 km/h and 90km/h respectively

The reason of this behaviour may be explained by FOS properties such as weight (pressure) distribution along the sensor length as well as sensor non-linearity and temperature dependence.

4. Fibre Optic Sensor Properties

Fibre-optic sensor (SENSORLINE GmbH., 2010) output light intensity changes due to the applied external vertical force were measured using of the optical interface SL MA-110 that was developed by SensorLine GmbH (SENSORLINE GmbH., 2010). Laboratory experiments with varying parameters (temperature, steel plate width and load speed) were made at the Institute of Polymer Mechanics (University of Latvia) with electronically controlled compression machine.

The first experiment examined the load characteristic according to the temperature change: FOS was placed into the tube of the soft thermal insulation material in which chilled carbon dioxide was circulating. The load from a compression machine was applied to the sensor through the tube and a 200 x 200 mm square steel plate (Figure 4(a)). It was found during this experiment that the optical response of the FOS was changing due to the warming; and it is important to notice, that no pressure has been applied (Figure 4(b)).

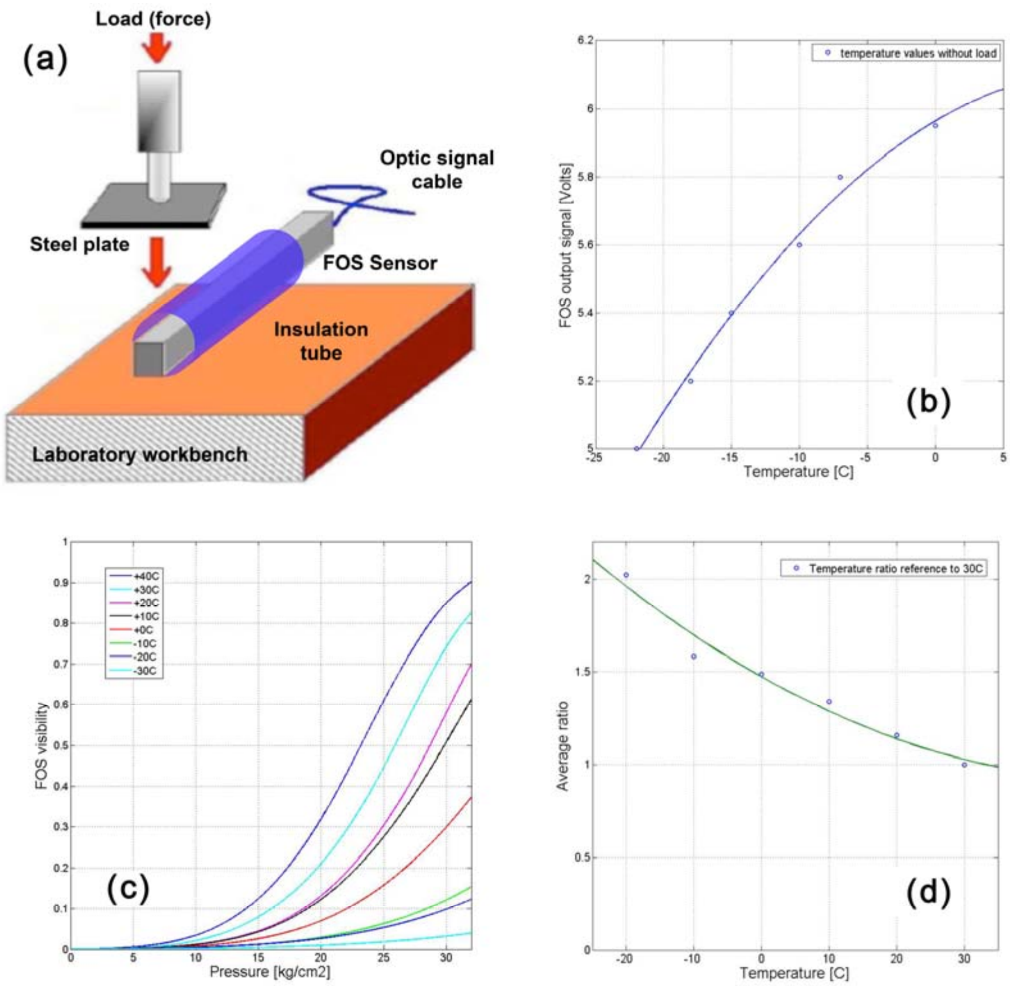

Figure 4. (a) Experimental laboratory equipment scheme, (b) FOS temperature dependence without applying load, (c) FOS load characteristics at different temperatures and (d) Fitted model of FOS various temperature load characteristic ratio values relative to 30°C degrees

FOS is permanently installed in the road surface, therefore environment temperature changes affect characteristics of the protective housing rubber (stiffness) and the medium where the light propagates. These changes introduce nonlinear distortions, which together with externally applied pressure on a FOS, are displayed on Figure 4(c). Relations between the load characteristics at the different temperatures are displayed on Figure 4(d). These relations can be conditionally described by polynomial approximation model:

$$LC_{T[C]} = LC_{30[C]} \cdot (a_2 \cdot t^2 + a_1 \cdot t + a_0), \tag{3}$$

where $LC_{T[C]}$ is desired load characteristic at $T^{o}C$ degrees, $LC_{30[C]}$ is load characteristic at $30^{o}C$ degrees and $\mathbf{a}_{2,1,0}$ are coefficients of least square optimisation calculated from Figure 4(d).

In the real environment tyre footprint width may vary depending on tyre size and inflation pressure, which will result in the different force redistribution. The second experiment shows this dependence (Figure 5(a)), these measurements were made at constant temperature 14°C degrees and constant loading speed 20 mm/s.

Relations between the load characteristics obtained using the different steel plates are displayed on Figure 5(b). These relations can be conditionally described by exponential approximation model:

$$LC_{W\,[mm]} = LC_{200[mm]} \cdot a_1 (1 - e^{a_0 / W}), \tag{4}$$

where $LC_{W[mm]}$ is desired load characteristic with W mm wide plate, $LC_{200[mm]}$ is load characteristic with 200 mm wide plate and $a_{1,2}$ are coefficients of least square optimisation calculated from Figure 5(b).

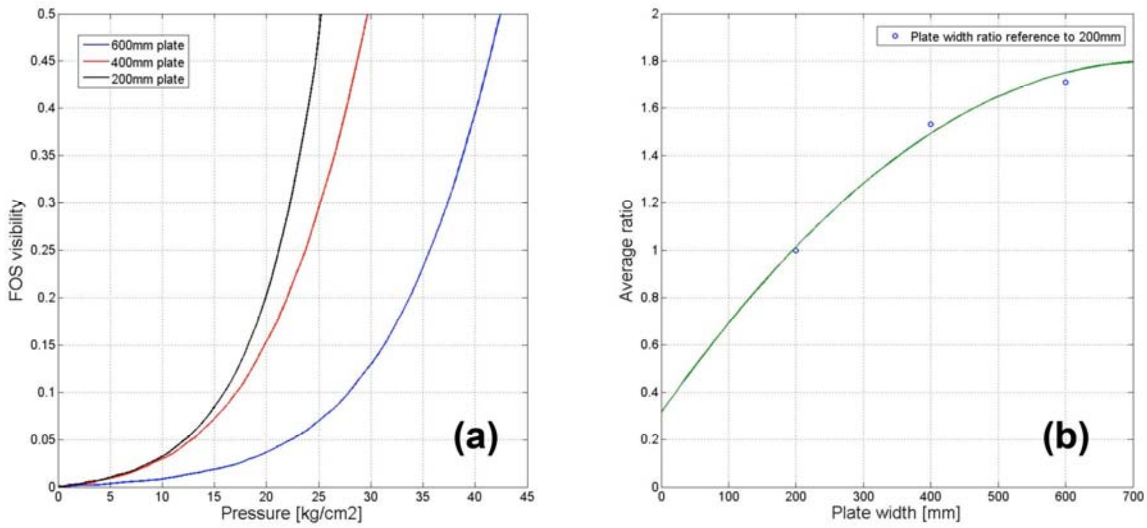

Figure 5. (a) FOS load characteristics with the different steel plate widths and (b) Fitted model of FOS various steel plate width load characteristic ratio values relative to 200x200 mm steel plate

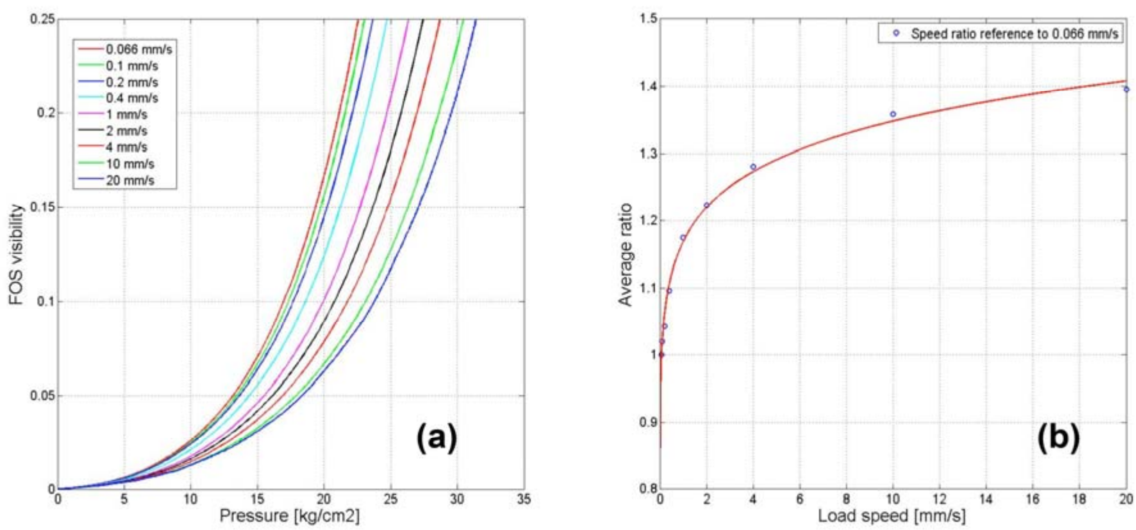

Figure 6. (a) FOS load characteristics at different load speeds and (b) Fitted model of FOS various load speed load characteristic ratio values relative to 0.066 mm/s load speed

The vehicles are crossing the FOS at the different speeds and the sensor reaction is different due to its inertia properties. Therefore the third experiment was dedicated to study FOS output signal dependence on applied force at the different speeds (Figure 6(a)): these measurements were made at the constant temperature 17^{o}C degrees and the steel plate size 200 mm. Relations between the loads characteristics at the different applied speeds are displayed on Figure 6(b). These relations can be conditionally described by power approximation model:

$$LC_{S\,[mm/s]} = LC_{0.066[mm/s]}(a_1 + S^{a_0}), \tag{5}$$

where $LC_{X[mm/s]}$ is desired load characteristic at S mm/s, $LC_{0.066[mm/s]}$ is load characteristic at 0.066 mm/s and $a_{1,0}$ are coefficients of least square optimisation calculated from Figure 6(b).

5. Vehicle Speed and Tire Contact width Evaluation

Using FOS A (FOS B) and FOS 1 (FOS 2) symmetric signals, which are shown in Figure 7, it is possible to calculate the speed of each axle, also the truck speed by calculating the average of the values found before. In order to do this, it is necessary to normalize the signals, filter out the noise and obtain symmetrical signal components. Then impulse peak time value of these components will be used in the axle speed calculation. Distance between FOS A and FOS 1 (or FOS B and FOS 2) should be known in advance; in our case it is equal to 3 m (see Figure 8).

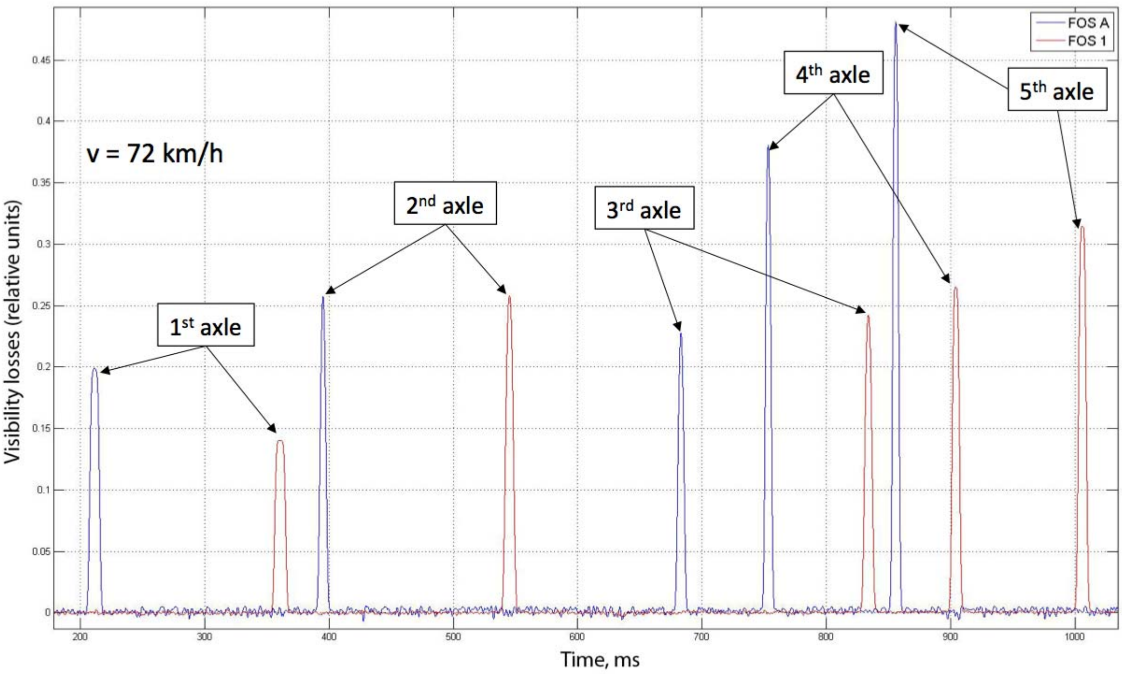

Figure 7. FOS vertical weight component (symmetric) of s1_A, B, 3, 4_70km_27_09_2013 signal

Calculated axle and vehicle speeds, based on the FOS signal peak time of symmetric components, are shown in Table 2.

Table 2. Calculated speed values of s1_A, B, 3, 4_70km_27_09_2013 signal

Speed/axle	1st axle	2nd axle	3rd axle	4th axle	5th axle	Vehicle
Calculated speed [km/h]	**72.34**	**72.00**	**71.63**	**71.56**	**71.93**	**71.89**

Using FOS 1d and FOS A (or FOS 1), which are shown in Figure 8(a), as well as the symmetric FOS pair signals, it is possible to evaluate left and right tyre footprint widths. In order to do this, it is necessary to normalize the signals, filter out the noise and make linearization of the signals according to the pre-calculated axial velocity and temperature of the FOS.

Then pulse widths of perpendicular and diagonal FOS (see Figure 8(b)) are measured on experimentally chosen level of 0.4, multiplying this width subtraction by corresponding axle speed will be the evaluation of tyre footprint.

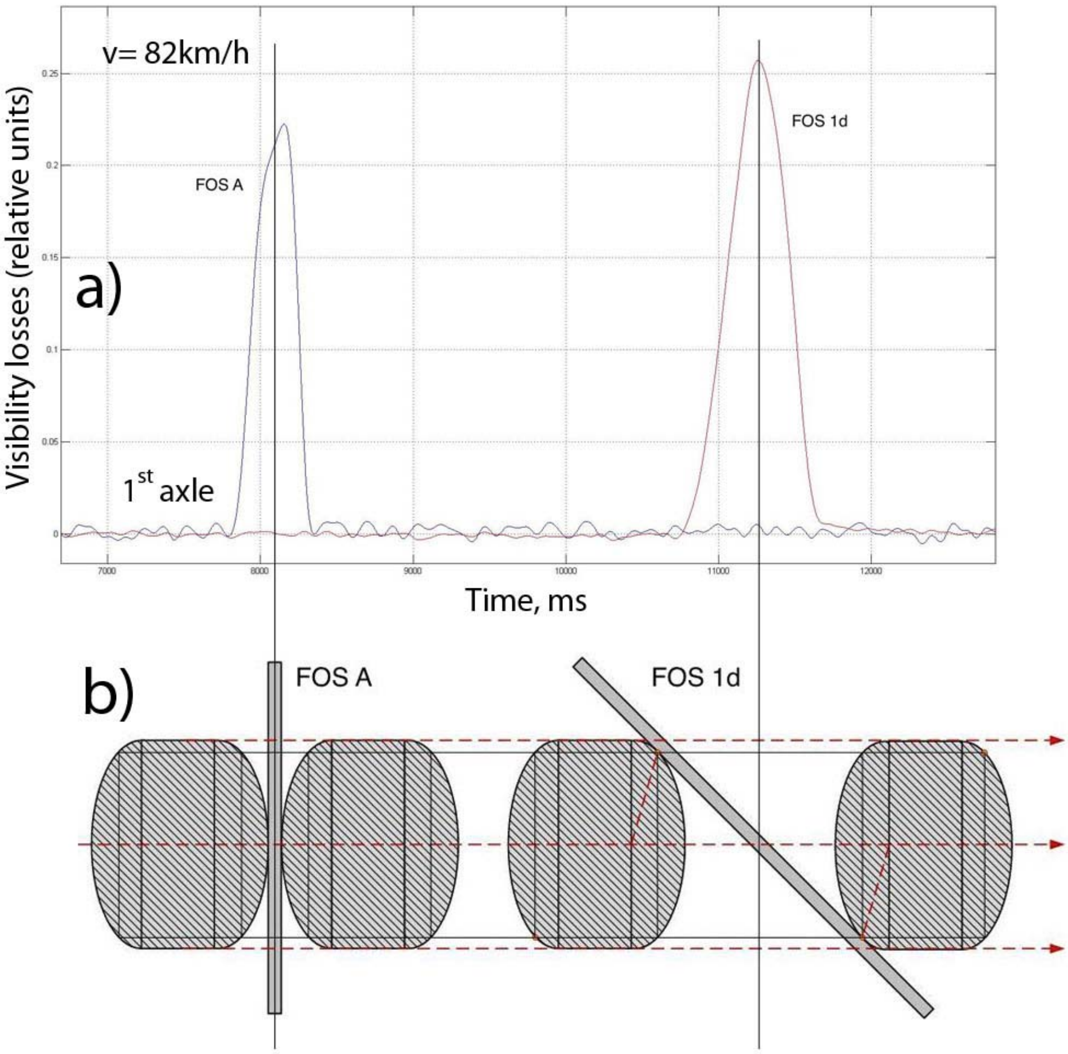

Figure 8. (a) FOS A and FOS 1d filtered s1_A,B,1d,2d_90km_27_09_2013 signal; (b) Tyre footprint interaction with FOS

Table 3. Evaluated tyre footprint width of s1_A, B, 1d, 2d_90km_27_09_2013 signal

Parameter / axle	**1st axle**	**2nd axle***	**3rd axle**	**4th axle**	**5th axle**
Footprint width [mm]	**315**	**680**	**385**	**385**	**385**
Evaluated footprint width [mm]	**310.317**	**890.633**	**399.993**	**375.202**	**387.925**
Error [%]	**-1.487%**	**30.975%**	**3.894%**	**-2.545%**	**0.499%**

* – dual wheels (the distance between two neighbour dual wheels approximately is 40–50 mm and it cannot be measured exactly)

6. Tyre Footprint and Weight Estimation

As it is clearly seen from the expression (2), the A_t area of the tyre footprint should be known to calculate the axle weight by the registered FOS signal (Batenko & etc., 2011). The form of the signal is non-symmetric and sufficiently distorted by the rolling process of the wheel on the road surface (see Figure 9(a)).

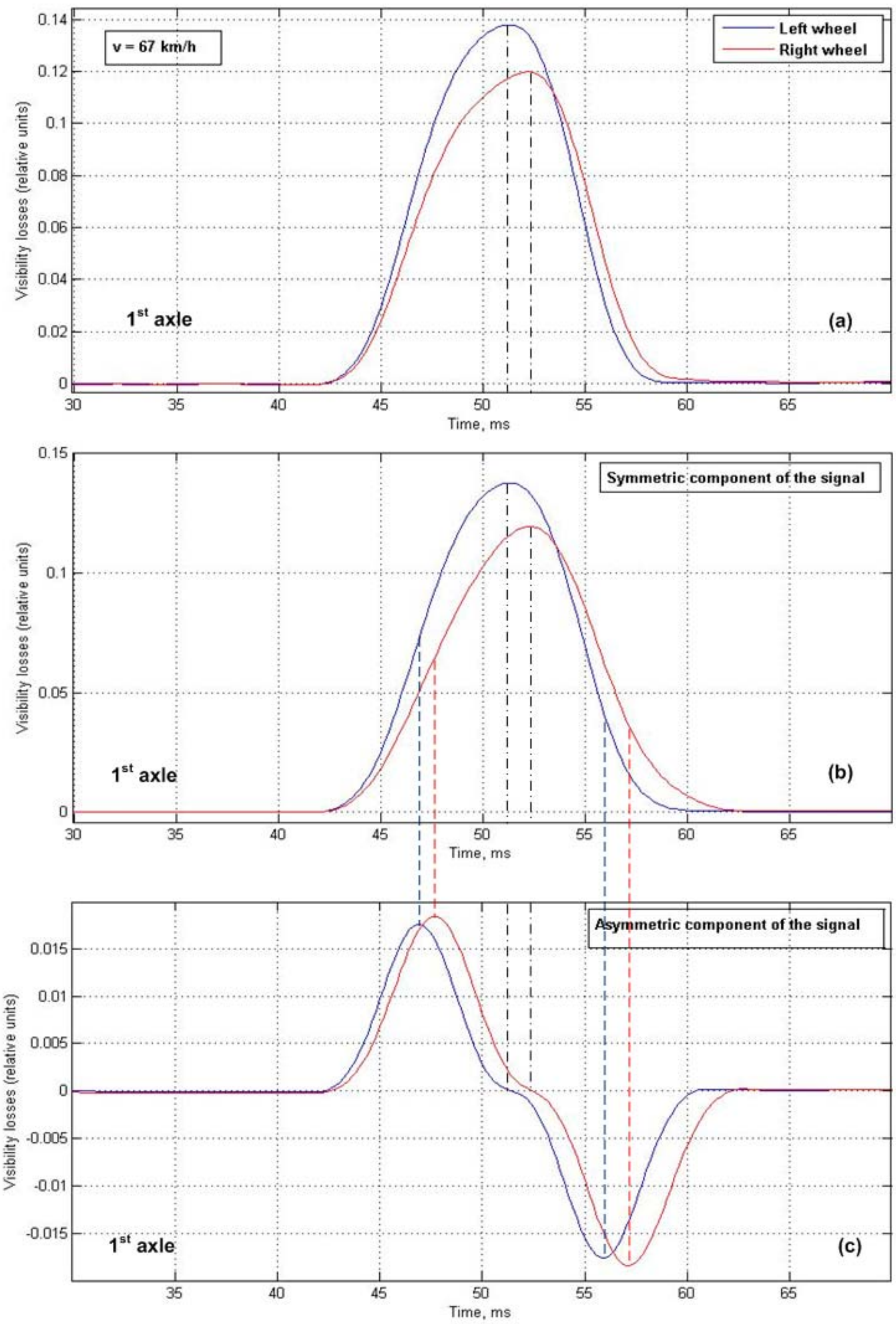

Figure 9. (a) FOS output signal in the form of visibility losses (formula 1), (b) Approximated vertical weight component (symmetric), and (c) Approximated asymmetric component depending on horizontal velocity and friction (Krasnitsky, 2012)

One of the possible explanations of the signal waveform distortion is the idea about the common interaction of two factors (Krasnitsky, 2012): vertical dead weight gravity of conditionally immovable wheel (according to wheel geometry it must be symmetric, see Figure 9(b)), and the force of friction (it depends on the pavement and tyre properties, wheel's speed and weight, and its expected waveform is asymmetric, see Figure 9(c)). The problem of the decomposition of the non-symmetric signal in 2 parts (symmetric and asymmetric) can be solved by the polynomial approximation using the least square method and the further grouping of members with even and odd powers separately or by standard even-odd decomposition of the signal on finite window (Mesco, 1984; Vinay & etc., 2006).

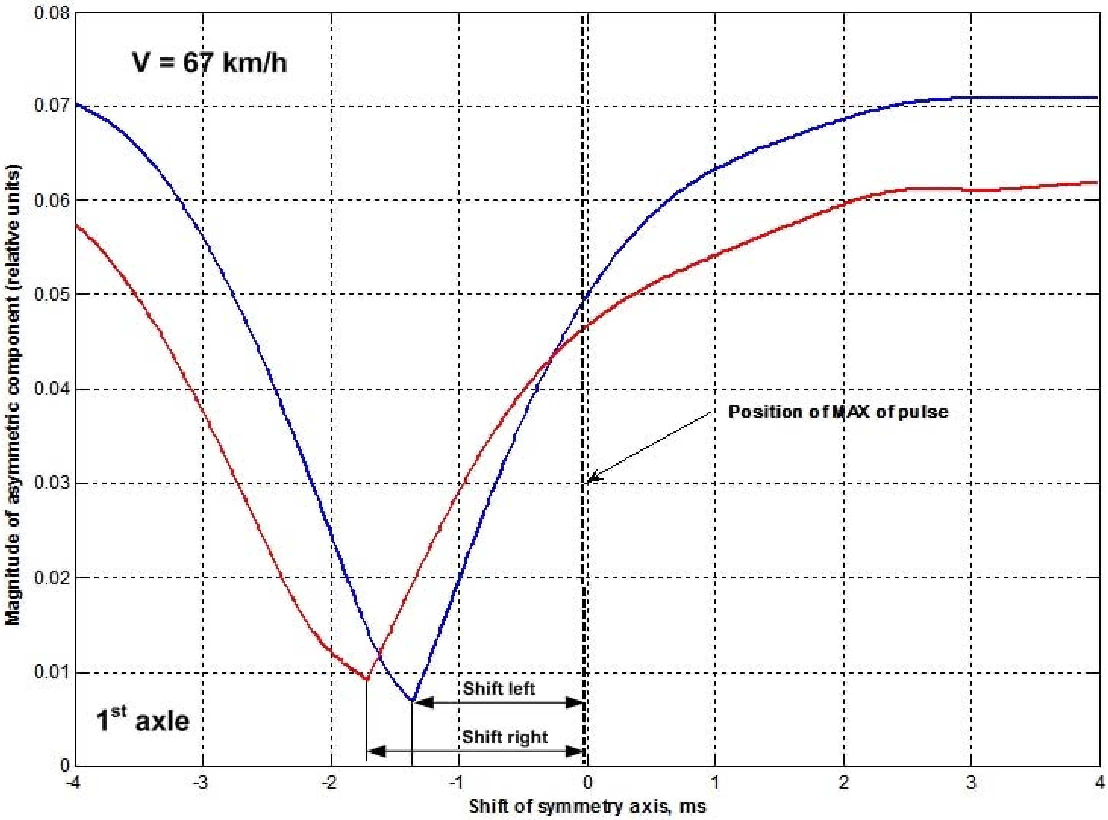

Figure 10. Approximated asymmetric component magnitude as the function on symmetry axis shift from the maximum of the pulse

On the other hand, by assumption that the vehicle moves uniformly and all forces maximally compensate each other, we can accept that the friction force is as minimal as possible (rolling friction only without sliding friction). It is possible to minimize the friction component magnitude moving the axis of symmetry before the pulse (see Figure 10). This dependence is obtained by calculation of the maximum (magnitude) of asymmetric component of the signal changing the shift between maximum of initial pulse form and location of symmetry axis. It will be minimal at the position conditionally named as the "mass centre" of the pulse (see Figure 11(a)).

The waveform of the friction component on Figure 11(b)) sufficiently differs from the same on Figure 9(c). Two maximums and two minimums clearly locate the characteristic points for the tire footprint estimation in the elliptic approximation (see Figure 11(c)).

Now the problem of the tyre footprint area estimation may be solved. Multiplying the impulse length by the speed of the wheel we can calculate the length of the footprint. In the considered examples (Figures 9 and 11) it is $\boldsymbol{L_{left}}$ = 0.1905 m and $\boldsymbol{L_{right}}$ = 0.1976 m. It agrees with another data for the wheel R22.5 and tyre width of 315 mm for the 1st axle.

Applying the above-mentioned approach to another vehicle's axles and wheels we can estimate the length and form of each tyre footprint. Of course, the width of the 2nd axle's tyre we consider as double (double wheels for Volvo FH12 vehicle's the 2nd (motor) axle).

Full data of footprint lengths for experimental cargo vehicle (see Figure 2, 11, 12 and Table 1) are the following: the left side wheels lengths are $\boldsymbol{L_{L12345}}$ = {0.1905 0.1652 0.1278 0.1354 0.1379} meters, and the right side wheels lengths are $\boldsymbol{L_{R12345}}$ = {0.1976 0.1799 0.1509 0.1449 0.1356} meters. The difference between the lengths of each wheel can be explained by the fact that the 2nd axle has the double-wheel, the trailer tyres but (axles No 3–5) width is 385 mm.

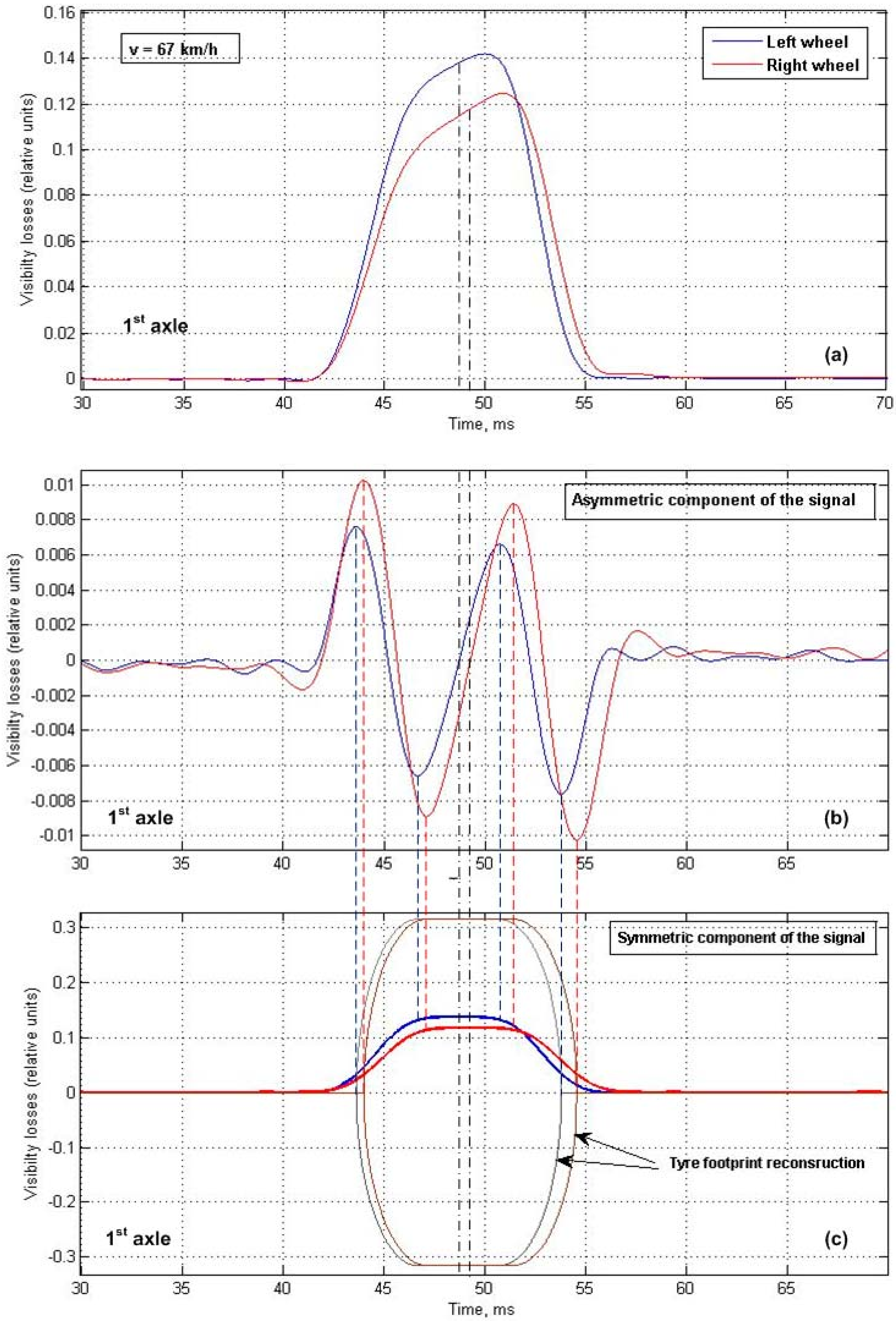

Figure 11. (a) FOS output signal in the form of visibility losses in dimensionless units, (b) Approximated vertical weight component (symmetric), (c) Approximated asymmetric component and tire footprint reconstruction in case of minimal friction condition

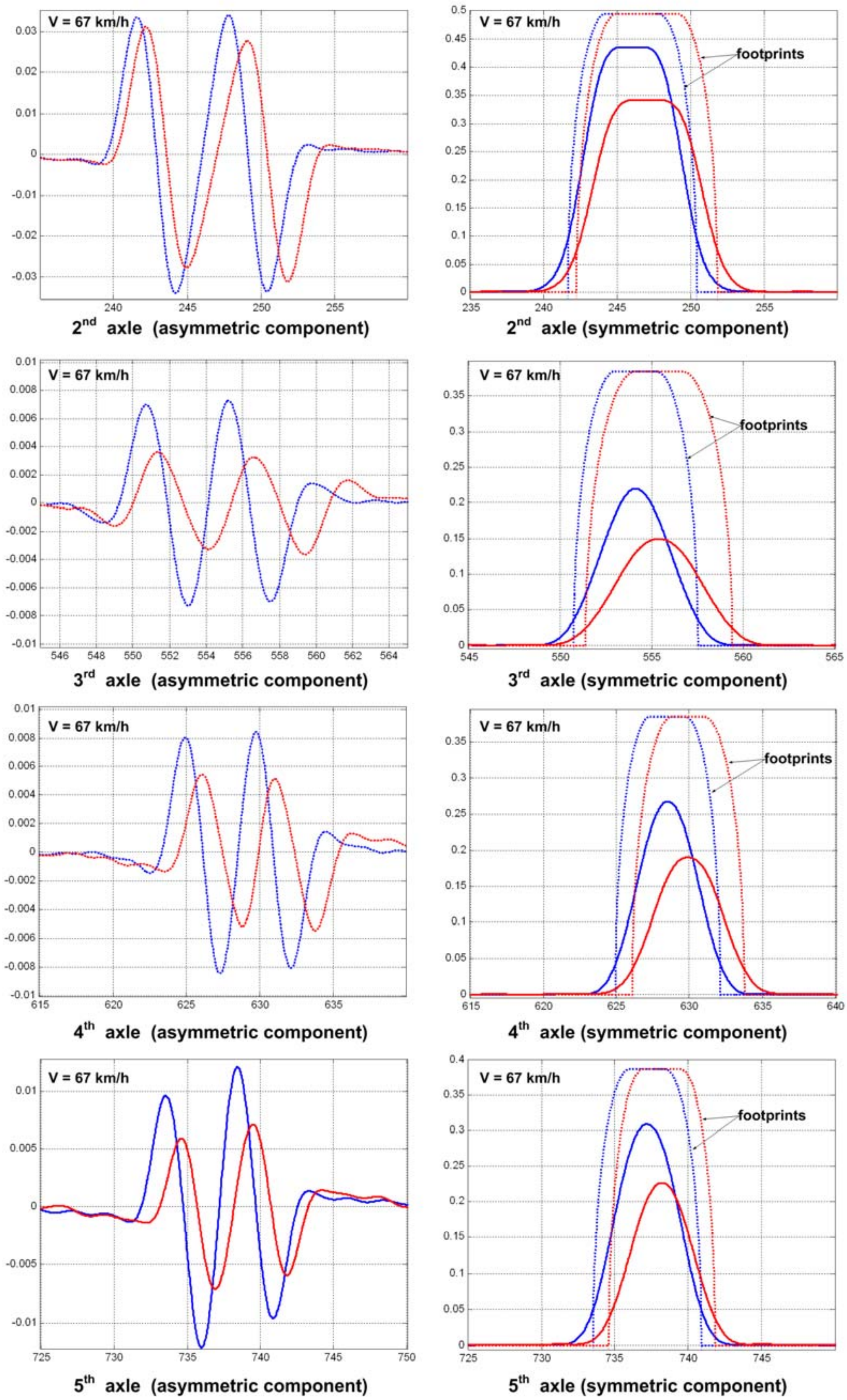

Figure 12. The results of axle's signals deconvolution on symmetric (from the right) and asymmetric (from left) components for the 2nd, 3rd, 4th and 5th axle and the form of footprint reconstruction (half of area) respectively

Applying the sensors signal processing algorithm together with the of estimation of the tyre footprint area and approximation of the nonlinear characteristics of the FOS (Figures 4, 5 and 6) for the suitable range of temperatures, it is possible to estimate the following weights of axles (Table 4):

Table 4. The results of the axle weight estimation and errors for the different measurements at the speeds 10–90 km/h (two sets of measurements per speed bin)

Date: 20.04.2012 (Air Temperature +12°C)						
Etalon axle's weight (tons):		7.296	12.619	5.509	5.641	5.844
Speed: 10 km/h						
No	**Parameter:**	**1st axle**	**2nd axle**	**3rd axle**	**4th axle**	**5th axle**
1	Axle's weight (tons)	7.3392	12.7267	4.7930	5.0592	5.8173
	Error (%)	0.589%	0.855%	-12.994%	-10.317%	-0.453%
2	Axle's weight (tons)	7.2190	14.0050	4.6014	5.1721	6.5539
	Error (%)	-1.058%	10.985%	-16.472%	-8.316%	12.152%
Speed: 20 km/h						
1	Axle's weight (tons)	7.1375	12.9337	5.3205	6.2553	6.5012
	Error (%)	-2.176%	2.496%	-3.417%	10.885%	11.251%
2	Axle's weight (tons)	7.2929	13.5535	4.4927	4.8372	5.6539
	Error (%)	-0.046%	7.408%	-18.445%	-14.253%	-3.248%
Speed: 50 km/h						
1	Axle's weight (tons)	7.5824	11.9901	5.3806	5.4392	5.5499
	Error (%)	3.921%	-4.982%	-2.327%	-3.582%	-5.029%
2	Axle's weight (tons)	7.4452	12.4781	5.1152	5.3775	5.6148
	Error (%)	2.042%	-1.114%	-7.144%	-4.676%	-3.918%
Speed: 70 km/h						
1	Axle's weight (tons)	7.5129	12.1787	5.2473	5.6684	5.6978
	Error (%)	2.969%	-3.487%	-4.746%	0.482%	-2.497%
2	Axle's weight (tons)	7.4754	12.4669	5.2623	5.7398	5.8544
	Error (%)	2.455%	-1.204%	-4.474%	1.747%	0.183%
Speed: 90 km/h						
1	Axle's weight (tons)	7.3327	12.8335	5.0597	5.3737	5.6183
	Error (%)	0.499%	1.702%	-8.152%	-4.744%	-3.859%
2	Axle's weight (tons)	7.5990	12.0713	5.1834	5.6570	5.8492
	Error (%)	4.149%	-4.338%	-5.907%	0.278%	0.094%

As it can be seen from the Table 4, the most preferred for the measurements are the velocity ranges from 50 km/h and above: the measurement errors of the axle loads do not exceed 10%, which is consistent with the problem of the pre-selection of the overloaded vehicles. The dynamics of vehicle breaking or acceleration is more visible at the low velocities. It can seriously distort the waveform of asymmetric friction component and change characteristic points for tyre footprint estimation. The source of the relatively big measurement errors at the low velocities are the distortion and footprint area reconstruction errors because of the vertical oscillations of the dynamic motion of the vehicle, whose amplitudes are smaller at the higher speeds.

Taking into account the properties of each individual sensor, the calibration of FOS should be conducted twice: at first in the laboratory (load characteristics in the temperature range from –20°C to +30°C), and, secondly, after installing the sensor in the road surface using the vehicles with allowed but known weight.

7. Conclusions

Fibre-optic sensors (FOS) are mainly used as the vehicle detectors because of the complicated dependence of a set of factors (sensor's surface temperature, area of impact (vehicle's tyre width), the speed of loading, and vehicle velocity). The set of input parameters made relatively problematic the task of weigh-in-motion using FOS. The results of the present research demonstrate that the factors mostly impacting the FOS measurement accuracy can be investigated and included into the axle weight calculations.

An idea to normalize the FOS output voltage by the sensor visibility losses (changing from 1 to 0) parameter helps to avoid the influence of the static voltage source instability as well as the conditions of sensor installation into the pavement. Each instantaneous measured value of the rolling wheel is independent here from the output voltage for the unloaded sensor. Also, the static part of the temperature dependence is compensated by this way.

An innovative approach to decompose each wheel response into the gravity (symmetric) and the rolling friction (asymmetric) components near the "mass centre" of the pulse, leads to the possibility of tyre footprint area estimation and weight calculation based on mixed Basic and Area method. Preliminary results of the proposed method for WIM using FOS demonstrates the accuracy of measurements are in range of less than 10% of the measured weight. It is sufficient for the problem of overloaded vehicles pre-selection.

The experimental results show that the range of the vehicles velocity from 50 to 90 km/h seems more appropriate for WIM based on fibre-optic sensors. From the authors point of view, using the additional signal processing efforts, it is possible to achieve the consistent accuracy level not only at the high speeds (above 50 km/h), but also at the low speeds (10–50 km/h). We mean B+(7) according to COST 323 for the high speeds and D2 according to OIML R134 for the low speeds (O'Brien & Jacob, 1998).

Acknowledgements

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JUSTIFICATION OF FINANCIAL SAFETY ANALYSIS APPROACH IN CARGO-AND-PASSENGER FERRY OPERATIONS MANAGEMENT

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Currently, ferry services are widespread in Europe, the Baltic States, the CIS and they continue to progress rapidly despite the unstable global economy. An activity of modern cargo-and-passenger fleet is based on nevertheless the perspective of stable profit generation. In conditions of ferry market instability, the important task is to ensure the break-even analysis in operation of vessels and justification of relevant quantitative indicators. At the same time, when managing the production activity of the ferry operators and, in particular, when analysing the ferry operation the indicator of its financial safety factor is of great importance.

This paper refines static indicators and determines dynamic indicators of critical quantity of cargoes and passengers in ferry loading; gives analytical method of its justification; develops analytical method and presents graphical method of financial safety factor estimation when loading of cargo only or boarding of passengers only, as well as performing composite actions – loading of cargoes and picking up passengers.

Keywords: ferry transportation, cargo-and-passenger ferry, dynamic indicators, critical loading, financial safety factor

1. Introduction

The ferry service is an important part of the transport process in the system of international freight and passenger transportation. Currently, ferry services are widespread in Europe, the Baltic States, the CIS and they continue to progress rapidly despite the unstable global economy.

The Black Sea countries provide transport and economic links in the west-east and north-south by ferries. Ferries of this region provide transportation of freight vehicles between Ukraine, Georgia, Turkey, Bulgaria, Romania and Russia. The most popular ferry transportation destinations in Ukraine are Kerch–Poti/Batumi, Odessa–Istanbul, Illichevsk–Batumi/Poti. The main participant in the Ukrainian Black Sea ferry market is the company "Ukrferry", which has the status of a national carrier in Ukraine.

The functioning of "Ukrferry", as well as activities of other carriers, is currently carried out in the consumer market (cargo and/or passenger), where transport supply exceeds the demand. In such a situation it is actually for the companies operating in the sphere of ferry traffic to develop an appropriate, adapted to the market characteristics, methodological support of decision-making processes for organization of ferry traffic and ferries management. One of the powerful tools for solving numerous administrative tasks related with the production activities of the shipping companies in the consumer market is a break-even analysis. It helps the ship owner, who seeks to make a profit under all the circumstances, do not lose sight of performance equilibrium quantities of individual vessels and a fleet as a whole. The practical realization of break-even analysis can justify such a critical level of transport production by which the revenues of company are equal to its costs. The break-even analysis also helps to justify the reasonability of (Kirillova & Kirillov, 2008):

- transportation of cargo which quantity is less than vessel manufacturing feasibility;
- discounting to cargo owners and/or tariff reductions;
- inclusion the port to the list of essential ones when designing the new shipping line;
- entering the vessel to the optional port of the existing line, etc.

The methodologies determining a break-even analysis in operations of the marine transport are presented in many sources. Thus, the sources (Vinnicov, 2001; Soyuzov & etc., 1979; Bakayev, 1965) state the composition and the procedure of forming the marine transport costs, method of their calculations and use by type of proceedings, the tasks of pricing and finances of the shipping company, the features of estimation of shipping companies economic activities in market conditions. The reports

(Kirillova, 2007; Kirillova & Meleshenko, 2012) formulate the provisions on justification of critical and commercially reasonable loading of cargo and passenger vessels, based on the method of break-even analysis. The works (Kirillova & Kirillov, 2008; Kirillova, 2006) develop the regulations on justification of optimal values of cargo vessel operation indicators using the method of marginal analysis. However, the systems of indicators presented in these sources do not take into account the possibility of a composite vessel loading with goods under different nomenclature ranges and passengers, which is not only widely practiced in cargo-and-passenger ferries, but is their specific feature. The science sources (Kirillova & Meleshenko, 2013a; Kirillova & Meleshenko, 2013b; Kirillova & Meleshenko, 2013c) propose the analytical method of determining the values of dynamic indicators of critical loading and operation of a cargo-and-passenger ferry. However, it is obvious that the actual size of the critical production of the transport is not an objective measure for different-sized vessels especially from the position of a comparative analysis of their activity as the volume of cargo transportation by these vessels is different. In this connection, it is necessary to justify such an indicator, which, regardless of the technical and operational vessel characteristics, allows understanding how much percent one can reduce the amount of transportation services (shipments) on for reaching the loss-free ship operation. This indicator is “the ratio of financial safety” evaluated in percentages. The indicators presented in above-mentioned sources do not include the ratio of financial safety that stipulates the necessity of the additional research.

Thereby, the aim of the study is to improve the method of determining the break-even analysis in operations of cargo-and-passenger ferry through the development of theoretical and methodological principles on justification of its financial safety factor.

2.1. Theoretical aspects

The main production of shipping company operating cargo-and-passenger ferry is the multinomenclature because the transportation facilities are cargoes and passengers. This fact makes it necessary to take into account the parameters of freight and passenger traffic to justify the decisions related to the organization of the ferry transportation and management of ferries. The importance in the consumer market, as mentioned above, gets a break-even analysis. During its realization the static indicators of critical ferry loading with cargoes (N_i^{cr}) and passengers (N_{pass}^{cr}) can be easily defined under the provisions formulated in (Kirillova & Kirillov, 2008):

$$N_i^{cr} = \frac{R_{fix}}{f_i - r_i} \text{ (at } f_i - r_i \neq 0\text{);} \tag{1}$$

$$N_{pass}^{cr} = \frac{R_{fix}}{f_{pass} - r_{pass}} \text{ (at } f_{pass} - r_{pass} \neq 0\text{),} \tag{2}$$

where R_{fix} – fixed costs applied to the ship in the concerned voyage. They include direct fixed costs (depreciation, agent fees, the cost of loan repayments, crew maintenance, insurance, repairs, supplies, etc.) and indirect fixed (administrative management and general operational) costs;

f_i ; f_{pass} – rate for carriage the cargo of the i^{th} nomenclature range and, accordingly, the price of passenger tickets;

r_i ; r_{pass} – unit variable costs for transportation the cargo of the i^{th} nomenclature range and for maintenance of one passenger. They include fuel and lubricants costs, port, channel, mooring, pilotage, towing and other fees, charges for freight operations, brokerage commissions and other variable costs depending on the value of the vessel operation.

In general, the composition of fixed and variable costs is determined by the decision maker (DM), depending on the purpose of the analysis and the form of ship operation organization. Thus, the static indicators of critical ferry loading are defined separately for cargoes (N_i^{cr}) (1), separately for passengers (N_{pass}^{cr}) (2) and are independent from each other. At the same time, it is obvious that cargo-and-passenger ferries combine the properties of the cargo vessels and the passenger vessels; hence the efficiency of their operation is specified by both the amount of cargoes and the number of passengers in the ship loading. It requires the elaboration and justification of another approach to the break-even analysis of production activity of shipping companies operating cargo-and-passenger ferries.

Different ferry spaces (rooms) are intended for cargoes and passengers, namely the cargo decks are for goods; cabins are for passengers. This enables the simultaneous consideration of cargo and passenger flow parameters in relation to each other despite the different dimension of indicators granting their quantitative assessment.

The indicators reflecting the amount of cargoes and passengers in ferry loading have an impact on the economic results of its operation. As the applications for the cargo transportation are being received from cargo owners and/or as the tickets are being bought by passengers, the information about their quantity is updated at the certain intervals (once a day, once in 3 days, etc.). On the ground of the received information the step-by-step adjustment of relevant functionally dependent targets is made. The period of information clarification and, hence, the interval of data correction is set by DM. Thus, the values of planned targets are corrected in each step t of the decision-making, which corresponds to the certain period of refinement and updating of data about cargoes $(N_i^{(t)})$ volume and passengers $(N_{pass}^{(t)})$ number on the grounds of:

– the information stated in the newly received applications from the cargo owners;

– the information about the newly purchased tickets by passengers.

Therefore, at step-by-step decision-making related to the justification of cargo-and-passenger ferry operation in the consumer market conditions, it is proposed to use the following interrelated and interdependent dynamic indicators of the critical vessel loading:

– the critical quantity of cargoes $(N_i^{cr(t)})$;

– the critical number of passengers $(N_{pass}^{cr(t)})$.

The dynamic indicators of critical cargo-and-passenger ferry loading reflect such a minimum quantity of cargoes $(N_i^{cr(t)})$ and passengers $(N_{pass}^{cr(t)})$ in composite vessel loading during the development of which the company' costs $(R^{(t)})$ in step t of decision-making are compensated by its income $(F^{(t)})$. As a rule, in the situation of the consumer market ensuring of the full utilization of ferry manufacturing feasibilities caused by its technical characteristics is not possible. In this regard the fulfilment of the conditions is a prime consideration (3) (Kirillova & Meleshenko, 2013b).

$$\left.\begin{array}{l} N_i^{(t)} > N_i^{cr(t)} \ (i \in I); \\ N_{pass}^{(t)} > N_{pass}^{cr(t)}. \end{array}\right\}, \tag{3}$$

where $N_i^{(t)}$ – the quantity of the ith nomenclature range cargo planned to transportation that was refined in step t of decision-making;

$N_{pass}^{(t)}$ – the number of passengers planned to transportation and service in voyage that was refined in step t of decision-making;

$N_i^{cr(t)}$; $N_{pass}^{cr(t)}$ – the critical quantity of the i^{th} nomenclature range cargo and, accordingly, the passengers corrected in step t;

I – the set of cargo nomenclature ranges planned for the carriage (automobile equipment, rail buses, containers, etc.).

The restrictions (4) regulate the cargo-and-passenger ferry operation in accordance with its specifications (Kirillova & Meleshenko, 2013b).

$$\left.\begin{array}{l} N_i^{(t)} \le N_i^{\max} \ (i \in I); \\ N_{pass}^{(t)} \le N_{pass}^{\max}. \end{array}\right\}, \tag{4}$$

where $N_i^{\max}$ – the maximum possible quantity of the i^{th} nomenclature range cargo which could be taken on board in accordance with its specifications;

$N_{pass}^{\max}$ – the maximum possible number of passengers (including persons accompanying the cargo, drivers of the transported cars) that the vessel can take on board in accordance with its passenger capacity.

The restrictions (4) acquire a priority in situation of the ship owner market, when the demand for ferry services exceeds their supply and the desire to maximize the loading of the vessel is limited by its technical capabilities. However, the consumer market does not exclude the need to comply with the given group of limits. Thus, the ferry cargoes and passengers carriage is break-even under the conditions (2) and (4) (Kirillova & Meleshenko, 2013b):

$$\left.\begin{aligned} &N_i^{cr(t)} < N_i^{(t)} \le N_i^{\max} \ (i \in I); \\ &N_{pass}^{cr(t)} < N_{pass}^{(t)} \le N_{pass}^{\max}. \end{aligned}\right\} \tag{5}$$

Let us consider the order of the analytical justification of indicators $N_i^{cr(t)}$ and $N_{pass}^{cr(t)}$.

The ferry operation in step t of decision-making is a break-even subject to the following equation: $F^{(t)} = R^{(t)}$, which may be refined as follows (Kirillova & Meleshenko, 2013b):

$$F^{(t)} = N_i^{(t)} \cdot f_i + N_{pass}^{(t)} \cdot f_{pass}, \tag{6}$$

$$R^{(t)} = R_{fix} + N_i^{(t)} \cdot r_i + N_{pass}^{(t)} \cdot r_{pass}, \tag{7}$$

$$N_i^{(t)} \cdot f_i + N_{pass}^{(t)} \cdot f_{pass} = R_{fix} + N_i^{(t)} \cdot r_i + N_{pass}^{(t)} \cdot r_{pass}. \tag{8}$$

On the ground of equation (8) it the critical quantity of the i[th] nomenclature range cargo ($N_i^{cr(t)}$) could be determined, it provides a break-even analysis for operations management in step t of decision-making (Kirillova & Meleshenko, 2013b):

$$N_i^{cr(t)} = \frac{R_{fix} - N_{pass}^{(t)} \cdot (f_{pass} - r_{pass})}{f_i - r_i} \ \text{(at } f_i - r_i \ne 0\text{)}. \tag{9}$$

Similarly to the indicator of the critical quantity of cargoes $(N_i^{cr(t)})$ (9), the critical number of passengers $(N_{pass}^{cr(t)})$ could be determined in step t (Kirillova & Meleshenko, 2013b)

$$N_{pass}^{cr(t)} = \frac{R_{fix} - N_i^{(t)} \cdot (f_i - r_i)}{f_{pass} - r_{pass}} \ \text{(at } f_{pass} - r_{pass} \ne 0\text{)}. \tag{10}$$

The considered indicators of the critical quantity of cargoes $(N_i^{cr(t)})$ and the critical number of passengers $(N_{pass}^{cr(t)})$ are expressed in physical terms. However, these indicators are not objective when comparing the different-sized vessels, which volume of traffic differs in scores of times. Thus, besides the above-mentioned indicators of the critical quantity of cargoes $(N_i^{cr(t)})$ and the critical number of passengers $(N_{pass}^{cr(t)})$ when calculating break-even point in ferry operation, the ratio of financial safety expressed in percentage is proposed. The calculation of this ratio is proposed to be carried out in each step t of defining the information about the quantity of cargoes declared to transportation and the number of sold passenger tickets. The ratio of financial safety demonstrates the share which can reduce the amount of the transport services provision so that the company does not incur losses. The standard value of this indicator is set by DM, depending on the condition of the ferry transportation market, for example 10 % $(k_i^{FS(t)} \ge 10\%)$.

The ratio of financial safety in each step t of decision-making when loading the ferry with cargoes $(k_i^{FS(t)})$ and passengers $(k_{pass}^{FS(t)})$ is easily determined on the basis of provisions set in the book (Stoyanova, 2003):

$$k_i^{FS(t)} = \frac{(N_i^{(t)} - N_i^{cr})}{N_i^{(t)}} \cdot 100\% \text{ (at } N_i^{(t)} \neq 0\text{);} \tag{11}$$

$$k_{pass}^{FS(t)} = \frac{(N_{pass}^{(t)} - N_{pass}^{cr})}{N_{pass}^{(t)}} \cdot 100\% \text{ (at } N_{pass}^{(t)} \neq 0\text{).} \tag{12}$$

The analytical expression mentioned above (11), (12) can be graphically described using the two-dimensional coordinate system. Thus, the ratio of financial safety in providing the cargo transportation services $(k_i^{FS(t)})$ at a constant value (N_i^{cr}) depends on the quantity of the carried cargoes $(N_i^{(t)})$ (11), i.e. it is a function of respective argument:

$$y = f(x);$$

$$k_i^{FS(t)} = f(N_i^{(t)}) = \frac{(N_i^{(t)} - N_i^{cr})}{N_i^{(t)}} \cdot 100\%.$$

2.2. Graphical visualization in two- and three-dimensional coordinate systems

The graphic of this function is a curve, illustrated in the two-dimensional space. Therefore, when visualizing graphically the task of determining the ratio of financial safety, it is appropriate to use a right-handed two-dimensional coordinate system (Fig. 1), formed by the mutually perpendicular axes:

– by X-axis - OX, corresponding to the axis ON_i in this case;

– by Y-axis - OY, corresponding to the axis Ok^{FS}.

The maximum value of the ratio for the cargo ship $(k_i^{FS(\max)})$ is achieved with the maximum amount of cargoes $(N_i^{\max})$ on board, which, in turn, is limited by the technical characteristics of the vessel (capacity, tonnage, container capacity and passenger capacity).

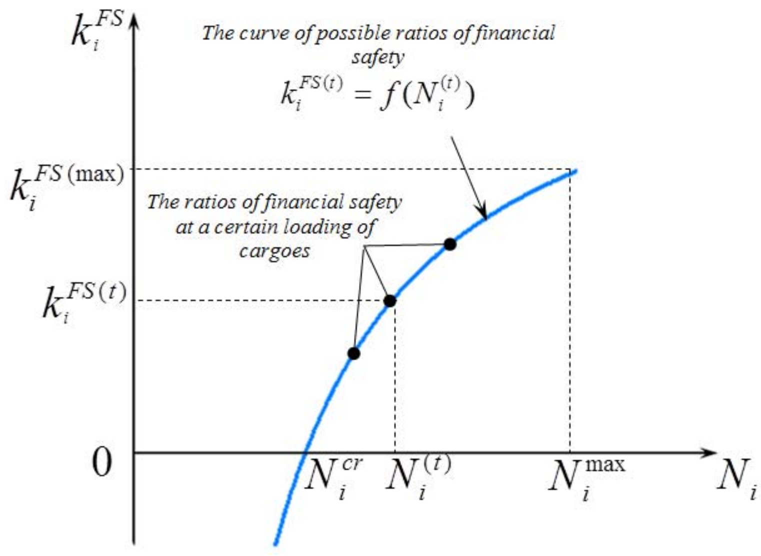

Figure 1. The ratio of financial safety when transporting the cargoes, determined through the quantity of cargoes, %

Each point of the curve expresses the proportion to which the company can reduce the amount of cargo transportation services so that it does not incur losses. That is, when reducing the amount of cargoes on the quantity equal to $(k_i^{FS} \cdot N_i)$, the company will make a profit $(\Pr_i)$ from the transportation of goods equal to zero. At ($N_i = N_i^{cr}$) the financial safety ratio (k_i^{FS}) possesses the value equal to zero: $k_i^{FS} = 0$.

The similar arguments can be made in respect to the financial safety ratio when transporting the passengers (k_{pass}^{FS}), which is a function of N_{pass} (Fig. 2).

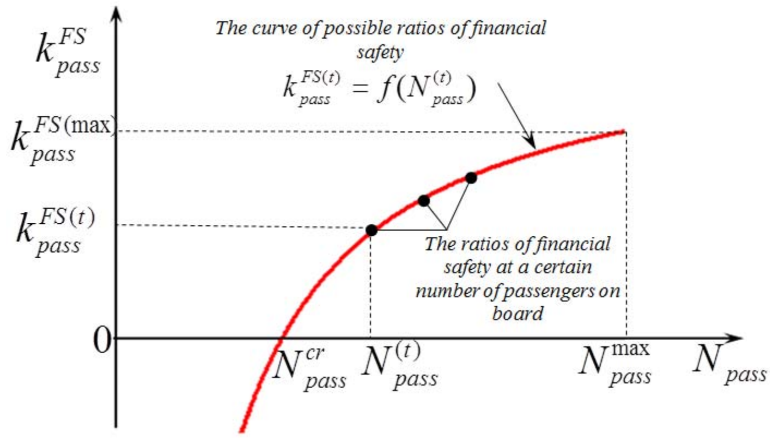

Figure 2. The ratio of financial safety when transporting the passengers, determined through the quantity of sold tickets, %

Each point of the curve expresses the proportion to which company can reduce the amount of passenger transportation services so that it does not incur losses. That is, when reducing the amount of the sold tickets equal to $(k_{pass}^{FS(t)} \cdot N_{pass}^{(t)})$, the company will make a profit $(\Pr_{pass})$ from the tickets sold equal to zero (Kirillova & Meleshenko, 2013a). At $(N_{pass} = N_{pass}^{cr})$ the ratio of financial safety is also equal to zero: $k_{pass}^{FS} = 0$.

However, the mentioned formulas of calculating the indicators (11), (12) as well as their graphical interpretation (Fig. 1 and Fig. 2) do not take into account the possibility of composite vessel loading with various nomenclature of cargoes and passengers, which is not only widely practiced on cargo-and-passenger ferries, but is their specific feature. Consequently, the ratio of financial safety, when calculating break-even point in ferry operation, depends both on the amount of the transported cargoes and the number of the carried passengers.

It should be noted that the indicators of cargoes (N_i) and passengers (N_{pass}) loading are incommensurable, as in the first case the indicator (N_i) is measured in units (in items, rarely in metric tons and cubic measures) of i[th] nomenclature range and in other case the indicator (N_{pass}) is measured in number of passengers. Therefore, the ratio of financial safety taking into account the composite loading of the vessel is proposed to be calculated through the value of income which is measured in the same units as cargo loading and passenger loading.

Thus, the formula for calculating the ratio of financial safety when calculating break-even point in ferry operation can be represented as follows (13).

$$k^{FS} = \frac{((F_i + F_{pass}) - (F_i^{cr} + F_{pass}^{cr}))}{(F_i + F_{pass})} \cdot 100\% \text{ (at } F_i + F_{pass} \neq 0\text{)}. \tag{13}$$

At the same time it should be pointed out that income received from both cargoes (F_i) and passengers' (F_{pass}) transportation depends on the quantity of transporting cargoes and passengers, accordingly. In its turn, the critical volume of income received from cargoes (F_i^{cr}) and passengers' (F_{pass}^{cr}) transportation depends on the respective indicators of critical cargoes (N_i^{cr}) and passengers'

(N_{pass}^{cr}) vessel loading. As mentioned above, these indicators (N_i^{cr}) and (N_{pass}^{cr}) are dynamic when composite loading of cargo and passengers and their volume and quantity are defined in each step *t*. Thus, the formula (13) can be expressed as follows (14).

$$k^{FS(t)} = \frac{((N_i^{(t)} \cdot f_i + N_{pass}^{(t)} \cdot f_{pass}) - (N_i^{cr(t)} \cdot f_i + N_{pass}^{cr(t)} \cdot f_{pass}))}{(N_i^{(t)} \cdot f_i + N_{pass}^{(t)} \cdot f_{pass})} \cdot 100\% . \tag{14}$$

In addition, taking into account the afore-said, when the indicator $N_i^{cr(t)}$ is expressed through $N_{pass}^{(t)}$ and the indicator $N_{pass}^{кр(t)}$ is expressed through $N_i^{(t)}$, the formula (14) can be presented in the form of equations (15) and (16), respectively.

$$k^{FS(t)} = \frac{((N_i^{(t)} \cdot f_i + N_{pass}^{(t)} \cdot f_{pass}) - (\frac{R_{fix} - N_{pass}^{(t)} \cdot (f_{pass} - r_{pass})}{f_i - r_i} \cdot f_i + N_{pass}^{(t)} \cdot f_{pass}))}{(N_i^{(t)} \cdot f_i + N_{pass}^{(t)} \cdot f_{pass})} \cdot 100\%; \tag{15}$$

$$k^{FS(t)} = \frac{((N_i^{(t)} \cdot f_i + N_{pass}^{(t)} \cdot f_{pass}) - (N_i^{(t)} \cdot f_i + \frac{R_{fix} - N_i^{(t)} \cdot (f_i - r_i)}{f_{pass} - r_{pass}} \cdot f_{pass}))}{(N_i^{(t)} \cdot f_i + N_{pass}^{(t)} \cdot f_{pass})} \cdot 100\% . \tag{16}$$

Consequently, the ratio of financial safety is expressed by the function of two arguments: $k^{FS(t)} = f(N_i^{(t)}, N_{pass}^{(t)})$. The graphic of this function is a surface, illustrated in three-dimensional space. Therefore, visualizing graphically the task of justification of critical cargo-and-passenger ferry loading, it is reasonable to use a right-handed three-dimensional coordinate system (Fig. 3), formed by mutually perpendicular axes:

– by X-axis – OX, corresponding to the axis ON_i in this case;

– by Y-axis – OY, corresponding to the axis Ok^{FS};

– by Z-axis – OZ, corresponding to the axis ON_{pass}.

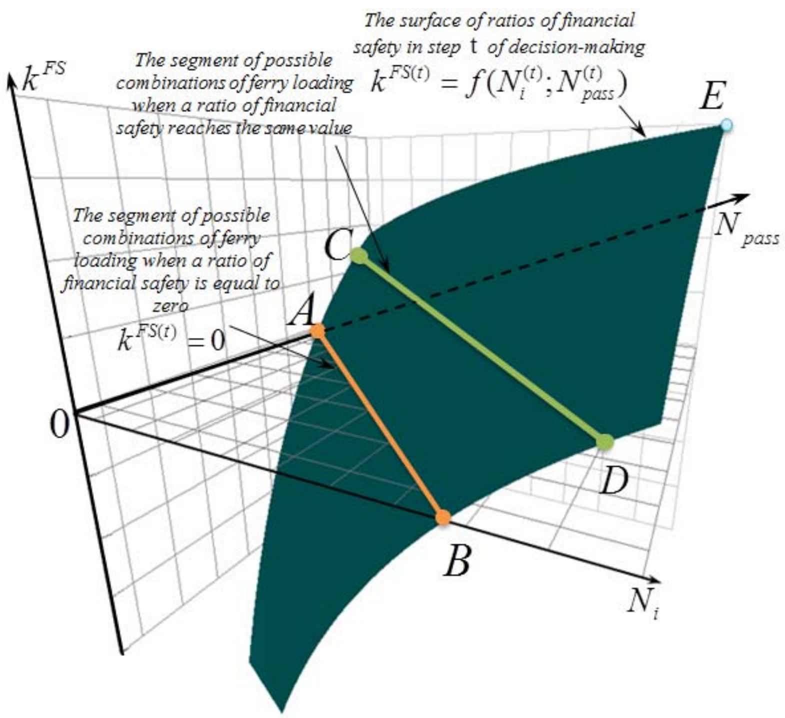

Figure 3. The graphical visualization of the task of determination of the ratio of financial safety of a cargo-and-passenger ferry

The three-dimensional analysis of graphic (Fig. 3) visually shows that the break-even ferry loading, i.e. the loading at zero ratio of financial safety is reflected by segment AB over which the surface given by function $k^{FS(t)} = f(N_i^{(t)}; N_{pass}^{(t)})$ and the plane formed by axes $0; N_i$ and $0; N_{pass}$ are crossed. It means that break-even cargo-and-passenger ferry loading may have a number of variants; each of them is reflected by a certain point lying on segment AB (Fig. 3). The place of position of each point depends on proportion of parameters $N_i^{(t)}$ and $N_{pass}^{(t)}$ in step t of decision-making. In other words, the point, lying on this segment and reflecting the value of critical cargo-and-passenger ferry loading, moves along the segment depending on step t of decision-making and quantitative combination of cargoes $(N_i^{(t)})$ and passengers $(N_{pass}^{(t)})$ in ferry loading.

As it is known, each point in three-dimension space has coordinates $(X; Y; Z)$. In the concerned case (Fig. 3) each point of ratio of financial safety when loading the ferry both with cargoes and passengers in step t of decision-making is characterized by coordinates $(N_i^t; k^{FS(t)}; N_{pass}^t)$ and belongs to the surface expressed by function $f(N_i^{(t)}; N_{pass}^{(t)})$. Obviously, as well as in case of break-even ferry loading (Kirillova &Meleshenko, 2013c) the ratio of financial safety may reach the same value at different combinations of cargoes $(N_i^{(t)})$ and passengers $(N_{pass}^{(t)})$ in the ferry loading. For each value of $k^{FS(t)}$ this combination may be graphically presented in the form of segment CD (Fig. 3) corresponding to the following conditions:

– the segment CD is parallel to the surface formed by axes $0; N_i$ and $0; N_{pass}$ $(CD \parallel 0 N_i N_{pass})$;
– the segment CD belongs to the surface expressed by function $f(N_i^{(t)}; N_{pass}^{(t)})$ $(CD \in f(N_i^{(t)}; N_{pass}^{(t)}))$.

The maximum value of ratio of financial safety is reached in point E (Fig. 3) with coordinates $(N_i^{\max}; k^{FS(\max)}; N_{pass}^{\max})$.

The usage of theoretical and methodical positions in the production activity of shipping companies when realizing the analysis function of cargo-and-passenger ferry operation and the graphical visualization of such analysis results enable:

– to define the values of ratio of financial safety in each step t of decision-making subject to updating the information about the quantity of cargoes declared for transportation $(N_i^{(t)})$ and about the number of sold tickets $(N_{pass}^{(t)})$;
– to justify possible (typical) variants of ferry loading with cargoes $(N_i^{(t)})$ and passengers $(N_{pass}^{(t)})$, at which the standard (e.g. 10%) value of ratio of financial safety determined by DM is being reached;
– to reveal possible variants of critical ferry loading with cargoes $(N_i^{(t)})$ and passengers $(N_{pass}^{(t)})$ at which the ratio of financial safety is equal to zero.

The application of the achieved results of analysis when managing the ferry operation allows making the decisions relating to:

– the determination of quantity of cargoes and/or passengers, which must be involved in transportation;
– ascertaining the share by which the value of transport services of cargo and passengers transportation may be reduced;
– the justification of value of reduction in the tariff for cargo transportation and, respectively, to the determination of the sum by which the passenger ticket cost may be reduced so that the ferry company takes profit and in case of unfavourable market situation does not incur losses.

3. Conclusions

As a result of research:

1. The dynamic indicators of critical cargo-and-passenger ferry loading have been determined.

2. The process of justification of dynamic indicators of critical quantity of cargoes $(N_i^{cr(t)})$ and passengers $(N_{pass}^{cr(t)})$ in cargo-and-passenger ferry loading has been formalized.

3. The ratio of financial safety when calculating break-even point in ferry operation has been ascertained.

4. The process of justification of ratio of financial safety in case of the composite ferry loading with cargoes and passengers $(k^{FS(t)})$ in each step t of updating the information about quantity of cargo declared for transportation $(N_i^{(t)})$ and number of sold tickets $(N_{pass}^{(t)})$ has been formalized.

5. The graphical visualization of task of determination of cargo-and-passenger ferry' ratio of financial safety has been presented.

6. The usage of the introduced theoretical and methodical positions when analysing the cargo-and-passenger ferry operation, as well as a graphical visualization of the results of such analysis enables to make effective management decisions that ensure Ferry Company to make a profit, and in case of unfavourable market conditions they help to avoid losses.

In general, the theoretical and methodical aspects proposed and formulated in the research contribute to the improvement of the analysis of the cargo-and-passenger ferry operation, and applying the results of the procedure described above enables to make the efficient management decisions when planning and regulating the ferry operation.

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PROBLEMS OF THE SUPPLY CHAIN RELIABILITY EVALUATION

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Reliability is one of the most important characteristics of the functioning of supply chains. The carried out analysis have shown that, despite some progress, a number of questions remain open, in particular, the terminology, the selection of key indicators and methods of their calculation as well as there is no economic evaluation of redundant and restorable supply chains.

The paper presents a formed conceptual apparatus of logistics systems' reliability theory, the discrete-continuous model of the simple supply chain's functioning as well as it contains the proposal to assess the reliability not only with the help of faultlessness but as well by using the leading function of costs associated with the maintenance of supply chains' operability.

Keywords: reliability, supply chains, terminology, methods of analysis, models of failures

1. Introduction

Reliability is one of the most important characteristics of the functioning of supply chains since it has a significant impact on the completeness and quality of delivered parties, on the execution time of logistics cycle and on logistics costs in supply chains. Since the processes of interaction between the companies, that are participants of the supply chain, become more complicated, this leads to the need of improvement of methods used to assess the reliability of supply chains and to search for active ways to improve reliability.

Analysis of a number of studies have shown that in many matters relating to the reliability of supply chains (such as terminology, classification of concepts and principles, analytical tools, failure models and its experimental evaluation) there is a significant range of opinions. Let us consider them in detail and in our opinion it will help to form the topics of research aimed at solving problems of reliability assessment of supply chains.

First of all, start with the terminology. According to (Institute of Electrical and Electronics Engineers, 1990) “reliability is defined as the ability of a system or component to perform its required functions under stated conditions for a specified period of time”. Obviously, this definition refers to technical systems; however it is used for risk assessment in supply chains (Wolfgang & Thorsten, 2006). In study (Blanchard, 2004) there is a similar definition: “Reliability can be simply defined as the probability that a system or a product will perform in a satisfactory manner for a given period of time when used under specified operating conditions”.

Another approach to the interpretation of reliability is given in (Mirotin & Sergeev, 2002; Zaitzev & Bochazev, 2010; Zaitzev & Uvarov, 2012). For instance, study (Mirotin & Sergeev, 2002) contains the term “economic reliability”. The economic reliability is defined as “the system's feature, which allows ensuring the values of guaranteed economic indicators of the system with minimal costs (material, labour, etc.) or with the greatest possible economic benefit in a planned period of time”.

Even greater diversity occurs when using terms such as “disruption”, “interruption”, etc. Obviously, without the systematisation of basic concepts it is difficult to solve the problem of reliability assessment of supply chains.

Secondly, consider the analytical tools. For our purpose the studies, that contain the quantitative methods of assessing the reliability of supply chains, can be divided into two groups.

In the first group of studies the assessment of the reliability of supply chains is carried out on the basis of the so-called circuit reliability (serial, parallel and mixed compound of elements with different types of redundancy – “active/hot”, “standby/cold”) (Blanchard, 2004; Mirotin & Sergeev, 2002; Zaitzev & Bochazev, 2010). All estimates are based on the probability of faultless operation of the elements of chain.

The second group of studies contains failure models, which, by analogy with technical systems (Gertsbakh & Kordonsky, 1966), can be presented by the following types:

– the model of the “perfect” or “ideal” order (Ballou, 1999; Christopher, 2004);

– the model of “supply and demand” (Wolfgang & Thorsten, 2006);

– the “just-in-time” model (Lukinskiy & etc., 2007).

Common to these groups is that they are based on probability theory. According to (Blanchard, 2004) probability, the first element in the reliability definition, is usually stated as a quantitative expression representing a fraction or a percent signifying the number of times that an event occurs (successes), divided by the total number of trails.

In general, by characterizing this direction it should be emphasized that, on the one hand, qualitative indicators and expert evaluations of reliability were replaced by quantitative indicators of assessment and, on the other hand, most models require further development and generalization.

Thirdly, consider experimental evaluation methods. In most studies the assessment of reliability indicators in supply chains reduces itself to recording the amount of “n” disruptions (interruptions) that occurred during the execution of N logistics operations:

$$SL = \frac{N-n}{N} = 1 - \frac{n}{N}, \qquad (1)$$

where SL – service level.

The level of service, which is calculated by the formula 1, is taken as the probability of faultless operation P.

However, the uncertainty of this approach becomes apparent if not one but several features, which characterize the state of disruption (interruption), are recorded during the execution of a logistics operation.

For example, Table 1 shows the results of calculation of faultlessness for several options of perfect order's formation in case of 20 deliveries and three criteria of failures as well as various combinations of these criteria (Zaitzev & Uvarov, 2012).

Table 1. The calculation results of probability of faultless formation of perfect order

Criterion of failure	Base option	First option	Second option			Third option		
	P_i^*	n_i^{**}	(3)	(2)	(1)	(3)	(2)	(1)
1. Fulfillment of an order out-of-time	0,9	2	2	-	-	1	-	1
2. Number of orders that are fulfilled not to the fullest extent	0,8	4	(2)	2	-	(1)	2	1
3. Number of improperly executed documents	0,5	10	(2)	(2)	6	(1)	(2)	7
Total number of all types of failures		16	2	2	6	1	2	9
Probability of faultless formation of perfect order	0,36	0,2	0,5			0,4		
Note: $*P_i$ – probability of faultless execution of i^{th} operation; $**\ n_i$ – number of failures when executing i^{th} operation								

Let us analyse the results shown in Table 1. The base variant of calculating the probability of faultless formation of perfect order corresponds to the classical rule of serial connection of elements.

$$P_0 = \prod_{i=1}^{3} P_i = 0,9 \times 0,8 \times 0,5 = 0,36 .$$

The first option presents independence and the lack of correlation of failures when executing each operation and the corresponding probability is determined by the formula 1.

$$P_1 = 1 - \frac{\Sigma n_i}{N} = 0,2.$$

The second option includes the maximum possible combinations of events: three criteria of failures occurred simultaneously when executing two orders; two criteria of disruptions happened during execution of another two orders and only one criterion of failure occurred when executing last six orders, the corresponding probability is P_2 = 0,5.

The third option is one of the possible combinations of criteria of failures in a single delivery, the probability of faultless formation equals to P_3 = 0.4.

Thus, by analysing the different sources one can make the following conclusions:

1. Unified definitions of key terms as well as decomposing of supply chain into components are lacking when assessing the reliability of logistics systems.
2. Different studies lack a single opinion about supply chains, their properties and characteristics, which is why there are problems in description of supply chains and in analysis of the processes occurring in them.
3. Methods for assessing the reliability, which are proposed in considered studies, can be used only if initial data is available but methods for data collection are not considered.
4. The probability of faultless operation is considered as the main indicator of reliability, but there are no methods for reliability assessment that characterize restorability and operability.
5. It is proposed to base on the number of failures when assessing flows of failures, but there is no proper classification of failures and consideration of consequences of their occurrence in considered studies.

2. Formation of Conceptual Apparatus of Logistics Systems' Reliability Theory

Table 2 shows the basic terms and definitions that have been formed on the basis of an analysis of studies on logistics and supply chain management studies, as well as the following approaches:

1) technical approach based on the theory of reliability of complex systems;
2) economic approach that involves evaluation of the reliability of supply chains on the base of logistics costs, breaches of contractual obligations (fines, etc.) or KPI indicators;
3) situational approach that includes recording of time parameters of business processes in supply chains, which are based, in particular, on the fundamental concepts of JIT, QR, etc.

Table 2. The revised terms of supply chain's reliability theory

Term	Definition
Reliability	It is property to maintain all characteristics of supply chain & its links/elements within the established values (faultlessness, durability, restorability, conservability), which characterize supply chain's ability to perform all of its functions in the concrete conditions in accordance with the terms of contracts between its parties
Faultlessness	Property that characterizes supply chain's ability to operate continuously without disruptions for a specified time in accordance with the contractual terms between its parties
Restorability	It is property, which characterizes ability of supply chain to eliminate emergent disruptions and its consequence, brining the chain back to operable good state
Runability/ Good state	The supply chain's state, in which its functioning corresponds to the terms of contracts concluded between the members of this supply chain
Fault/ faulty state	The state of the supply chain at which it is able to perform all of its functions, in spite of the violation of the terms of contracts between its parties
Operability	The state of the supply chain at which it is able to perform its functions in accordance with the agreements between the parties in the supply chain
Inoperability	The state of the supply chain at which it is not able to perform its functions in accordance with the agreements between the parties to the supply chain for any reason
Defect	Internal action entailing acceptable deviation from the terms of contracts between supply chain parties
Damage	External action entailing acceptable deviation from the terms of contracts between supply chain parties
Failure/ Disruption	Loss of supply chain's or its elements the ability to perform its functions in accordance with the contracts between chain's members
Interruption/ transient fault	Failure/ Disruption, which leads to a short-term loss of operability & could be removed by negligible efforts without significant investment of time and finances

In our opinion the formation of the conceptual apparatus has to include not only revised terms and definitions but failure modes that occur in the supply chain (Table 3) and the classification of supply chains (Table 4).

Undoubtedly, Table 3 covers a small part of failures that occur in real supply chains. Therefore, in our view, provided information is the first step in this direction and, of course, research should be continued.

A similar conclusion can be drawn and for Table 4, which presents consolidated classification of supply chains in terms of reliability. In the future the Table 4 should be extended by including the types of redundancy of elements (“hot”, “cold”), the presence of “switches” (here the case is about participation of the operator in the supply chain management), etc.

Thus, supply chains are complex systems, which have independent functionality, they consist of many interacting components (subsystems) and thereby they acquire new properties that cannot be reduced to the properties of subsystem level.

Table 3. Failure modes that occur in the supply chain

Group of failures	Description	Example
Failures in quantity	The deviation of the actual quantity of goods in the supply from planned	Shortage, overload, etc.
Failures in quality	Inconsistency of the actual quality of goods agreed in the order	Wetting of cargo, cargo damage, etc.
Failures in nomenclature	Inconsistency of the actual delivery of the ordered nomenclature	Incorrect complete set unit load, etc.
Failures in the document	Incorrect execution of documents or errors in their of treatment between SC members	Loss or error in compiling of documents, etc.
Failures in the informing	Errors in the process of exchange of information between SC members	Late informing about the arrival of transport for loading, etc.
Temporary failures	Disruption of a schedule of operations in the SC	Delay loading or late arrival of the vehicle, etc.
Equipment failure	Failures of technical equipment used in the supply chain	Breakage the vehicle, material handling equipment, etc.
Emergency situations	The influence of extreme situations caused by natural disasters, force majeure and other causes, which may not affect members of the supply chain	Natural disasters, government restrictions, social disruption, etc.

Table 4. Classification of supply chains

Criterion	Types	Example
By the number of planned realizations	One-time	For single use only
	Reusable	For continuous operation
Where possible eliminate failures and their consequences	Restorable	Part of the failures occurred and their consequences can be eliminated, and the chain is restored
	Not restorable	Disruption of supply is due to any failure in the supply chain
By the presence of duplicate (parallel) elements	Redundant	There are in the chain parallel duplicate elements
	Nonredundant	All elements and links in the chain have a serial connection

Obviously, in the supply chain one should allocate links of chain (participants of the supply chain) and elements (operations that are performed in the chain). Such decomposing, which allows presenting a particular supply chain as a complex of companies and the operations they perform, enables the assessment of any supply chain.

For calculation of the reliability indicators of logistics system let's use the idea of a simple supply chain (SSC). By “simple supply chain” we shall mean the following:

– a part of the logistics chain (channel), which include at least two major links of logistics system such as “supplier” and “consumer” that are connected to each other by logistics operations: purchase, order processing, transportation and storage, etc.;

– SSC extension is possible due to main intermediaries (“the third party” in logistics): carriers, freight forwarders, warehouses, etc.;

– any supply chain can be represented as a set of individual SSC.

The proposed decomposing is simple and has adjustable level of detail that provides the best way to analyse the functioning of the supply chain.

We should also note the additional properties of supply chains and, first of all, the property of self-organization, which is purposeful adaptive behaviour in complex environments through adequate changes both internal and external conditions. Essentially supply chains are considered restorable, which is why when assessing reliability one should take into account this the most important property.

Assessing the impact of such characteristics of supply chains as longevity and storage-ability on reliability is complicated, as they are more dependent on external factors, which are characterized by a high degree of uncertainty. Certainly the consideration of such characteristics can improve the accuracy of reliability assessment, but at this stage they can be neglected.

3. Development of Discrete-Continuous Model of the Simple Supply Chain

In accordance with described approach the supply chain can be presented as a discrete-continuous model and described as a graph, which is based on the Gantt chart:

- the order quantity, its nomenclature, product quality, availability of properly executed documents, etc. can be referred to discrete variates;
- time characteristics and characteristics of reliability of technical products used in the supply chain can be referred to continuous variates;
- discrete-continuous or combined variates can be introduced for registration of expenditures of time that is required to perform operations until binary indicator “fulfilment of schedule”, which will take the values “yes” or “no”.

Suppose that we have the supply chain in which the delivery of finished goods is made from the plant of manufacturer to warehouse or distribution centre (Figure 1). The graph illustrates that the chain includes 8 basic operations that must be made to fulfil the order within the specified time intervals:

1. Agreement of supply $[0; t_1]$.
2. Order packing at warehouse $[t_1; t_2]$.
3. Processing of documents for cargo dispatch $[t_2; t_3]$.
4. Vehicle loading $[t_3; t_4]$.
5. Cargo transportation $[t_4; t_5]$.
6. Unloading $[t_5; t_6]$.
7. Processing of documents when receiving cargo $[t_6; t_7]$.
8. Placing of cargo at warehouse $[t_7; t_8]$.

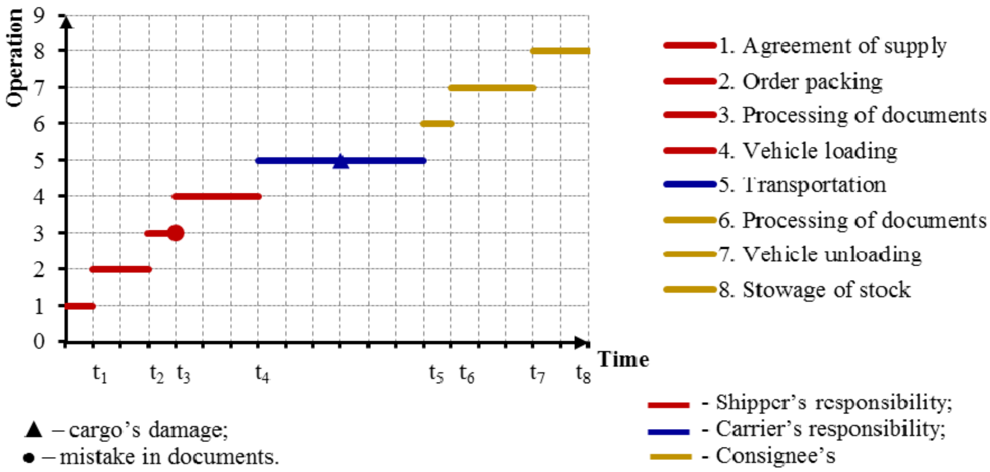

Figure 1. The supply chain can be represented as a graph based on the principle of a Gantt chart

Proposed graph shows the time characteristics of operations as well as allows illustrating possible parallel execution of these operations, for instance, processing of documents and vehicle loading. Failures (disruptions) in the supply chain can be marked on the chart. For example, mistake in documents and cargo damage occurred during transportation are marked by appropriate symbols on Figure 1.

Consider the example of the formation of costs flow in the supply chain (Figure 2). Assume that during the first delivery the vehicle was loaded with a delay that is why the carrier invoiced penalty for waiting time on 5000 roub. (see the 1st delivery on Figure 2).

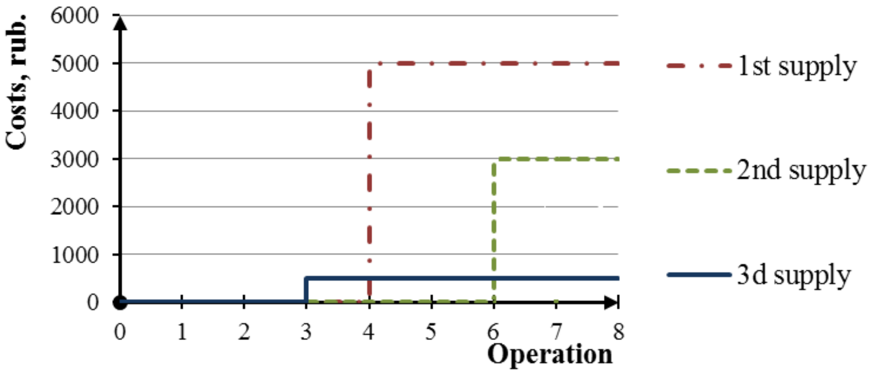

Figure 2. The diagram of formation of flow of costs associated with the maintenance of supply chains' operability

During fulfilling of the second delivery when unloading the vehicle at warehouse the cargo of consignee was damaged and the damage amounted to 3000 roubles (see the 2nd delivery on Figure 2). During the third delivery of cargo the transport documents were incorrectly processed, the correction of which costs 500 roubles (see the 3rd delivery).

When forming a discrete-continuous model it is necessary to take into account that the number of operations may different depending on the complexity of the supply chain, as well as the allocation of responsibility between participants, for instance, the carrier is responsible for transportation, etc.

4. Evaluating the Reliability of Logistics Operations on the Basis of Statistical Data

According to the developed model, reliability is assessed on the basis of the collected data on execution of operations for several deliveries in the supply chain. First of all, the assessment of operations is made, after that the whole supply chain is evaluated. When estimating operations it is necessary to distinguish between failure modes, since they have different effects on the functioning of the supply chain and entail different consequences. For example, operations that involve equipment, namely, vehicles (transportation), cranes, forklifts, conveyors (loading, unloading, materials handling), are characterized by means of intensity (Figure 3) or the leading function of flow of failures and corresponding indicators of reliability: mean-time-between-failures, availability factor, etc.

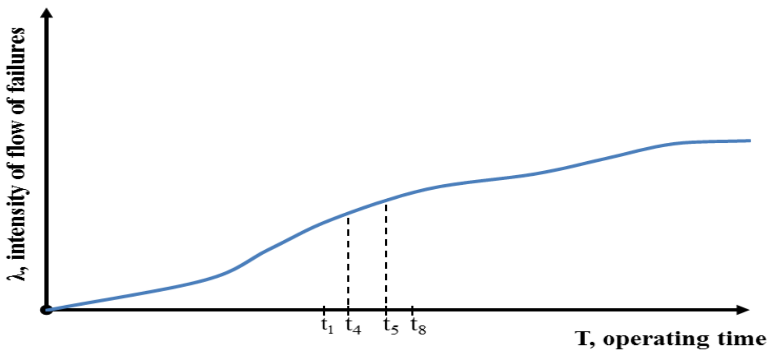

Figure 3. Intensity of flow of failures of vehicle

The studies have shown that it is necessary to distinguish three main indicators of reliability of the supply chain: faultlessness, restorability and the costs of maintenance of operability. The first two indicators can be described with the help of probabilistic characteristics of execution of operations in supply chain and these characteristics can be calculated by the combination of different methods depending on different failure modes. The costs of maintenance of the supply chain's operability should be calculated quantitatively depending on the frequency of their occurrence. Thus, the assessment of the reliability of the supply chain should be carried out on the basis of the combination of probability and cost characteristics of operations.

As pointed out above, in many studies the probability of faultless operation of the supply chain is used as the main indicator. Obviously that for a discrete-continuous model with a serial connection of elements the formula for serial connection of elements can be used for calculating faultlessness.

Besides, there is a certain probability that the failure will occur, but its effects can be eliminated, leaving the supply chain in good operation condition.

To take into account the restoration of the supply chain, for example, with the help of redundant elements after the failure when the i^{th} operation is executed, the values of P_i should be corrected.

Consider one of the possible approaches based on addition theorem and multiplication theorem of the probability of events.

Assume that event A is the formation of a perfect order and its probability is p_A, and thus the probability of imperfect order equals to $q_A = 1 - p_A$.

In warehouses of supply chain, which receive orders (or where they are formed), there are insurance stocks. Then the event B is the availability of safety stock and its probability is p_B, and the probability of its absence (i.e. deficit) equals to $q_B = 1 - p_B$.

The calculation formula based on the theorem about the repetition of experiments to assess the probability of a combination of events A and B can be written as:

$$Q + P = p_A p_B + p_A \cdot q_B + p_B \cdot q_A + q_A \cdot q_B, \tag{2}$$

Obviously, the sum of the first three summands reflects the probability of faultless performance of considered logistics operation - p, and the last summand reflects the probability of failure –q.

Further development of this approach, which reflects the specifics of the internal redundancy of the supply chain, should provide not only more accurate probable description of the perfect order but also the quantitative status of safety stock at the time of delivery (or formation).

Finally, if we assume that all failures and corrective actions lead to costs, the reliability evaluation reduces to the calculation of these costs, i.e. the flows of failures in supply chains can be presented as the flow of costs of operability’s maintenance. Then on the analogy with technical systems one can consider the intensity of flow of costs per delivery as well as an integral characteristic, namely the leading function of flow of costs per delivery.

5. Approbation: the Example of Calculating the Reliability of the Supply Chain

To illustrate the developed approach let’s consider the simulation results of ten deliveries of products from producer to consumer without intermediaries taking into account that any delivery can be presented as the combination of eight logistics operations (Table 5). Accordingly, the first three deliveries are shown on Figure 2.

Apart from failures the Table 5 shows the costs associated with the restoration of supply chain's operability.

Table 5. Recording of failures (disruptions) and costs associated with the maintenance of supply chains’ operability

№ of supply	Costs that are incurred during execution of operations in supply chain, rubles							
	1st op.	2nd op.	3rd op.	4th op.	5th op.	6th op.	7th op.	8th op.
1	0	0	0	5000	0	0	0	0
2	0	0	0	0	0	3000	0	0
3	0	0	500	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	8000	0	0	1000	0
6	0	0	0	0	0	0	0	0
7	0	0	1000	0	0	0	0	0
8	0	0	0	0	0	2000	0	0
9	0	0	0	0	20000	0	0	0
10	0	0	0	0	0	2000	0	0
Number of failures	0	0	2	2	1	3	1	0
Total costs, y.e.	0	0	1500	13000	20000	7000	1000	0

By using the data from the Table 5 let's calculate the indicators of reliability of the supply chain (Table 6).

Consider the approach to assessing the probability of faultless operation P_0 without redundancy.

Since the supply chain consists of eight operations, which are performed sequentially, for calculation of P_0 can be used the classical formula of probability theory:

$$P_0 = \prod_{i=1}^{8} P_i = 1 \times 1 \times 0,8 \times 0,8 \times 0,9 \times 0,7 \times 0,9 \times 1 = 0,363,$$

where P_i – the evaluation of faultlessness of i^{th} operation.

Value $P_0 = 0,366$ indicates that the supply chain is almost inoperable and requires adjustment.

Consider the approach to assessing the probability of faultless operation with account of redundancy when the 3, 5 and 7 operations are executed.

We remind that operations 3 and 7 "processing of documents" include an assessment of the perfect order. Let's carry out calculations in several stages.

Operation 3. We assume that insurance stocks at the warehouse of producer were increased and it allows providing the probability of availability of stocks at level $P_{ss,3} = 0,7$. Then by formula 3 (assuming that the probability of faultlessness of the perfect order is $P_3 = 0.8$) we find:

– the probability of formation of the perfect order (3[rd] operation) equals to

$$P_3^* = 0,8 \cdot 0,7 + 0,8 \cdot 0,3 + 0,7 \cdot 0,2 = 0,94;$$

– the probability of failure $Q_3^* = 0,06$.

Operation 5. Let's assume that the insurance stock at the warehouse of producer provides the probability of faultless operation at level $P_{ss,5}= 0,8$. We believe that this stock is enough to ensure the operability of the chain in case of late delivery (probability of delay in the delivery $q_5 = 0,1$). When using the formula 2, we obtain:

– the probability of faultlessness of 5[th] operation equals to $P_5^*= 0,98$;

– the probability of failure is $Q_5^*= 0,02$.

Operation 7. During calculation we will try to take into account the relationship of operations in the supply chain. So taking into account corrected 3[rd] operation, the option of the perfect order has the probability $P_3^*= 0,94$.

However, after such operations as loading, transportation, unloading as well as because of possible natural loss, destruction of unit packages, theft, etc. we can assume that the value of P_3^* will decrease, for example, to $P_3^*= 0,84$. Provided that the amount of safety stock at the warehouse is sufficient (and remains at $P_{7.saf}= 0,8$), similar to the calculations at previous stages we obtain:

$$P_7^*= 0,968;\ q_7^*= 0,032.$$

Thus the probability of faultless operation of corrected supply chain is $P^*= 0,500$.

Table 6. Calculation results of indicators of the supply chain reliability

Indicator	Logistics operations								Comment
	1	2	3	4	5	6	7	8	
Probability P_i	1,0	1,0	0,8	0,8	0,9	0,7	0,9	1,0	P_0=0,363
Number of failures* (cumulatively)	0,0	0,0	0,2	0,4	0,5	0,8	0,9	0,9	Leading function of flow of failures
Probability P_i in consideration of redundancy	1,0	1,0	0,94	0,8	0,98	0,7	0,97	1,0	P_0*=0,500
Costs associated with performance restoration*, thous. rub.	0	0	0,15	1,3	2	0,7	0,1	0	Intensity of flow of costs
Costs associated with performance restoration * (cumulatively), thous. rub.	0	0	0,15	1,45	3,45	4,15	4,25	4,25	Leading function of flow of costs
*per one delivery									

Consider the economic approach to assessing the reliability of the supply chain. Current state of the considered supply chain can be evaluated on the basis of data collected by constructing "the flow of failures" in the form of the leading function of flow of costs, which allows characterizing the reliability of supply chains as restorable systems. The leading function is constructed (Figure 4) on the basis of data of costs calculated cumulatively (Table 6).

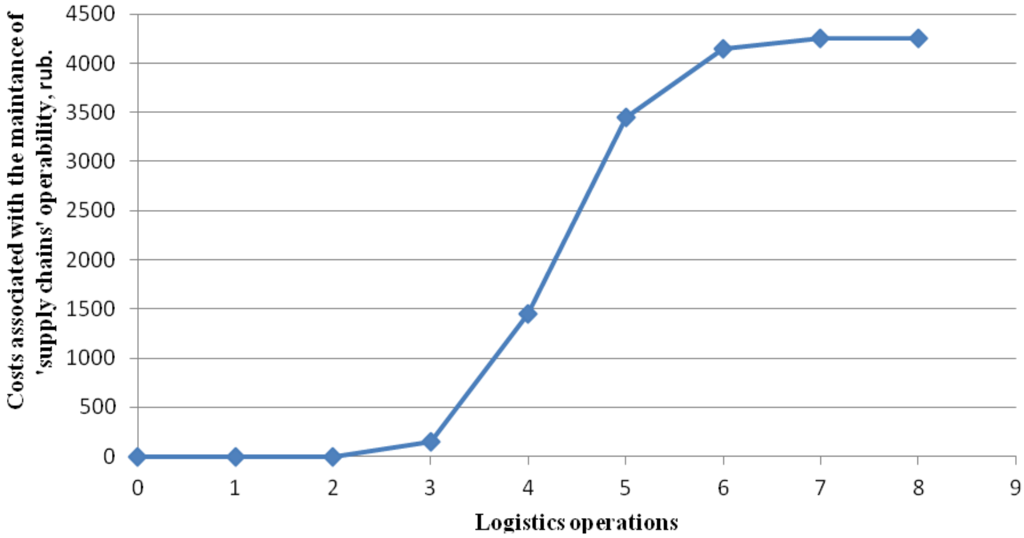

Figure 4. Leading function of flow of costs associated with the maintenance of supply chains' operability

6. Conclusions

The results of calculations of probabilities of supply chains' faultless operation, which take into account the elements of redundancy in the form of insurance stocks in the warehouses of suppliers and consumers, differ significantly from the results obtained on the basis of existing approach, which implies the sequential execution of logistics operations without corrections. It emphasizes once again that supply chain should be seen as a system of "man-machine-environment", which integrates the material and accompanying flows (financial, information flows and others) and is capable of self-organization and self-learning.

The proposed terminology of basic concepts and definitions of reliability of supply chains undoubtedly requires further discussion and improvement. At the same time, after the unifying of terminology it will be possible to form unambiguous and reliable databases of real supply chains.

Analysis of the intensities and leading functions of flows of costs associated with the maintenance of supply chains' operability makes it possible not only to evaluate their effectiveness, but also to find alternative solutions that will improve their reliability. Simultaneous use of probabilities of faultless operation of logistics operations and the flows of costs is the basis for the finding of "bottlenecks" in the supply chain and will promote making optimal management decisions for the elimination of these "bottlenecks" in case of limited resources.

Further development of the proposed approach for assessing the reliability of the supply chain, in our opinion, is impossible without the formation of new analytical tools in the form of complex models of failures while executing logistics operations, and these new analytical tools should be used not only for existing supply chains, but also during the design or re-engineering of logistics systems.

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HOMOGENIZATION EFFECTS OF VARIABLE SPEED LIMITS

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Changing factors (mainly traffic intensity and weather conditions) affecting road conditions require a suitable optimal speed at any time. To solve this problem, variable speed limit systems (VSL) – as opposed to fixed limits – have been developed in recent decades. This term has included a number of speed management systems, most notably dynamic speed limits (DSL).

In order to avoid the indiscriminate use of both terms in the literature, this paper proposes a simple classification and offers a review of some experiences, how their effects are evaluated and their results

This study also presents a key indicator which measures the speed homogeneity and a methodology to obtain the data based on floating cars and GPS technology applying it to a case study on a section of the M30 urban motorway in Madrid (Spain). It also presents the relation between this indicator and road performance and emissions values.

Keywords: Effectiveness indicator, variable speed limits, dynamic speed limits, GPS application, speed management, floating car data

1. Introduction

The main tool used by authorities to manage speed is the setting of speed limits, which tend to be fixed. However, the optimal speed cannot remain constant at all times, as the road conditions are affected by numerous factors, mainly traffic intensity and weather conditions (Giles, 2004).

Speed can be regarded as a key factor that directly affects certain aspects of the road such as traffic performance, road safety and environmental externalities.

1) Traffic performance

Together with intensity and density, speed is one of the key factors determining road capacity. At a critical speed and the corresponding critical intensity or density, the state of flow will change from stable to unstable and, speed differences and braking process can therefore lead to congestion and reduced road capacity (Van Nes & etc., 2008).

2) Road safety

It is generally accepted that high speeds involve a high risk to road safety. This idea is supported by a large number of studies which highlight the relationship between speed and road safety. For instance, ref. (Elvik, 2005) shows an extensive review of 98 studies containing 460 estimates of the relationship between changes in speed and changes in the number of accidents or accident victims, concluding "the relationship between speed and road safety is causal, not just statistical".

3) Environmental externalities

Apart from vehicle technologies, speed is a very important factor determining negative environmental effects such as CO_2 emissions, pollutants (Ntziachristos & Samaras, 2000) and noise (Makarewicz & Gałuszka, 2011).

The concern of traffic authorities to adapt traffic speed to changing road conditions has led in recent decades to the development of variable speed limits (VSL).

2. Variable Speed Limits. Classification

VSL is a broad term that includes many speed management systems with different motivations and control algorithms. VSL can be defined simply as speed limit management systems, which are time dependant. Some authors confine the term VSL to systems which utilize traffic detectors to determine the appropriate speed (Sisiopiku, 2011); however, this fails to take into account the existence of VSL, which operate following prefixed calendars or timetables based on historical data. It is thus necessary to classify VSL as follows:

2.1. Scheduled Variable Speed Limits (SVSL)

These are VSL which depend on a pre-established calendar or timetable. Among these, the following types can be identified:

Seasonal Variable Speed Limits

These are applied to a specific type of road and set the speed limit during a particular season, with the most common being the winter/summer speed limits.

An example can be found in the Nordic countries due to their extreme weather conditions during the winter months. In Finland the reason for lowering winter speed limits is primarily the adverse road and driving conditions (Peltola, 2000).

Experiments involving the setting of seasonal speed limits for safety reasons can be also found in the northern states of the U.S.A. For instance, the Wyoming Department of Transport first implemented the seasonal speed limit for six months beginning on October 15, 2008 (Wyoming Department of Transport, 2012).

In the Austrian region of Tyrol during the winter of 2006/2007, the speed limit was temporarily reduced on the Inn Valley Motorway from 130 km/h to 100 km/h, mainly due to high levels of air pollution during previous winter seasons (Land Tirol, 2012).

Hourly Variable Speed Limits

These are mainly applied to prevent or reduce certain negative externalities in a specific road section or street at particular times.

Experiments of this type can be found in some German or American cities where authorities have implemented VSL in school areas in order to reduce speed when schools are open or at exactly the times children are arriving or leaving (Lehming, 2008), (Transport and Main Roads, 2011).

There are also experiments related to noise reduction during night hours in residential areas or close to hospitals and other facilities. In the city of Berlin (Lehming, 2008), speed is limited during the night hours to 30 km/h in residential or mixed areas.

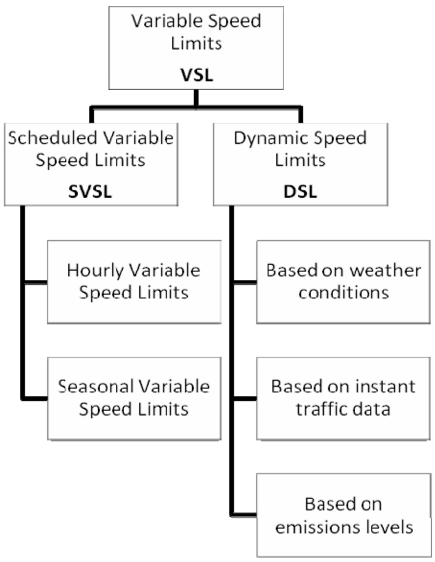

Figure. 1. Proposed classification of Variable Speed Limits

2.2. Dynamic Speed Limits (DSL)

The term "dynamic" implies a force which produces a change in state or movement. In this case, the "forces" that produce changes in speed limits are the conditions in and around the road. Therefore, Dynamic Speed Limits can be defined as a type of Intelligent Transport System (ITS) which produces changes in speed limits in response to accurate information regarding road, driving, weather and/or environmental conditions (Van Nes & etc., 2008).

In practice, the system consists of dynamic message signs (DMS) deployed along a roadway and connected via a communication system to a traffic management centre (Allaby & etc., 2007). After data processing and speed limit calculation, the new speed limit information is displayed on these DMS.

Pure manual control methods are based simply on a protocol that the operators activate when one or more levels (traffic intensity, visibility, air pollution, etc.) exceed the pre-set thresholds.

The concept of automatic DSL is based on various approaches, ranging from basic protocols according to particular thresholds (similar to manual methods) to complex algorithms based on multi-objective optimization, game theory, predictive control and genetic algorithms (Hegyi & etc., 2005; Xu & etc., 2006; Ghods & etc., 2010; Xiao-Yun & etc., 2010).

3. Evaluation of Variable Speed Limits

DSL are being implemented worldwide; however their effects are not yet clearly defined, and in some cases their benefit is not fully proven.

Based on international experiments and research studies, we summarize the way in which DSL affect the parameters of traffic performance, road safety and environmental levels, and the variables that are used to assess their effectiveness.

3.1. Traffic Performance

With regard to traffic performance and traffic flow behaviour, there are several parameters which may be affected by the implementation of DSL, including particularly speed and capacity.

The reduction in average speed and speed variations depends largely on the type of speed limits imposed (mandatory or recommended) and their enforcement. Most DSL operate as mandatory limits, such as the M25 controlled motorway around London (Highways Agency, 2004), although there are also some systems with recommended speed limits, such as the Motorway Control System (MCS) on the E4 in Stockholm (Nissan & Bang, 2006).

These systems are based on the capacity increase that occurs when speed and speed variations are reduced by high flow levels. Moreover, speed homogenization reduces the number of acceleration and deceleration manoeuvres and therefore the oscillations in traffic flow (García, 2009). Ref. (Heydecker & Addison, 2011) shows that under certain congestion conditions, speed determines density; based on this observation, the relationship between density and speed can be estimated depending on speed limits.

The reduction of speed limits has a considerable effect on the speed differential between lanes. In (Van Nes & etc., 2008), the conclusions show that it can be said that dynamic speed limit systems do increase the homogeneity of the driving speed.

Based on computer simulators, some authors evaluate positively the effects of DSL on traffic performance. Reference (Zhicai & etc., 2004) shows the simulation of a number of types of DSL scenarios, and the results indicate that the benefits of DSL are obvious when the traffic volume is equal to or greater than 2,800 veh. in a double-lane freeway. Ref. (Hegyi & etc., 2005) simulates the effects of DSL on the prevention of congestion caused by shockwaves, obtaining a reduction in total travel time of 21.7%.

Germany has a long tradition of implementing VSL, and in particular DSL. The first experiment was implemented in 1965 on the A8 motorway between Munich and Salzburg, with good results in terms of harmonization and reduction of speed differences between lanes. These results and many others from German motorways can be found in (Schick, 2003). Among these cases, we can highlight the report on the A5 motorway in Frankfurt. Based on data from video recording and induction loops, the authors found a significant increase in the empirical maximum traffic intensity in the southbound direction from 5,200 veh/h. to 5,900 veh/h. (about a 10% increase). However other studies in the Netherlands (Hoogendoorn, 1999) estimate the capacity increase at around 2%.

The M25 in the U.K. can also be highlighted as a successful implementation of DSL. During the first year of operation, a section of this controlled motorway absorbed a 1.5% increase in throughput over 5-hour peak periods, without any detectable increase in congestion levels. Traffic conditions have improved as a result of the reduction in frequency and severity of shockwaves. The study (Highways Agency, 2004) revealed a reduction of over 25% in the typical number of shockwaves during the morning peak period. It has also been observed that the traffic is now more evenly spread across all four lanes.

Reference (Nissan & Bang, 2006) studied the application of DSL on the E4 motorway through Stockholm, revealing that lane changes were reduced by over 50%, and that lane distribution became more balanced after the implementation. However, this phenomenon can have negative effects in sections with a high density of on-ramps, as this will lead to smaller gaps in the traffic on the outside lane, making the merging process more difficult and therefore creating congestion on the on-ramp (Knoop & etc., 2010).

Experiments were conducted on the ASF (Autoroute du Sud de France) in France in the summer of 2004, with the implementation of an innovative traffic control system on the A7 motorway, which includes

DSL. In the southbound corridor, the use of progressively slower speed limits depending on traffic volume has reduced congestion by between 16% and 40%, depending on the section (ECMT, 2007).

3.2. Road Safety

The effects mentioned in the previous section can also have a positive impact on road safety, as decreases in the speed limits can lead to a reduction in the speed differences between successive vehicles, resulting in a decline in rear-end collisions.

Reference (Lee & etc., 2007) presents a simulation-based study showing the potential safety benefits of DSL using a real-time crash prediction model integrated with a microscopic traffic simulation model. The study found that dynamic speed limits can reduce average total crash potential by approximately 25%, by temporarily reducing speed limits during hazardous traffic conditions. Positive effects of DSL have also been found in other simulation-based studies, such as (Piao & McDonald, 2008).

Regarding the study of the DSL implemented, an analysis of crash data in Germany has shown that the use of dynamic speed limit and speed warning signs reduced the crash rate by 20 to 30% (Robinson, 2000). Other German studies cited by (Schick, 2003) estimate a reduction in the number of accidents of over 30% (A5 motorway, near Frankfurt), and a similar decline in fatalities by more than 60%. In Stuttgart, the reduction in accidents caused by fog conditions is as high as 86%.

In the UK (Highways Agency, 2004) data are analysed from the M25 in order to compare them with the trends. The impact of introducing the controlled motorway driving environment (mainly DSL and managed lanes) has been an estimated reduction in injury accidents of 10% during the period of operation, and a decrease in the ratio of damage of 20%.

The aforementioned programme in the South of France also had very positive road safety results, with crashes reduced by 10–20% (ECMT, 2007).

Table 1. Summary of evaluation variables used in different research studies

Ref.	Case study	Variable	Effects
Traffic Performance			
(Makarewicz & Gałuszka. 2011)	Simulation of 12 rural roads	Standard deviation of the average speed	Depending on scenarios
(Zhicai & etc., 2004)	Simulation	Traffic volume, travel time, queue length, number of stops	Variable
(Hegyi & etc., 2005)	Simulation	Total travel time	21% reduction
(Hoffmann-Leichter, 1997)	A5 Motorway, Germany	Intensity	10% increase
(Hoogendoorn, 1999)	Simulation	Capacity	2% increase
(Highways Agency, 2004)	M25, U.K.	Throughput	1.5% increase
(Nissan & Bang, 2006)	E4 Stockholm	Lane changes	50% reduction
(ECMT, 2007)	A7 France	Congestion	16-40% reduction
Road Safety			
(Lee & etc., 2007)	Simulation	Total crash potential	25% reduction
(Piao & McDonald, 2008)	Simulation M6, U.K.	Time-to-collision Headway	Depending on scenarios
(Robinson, 2000)	German motorways	Crash rate	20% reduction
(Highways Agency, 2004)	M25, U.K.	Damage ratio	20% reduction
(ECMT, 2007)	A7 France	Crash number	10-20% reduction
Emissions			
(Zegeye & etc., 2010)	Simulation	Total emissions	35% reduction
(Highways Agency, 2004)	M25, U.K.	Emissions levels	Between 2-8% reduction
(Highways Agency, 2004)	M25, U.K.	Noise levels	0.7-2.3 dB reduction
(Land Tirol, 2012)	A12, Austria	NO_2 levels	3.6% reduction

3.3. Environmental effects

It is well-known that improved traffic flows can have a significant impact on emission levels (Benedekand & Rilett, 1998). There are very few approaches based on simulating emissions in DSL. Of particular note is the simulation of a case study based on model predictive control, where the total emissions are reduced by over 35% (Zegeye & etc., 2010).

Returning to the case of the M25 motorway in the U.K., in (Highways Agency, 2004) it was found that vehicle emissions have dropped as a result of reducing start-stop driving. Depending on the particular emissions measured, the decrease is between 2% and 8%. Fuel consumption has also been reduced. In parallel, there has been a favourable impact on noise as a result of the introduction of DSL systems between Junction 15 and 16. The reduction in stop-start driving and the improved compliance with the speed limits have reduced the weekday traffic noise adjacent to the motorway by around 0.7 decibels, with reductions at some points of up to 2.3 dB.

Another example can be found in Inn Valley in Austria. The effects of the implementation of DSL were analysed on this motorway after one year of operation (November 2007 to November 2008). In a before/after evaluation the results show that NO2 emissions were reduced by 3.6%. Also, the NO2 limit value for short-term exposure (half-hour limit: 200 g/m³) was exceeded only twice during the first year of operation, while without the DSL in operation, it is estimated that it would have been exceeded nine times (Land Tirol, 2012).

4. Methodology to Evaluate VSL Systems Using an Aggregate Effectiveness Indicator

4.1. Effectiveness indicator. Definition

Table 1 shows the large number of variables which are used in the scientific literature and other public reports to evaluate the effects of DSL. This fact highlights the need to find a single variable which makes possible to evaluate the system's effectiveness easily and concisely by aggregating the potential effects on traffic performance, road safety and emissions.

With regard to traffic performance, several of the aforementioned studies point out that the homogenization of speed (i.e., lower acceleration rates) contributes to a smooth traffic flow (García, 2009), an increase in capacity (Heydecker & Addison, 2011) and the attenuation of shockwaves (Hegyi & etc., 2005).

Likewise, road safety has been proven to be related with traffic and speed homogeneity (Van Nes & etc., 2008), (Piao & McDonald, 2008), (Fildes & Lee, 1993), (Wegman & etc., 2008). It can therefore be concluded that there is a clear relation between speed variations and number of accidents.

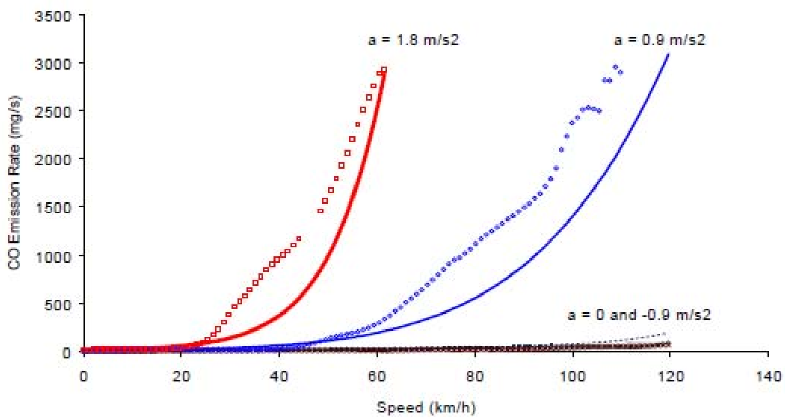

Figure. 2. Regression fit for CO emissions as a function of speed and acceleration rates. Source (Rakha & etc., 2000)

Many research studies (Rakha & etc., 2000; El-Shawarby & etc., 2005; Joumard & etc., 1995; Ding & Rakha, 2002) also state that, apart from mean or average speed, positive acceleration rates also have a major impact on emissions, as shown on Figure 2 from (Rakha & etc., 2000).

It has thus been possible to pinpoint instant acceleration as a key factor by evaluating the effectiveness of implementing DSL, and then proposing an aggregate indicator as follows:

Positive Accumulated Acceleration (PAA) is defined as the sum of the speed variations on a particular road section.

Mathematically, it is the cumulative integral of the positive acceleration law (1).

$$PAA = \int_0^t a^+(t)\,dt \cong \sum_0^t a_t^+ \cdot \Delta t = \sum_0^t \frac{\alpha \cdot (V_t - V_{t-1})}{\Delta t} \cdot \Delta t = \sum_0^t \alpha \cdot (V_t - V_{t-1}).$$

If $(V_t - V_{t-1}) > 0$ then $\alpha = 1$ (1)

Otherwise $\alpha = 0$.

Graphically, PAA is the positive area of the region bounded by the acceleration law, as shown on Figure 3.

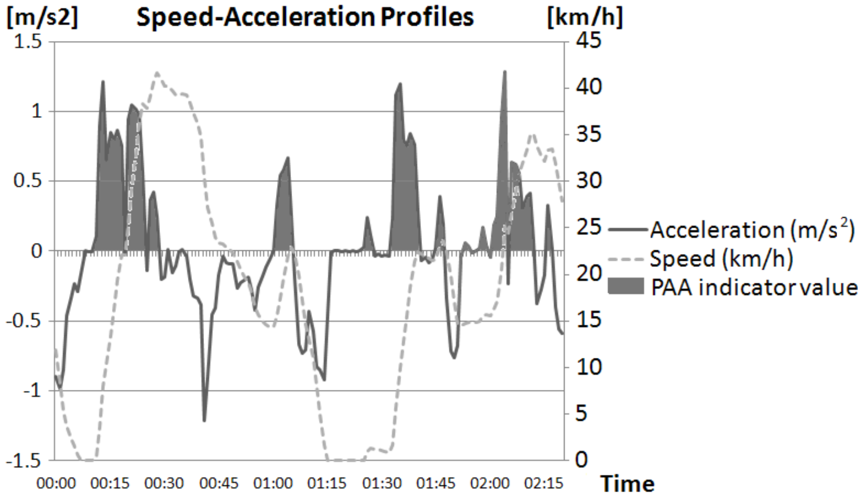

Figure 3. Graphic representation of PAA indicator from an acceleration function

The PAA indicator makes it possible to compare the same section before and after the implementation of DSL, thus evaluating its effectiveness.

4.2. Data collection and evaluation

As already mentioned, the PAA indicator is simply based on speed variations, and the data required to calculate it is relatively easy to obtain.

Speed data are often collected by induction loops located at certain points on the road, but this method makes it impossible to establish the speed evolution between two loops, and leads to the possibility of distorted results.

It is thus essential to obtain speed data at short time intervals, and the methodology proposed is therefore based on GPS technologies. With a small portable device it is very simple to collect and download speed data, position and so on every second, which allows a very accurate speed profile to be obtained along the road section analyzed.

The methodology is based on a before & after evaluation, by observing the evolution of the PAA indicator. Ideally, the number of trip repetitions should be fairly high in order to limit variations caused by other factors such as meteorology, extraordinary events, incidents, etc. In any case, the trips must be made in the same time slot and on days with similar behaviour in terms of traffic. In the event of a limited sample, particular care must be taken to ensure that the conditions are almost the same. The traffic intensity upstream must be guaranteed to be substantially the same when performing the before & after trips.

Once the valid data has been processed and selected, the implementation of DSL can be valued positively if the indicator PAAa (activated) is lower than PAAd (deactivated).

5. Pilot Test Case: West Section of Madrid M30 Motorway

5.1. Description

Madrid is a city of about 3.5 million inhabitants, and up to 6 million in its metropolitan area. The city is surrounded by three motorway ring-roads, with the M30 the closest to the city centre.

In the afternoon peak hours on a normal working day, the M30 has high traffic levels southbound on its east and west sections. In an attempt to avoid this habitual congestion and its externalities, the Madrid Traffic Department is testing a DSL system based on recommended speed limits.

The tested section is a three-lane motorway (southbound) with traffic intensity in the afternoon peak hours of around 3,300 veh/h. (upstream), and a length of 5.8 km. Most of the section is limited to 90 km/h, except the last 100 m., where the limit is 70 km/h. (tunnel entrance). The congestion is usually caused by the bottleneck situated at the M500 junction, as around 2,800 vehicles merge into the M30.

The DSL system consists of three Variable Message Signs (VMS) situated before the M500 junction. These VMS display a recommended speed limit of 40, 60 or 80 km/h, depending on the control algorithm. This is based on instant speed and traffic intensity data recorded by induction loops situated along the section.

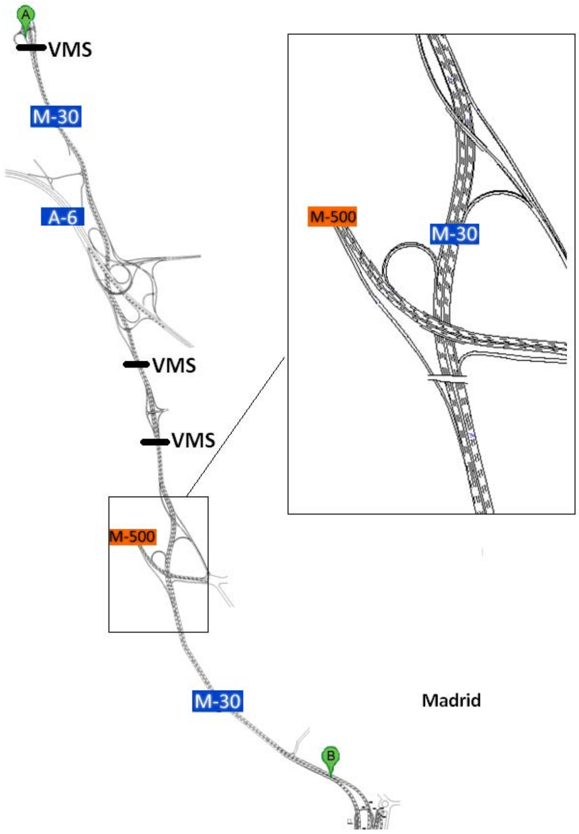

Figure 4. West Madrid motorway ring-road and the 5.8 km. test section (from A to B) with the location of the Variable Message Signs (VMS). The bottleneck junction where the congestion usually starts (M-500) is highlighted

A microscopic car study was undertaken in the afternoon peak traffic period between 18:00-20:00. A total of nine trips were made on the 6th and 7th June (Tuesday and Wednesday) with the DSL system activated. One week later (12th and 13th June) another nine trips were performed at exactly the same times, this time with the DSL system deactivated. The intensity levels upstream for the test days were very similar, with a maximum deviation of 2.63% from the mean value (Table 2). The weather was sunny and there were no particular incidents or accidents during the test trips, except for unusual congestion on 6 June, which caused the system not to be automatically activated.

Table 2. Traffic flow intensities upstream (Measuring point PM 22421)

Time	Date				Mean	Max. mean deviation
	05-June	06-June	12-June	13-June		
18:00	3159	3196	3114	3324	3198	-2.63%
19:00	3501	3544	3506	3440	3498	-1.65%

The mobile study was carried out using an instrumented vehicle (Skoda Fabia TDI) equipped with a GPS data recorder (747+ GPS Trip Recorder), which was subsequently downloaded as an Excel Sheet (.csv) and georeferenced (.kml) documents.

The data collected included travel distance (m), position and speed (m/s), recorded every second, enabling the PAA to be obtained as defined in the previous section.

Likewise, seven trips (Figure 5) in free flow (southbound mornings) were performed in order to study the variability of the PAA in similar conditions and to isolate the effects of DSL from any other which may influence the results (small disturbances and changes in driving style).

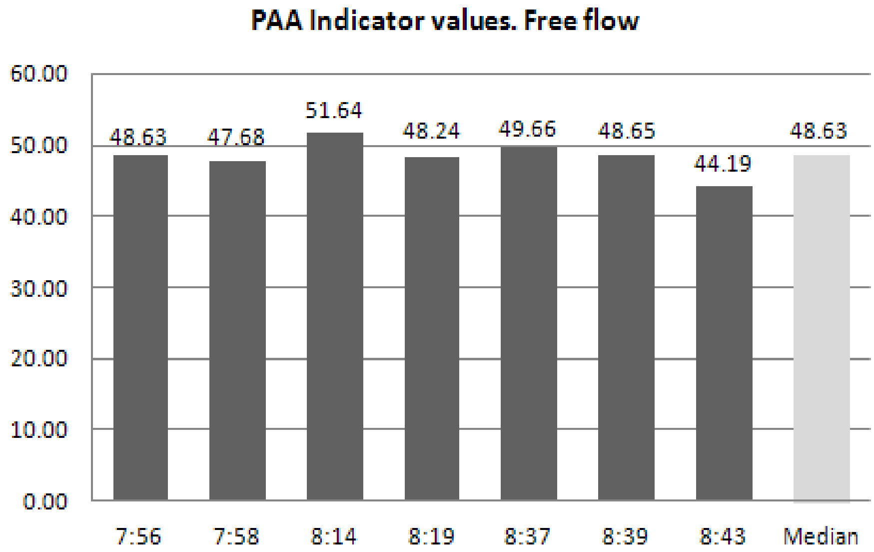

Figure 5. PAA indicator values in free flow. Obtained in the morning hours of the 5th and 6th June

From this analysis, it can be concluded that in free flow and in similar conditions, 99% (confidence level = 0.99, ά = 0.01) of the PAA results present a deviation from the median of less than 2.19 (confidence limits). Therefore any deviation greater than this value will be assigned to the effects of DSL.

5.1. Analysis of results

5.1.1. Effects on speed homogenization

Table 3 shows the resulting values of the PAAa and PAAd from the trips performed on the 5th and 12th June. The results on Wednesday 6 are considered invalid, as the system was automatically disconnected due to the unusual and extreme congestion (recorded speed under the operation thresholds).

Table 3. Values obtained for PAA Effectiveness indicator. Congested trips

Activated		Deactivated	
Tuesday 5 and 12. Afternoon peak			
Time	**PAA values**	**Time**	**PAA values**
18:30	91.68	18:29	92.04
18:52	88.20	18:52	88.89
19:11	72.23	19:10	90.99
19:32	59.62	19:32	105.88
19:51	63.54	19:55	69.36
Average	*75.05*	***Average***	*89.43*
Wednesday 6 and 13. Afternoon peak			
18:28	~~125.84~~	18:27	99.20
18:50	~~124.06~~	18:49	86.62
19:14	~~130.74~~	19:13	90.68
19:38	~~73.21~~	19:38	76.82
Average	~~*113.46*~~	***Average***	*88.33*

When the effects of DSL are isolated from any other effects, as described in the paragraphs above, the result shows that the PAAa falls by an average of 13.1%, compared to the PAAd.

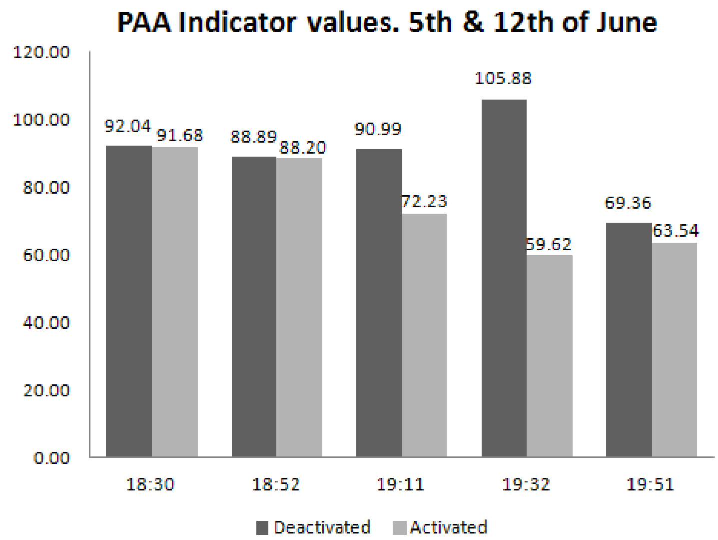

Figure 6. Comparison of the effectiveness indicator (PAA) on Tuesday 5th and 12th June

Figure 6 shows that PAAa and PAAd values are fairly similar, except for the trips that are highly affected by congestion. An analysis of the speed profiles on Figure 7 and the indicator values shows that in the 19:11 trip, the speed distribution is more homogeneous, although the congestion levels are similar. This fact causes the congestion on the following trip (19:32) to remain at similar levels (or even to decrease) while DSL is activated, and the queue length to increase while deactivated.

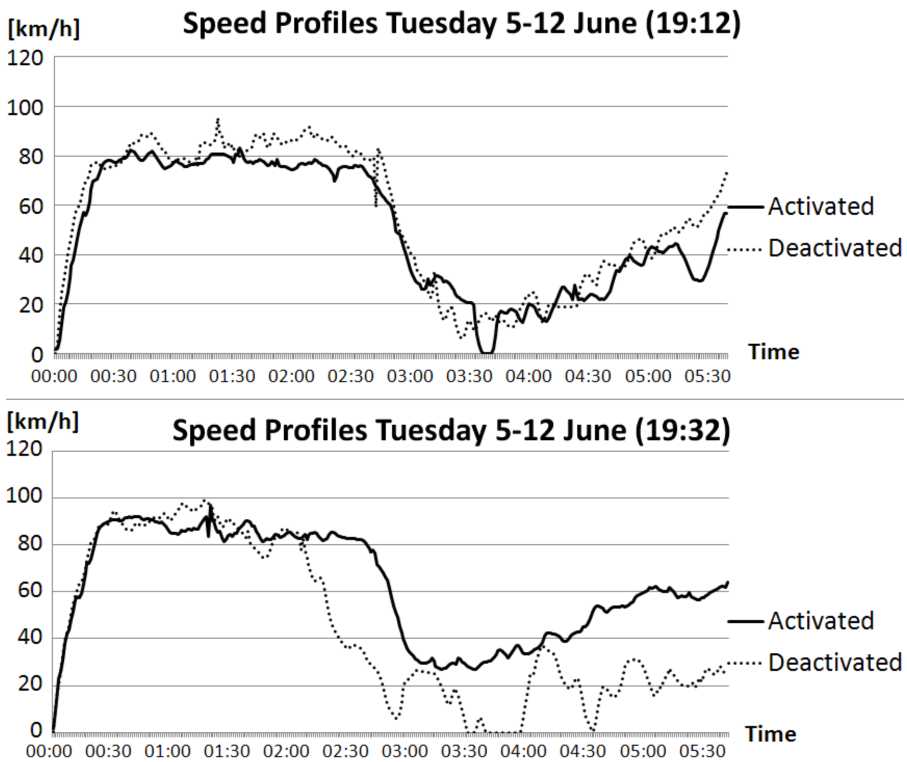

Figure 7. Comparison of speed profiles for trips with DSL activated and deactivated

5.1.2. Effects on traffic performance

As we have seen in the literature review, the effects of variable speed limits on traffic performance are site dependant, achieving most of the case studies positive results in terms of traffic throughput and travel times.

Table 4 shows the relation (in percentage) between traffic throughput downstream and upstream during the peak hours in the test days.

Table 4. Traffic throughput relation downstream/upstream the test section

Date	**05-June**	**06-June**	**07-June**	**12-June**	**13-June**	**14-June**	**Mean**
Activated	183%	181%	178%	-	-	-	181%
Deactivated	-	-	-	181%	177%	178%	179%

The results show a slight improvement of 2% in the relation between the traffic flow downstream and upstream during the test days.

Table 5 shows the travel times during peak hour trips on the 5^{th} and 12^{th} June. The results on Wednesday 6 are considered invalid, as the system was automatically disconnected due to the unusual and extreme congestion (recorded speed under the operation thresholds).

Table 5.Trip travel time per day (activated/deactivated)

Activated		Deactivated	
Tuesday 5 and 12. Afternoon peak			
Time	**Travel time**	**Time**	**Travel time**
18:30	7:59:00	18:29	6:59:00
18:52	7:28:00	18:52	6:15:00
19:11	6:35:00	19:10	6:10:00
19:32	5:36:00	19:32	7:24:00
19:51	4:45:00	19:55	4:46:00
Average	*6:28:00*	***Average***	*6:18:00*
Wednesday 6 and 13. Afternoon peak			
18:28	~~9:34:00~~	18:27	7:21:00
18:50	~~10:13:00~~	18:49	6:32:00
19:14	~~10:29:00~~	19:13	6:56:00
19:38	~~7:02:00~~	19:38	6:04:00
Average	~~*9:19:00*~~	***Average***	*6:43:00*

Rejecting the results of the 6^{th} June and comparing similar trips of activated and deactivated days, the result shows a 3% increase in travel time with the system activated.

From the traffic performance point of view, the results are contradictory. Firstly, the application of variable speed limits produces in this case a slight improvement in the throughput relation between traffic flow downstream and upstream the controlled section. On the other hand, travel time suffers a small penalty, which is related with the more restrictive speed limits.

However, it is important to mention that although this travel time increase, PAA values decrease when the system is activated. This means that the system achieves more homogeneous speed profiles for the same travel times (Figure 8).

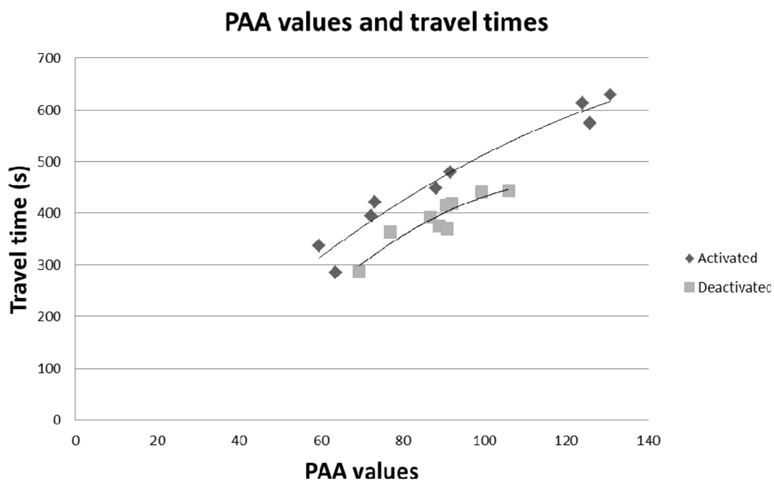

Figure 8. PAA values and travel times

5.1.3. Environmental effects

Together with road safety considerations, positive environmental effects are one of the main reasons for implementing variable speed limits systems in motorways. Most of the studies reviewed show positive results in case of emissions and fuel consumptions.

In the presented case study, reductions of PAA values, which mean more homogeneity in speed profiles, imply reductions in emissions and fuel consumption. This reduction can be quantified by introducing the speed profiles in micro emissions models, such as VERSIT+ (Smit & etc., 2007).

The output of the VERSIT+ model for the presented case study is summarized in Table 6.

Table 6. Trip travel time per day (activated/deactivated)

Activated				**Deactivated**			
Tuesday 5 and 12. Afternoon peak							
Time	**CO_2**	**NO_x**	**PM_{10}**	**Time**	**CO_2**	**NO_x**	**PM_{10}**
18:30	1021	1.880	0.2396	18:30	1040	1.994	0.2413
18:52	1037	1.985	0.2481	18:52	1058	2.103	0.2462
19:11	973.1	1.845	0.2173	19:11	1074	2.379	0.2387
19:32	961.6	1.845	0.2216	19:32	1102	2.226	0.2495
19:51	1014	2.209	0.2199	19:51	1034	2.303	0.2200
Average	*1001.3*	*1.952*	*0.2293*	***Average***	*1061.6*	*2.201*	*0.2391*
Wednesday 6 and 13. Afternoon peak							
Time	**CO_2**	**NO_x**	**PM_{10}**	**Time**	**CO_2**	**NO_x**	**PM_{10}**
18:28	1148	2.197	0.2704	18:27	1079	2.028	0.2523
18:50	1171	2.333	0.2819	18:49	1047	2.206	0.2426
19:14	1165	2.133	0.2703	19:13	1051	2.037	0.2431
19:38	1002	1.802	0.2442	19:38	1023	1.958	0.2380
Average	*1121.5*	*2.116*	*0.2667*	***Average***	*1050*	*2.057*	*0.2440*

As in previous analysis, rejecting the extreme results of the 6th June, the emissions savings are shown on Table 7.

Table 7. Emissions savings comparing the scenarios activated vs. deactivated.

Emissions	**CO2**	**NOx**	**PM10**
Savings	2.58%	4.14%	2.54%

Analysing the relation between Positive Accumulated Acceleration indicator and the emissions, both CO_2 and the pollutants show the same tendency. Despite this tendency is clear, NOxis not clearly correlated with the indicator, obtaining a low value of R^2. Figure 9, 10 and 11 show the relation between PAA and CO_2, NO_x and PM_{10} respectively.

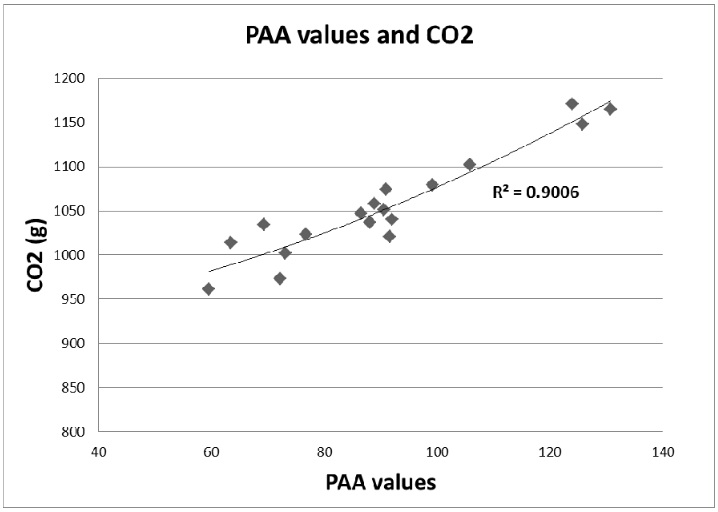

Figure 9. PAA values and CO_2 emissions

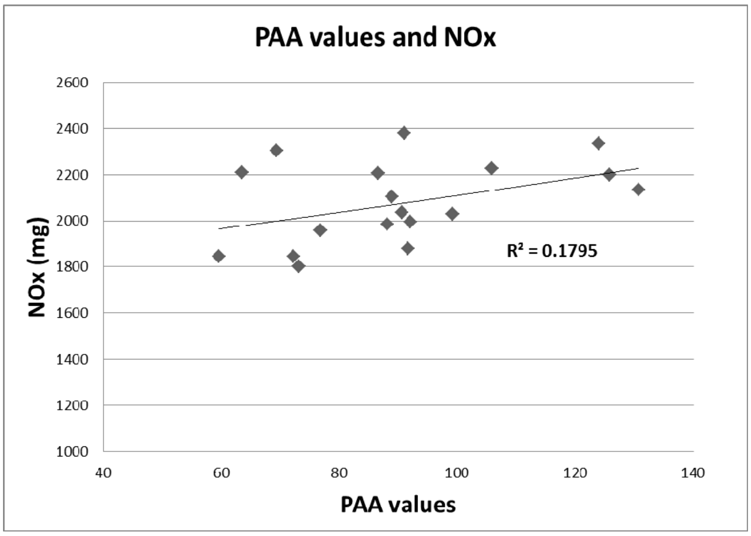

Figure 10. PAA values and NO_x emissions

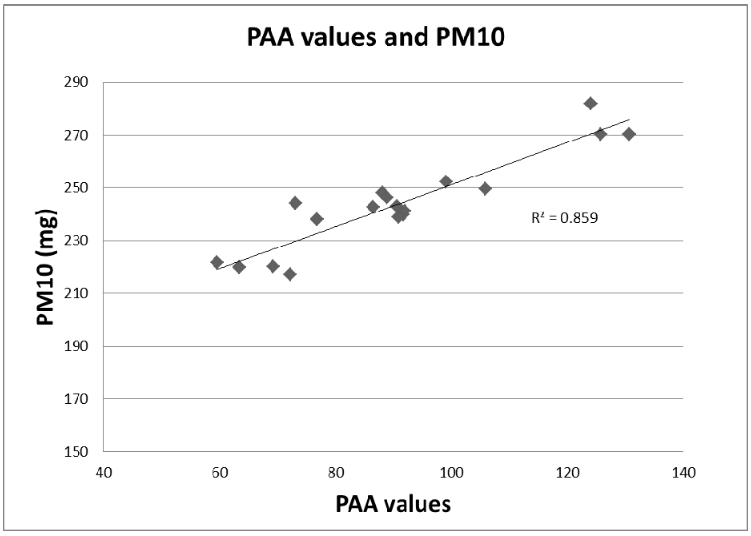

Figure 11. PAA values and PM_{10} emissions

6. Conclusions

After classifying Variable Speed Limits, the literature review has shown that in many cases VSL (and in particular VSL based on dynamic control) have been beneficial in terms of traffic performance, road safety and environmental effects. Based on the accumulated acceleration in a section (or instantaneous speed variations) the methodology described provides a single indicator (PAA) to evaluate whether the implementation of VSL is working properly and has the potential to produce the desired effects.

To evaluate the feasibility of the methodology on a practical level, a pilot study was carried out on a stretch of the M30 motorway ring-road in Madrid. This demonstrated the defined PAA effectiveness indicator to be specific, measurable, reliable and traceable.

Once the effects of driving variability have been statistically bounded by analyzing the trips in free flow, the variability in traffic intensities requires a greater number of routes. Regarding the traffic performance, traffic data extracted from induction loops shows an increasing traffic throughput when the system is activated, slightly penalising travel times.

After estimating the emissions based on the speed profiles, clear tendencies have been extracted by correlating the results with the PAA indicator, especially with CO_2 and NO_x.

Although it has been not possible to cross the obtained data with road safety figures, in general it can be concluded that the homogenization achieved by the implementation of variable speed limits systems has positive effects.

Future research in relation to this indicator could be directed towards establishing more solid quantitative relationships between changes in the value of the PAA effectiveness indicator and the VSL effects, especially regarding road safety.

Acknowledgments

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THEORETICAL INVESTIGATION OF TRAFFIC EQUILIBRIUM ON BRIDGES

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Road traffic flows on a straight road segment such as bridges are modelled in this article. The mathematical model of traffic flows has been constructed by using the method of lumped parameters. Changeable lane direction and road pricing has been theoretically investigated in order to understand the shifting in supply and/or demand curves of traffic participants in equilibrium. The article presents assumptions for constructing the mathematical model. Demand can be influenced by road pricing, in its turn, supply can be influenced by extension of infrastructure with reversible lanes.

Keywords: traffic flow, mathematical modelling, supply and demand curve, bridges

1. Introduction

Road transport is one of the main inland transport modes providing door-to-door services for people all over the world. Each inland territory is criss-crossed by interurban road and street network. Vehicle flows carry people, distribute industrial freight and work equipment on these network elements (Szendrő, 2010). In some cases, the variability of landscape may require additional infrastructural elements, such as bridges, to be built. Road pricing is an economic concept regarding the various direct charges applied for the use of roads. The road charges in this case include tolls and congestion charges, which may vary by time or by vehicle type (Gehlert et al., 2008). Road pricing has two distinct objectives: revenue generation, usually for road infrastructure financing, and congestion pricing for demand management purposes. Road pricing could be one tool of sustainable development, of sustainable transportation that could efficiently satisfy the needs of the future (Csete, 2006). In this paper, authors are only investigating price as a traffic controlling parameter. For the purposes of this article, externalities are considered to be a part of the pricing regime. The majority of road vehicles that are running on road elements and bridges are driven by internal combustion engines; therefore, besides practical use they also create a lot of problems, such as air pollution with combustion products and particulate matter, noise, vibration, utilization of used oil and other materials, recycling of cars and their parts. Cars consume a lot of energy; therefore when optimising traffic flows, a lot of wide-range problems are solved or balanced, from vehicle manufacturing to their utilization.

2. Methodology

A lot of burning problems arise when cars are used and here the main problems to be solved by both engineers and scientists are pollution reduction (through engineering or by driving less – changing behaviour) and energy saving. Various problems caused by vehicles are discussed in the article written by Makaras et al. (2011). These authors discuss vehicle dynamics in the flow, fuel consumption, the impact of dynamics of cars on the environment, touch upon the driver‘s model and various driving styles. Torok (Barabas & Todorut, 2011) investigated the dynamics of CO_2 emission reductions with increasing biofuel blends. Szendrő et al. (2012) investigated the adoption possibilities on the local level. Janulevičius et al. (2010)

presented the methodology of determining energy consumption taking into account engine capacity and specific fuel consumption. Wu and Liu (Wu & Liu, 2011) presented in their article the methodology of calculating fuel consumption by taking into account such criteria as aerodynamics and rolling resistances. The fuel consumption model was constructed based on the neural network theory. Smit et al. (2008) present and generalize three emission models, where the impact of congestion on motor vehicle emissions is evaluated differently and present indicators to identify transport congestion. The article also presents congestion identification models. Jovic & Doric (2010) used the programming package PTV Visio to model traffic flows on the urban street network and based on that present vehicle emissions. Jakimavičius & Burinskienė (2010) investigated vehicle flow optimization methods and their application possibilities when informing traffic users about the situation in the city. Péter and Bede (Bede et al., 2010)] analysed the optimal control in modelling of Reversible Lane System (RLS). The function of every element and the contacts between the elements can cease in case of direction change in any part of the network, and then new contacts and new functional elements are activated. The availability of the RLS was examined in a sample network depending on the traffic density, using a new principle, which responds to the dynamic change of the structure of the network graph (Peter & Bokor, 2011; Bede & Péter, 2014).

This article gives an example of applying mathematical models of traffic flows to simulate change in traffic flow condition when the supply and demand curves are shifted by changes in road pricing (due to changes in traffic flow or internalising external effects of road transport) or changes in lane direction (Bede & Péter, 2012), respecting road safety (Figure 1).

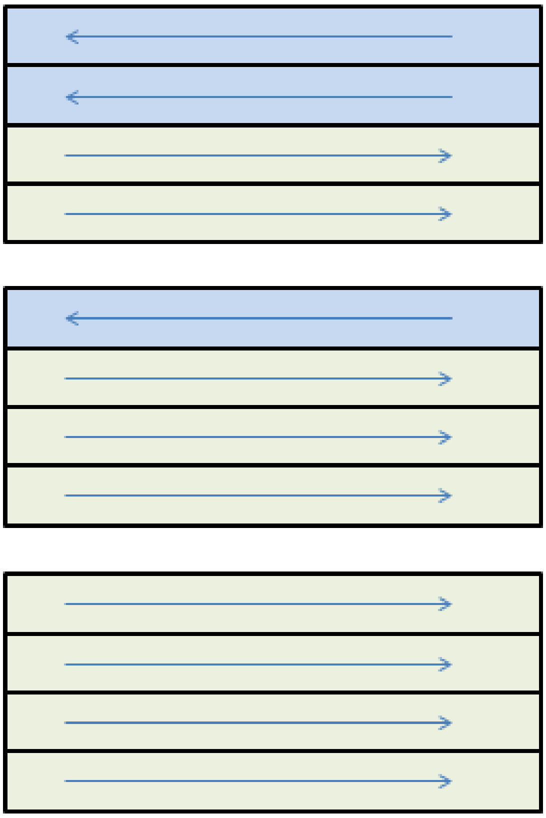

Figure 1. Possibilties of lane direction changing
(*Source: autors' compilation*)

When describing traffic flows, a traffic lane is used as a keyword. An assumption is made that cars cannot drive on an opposite traffic lane; therefore, the road is split into separate and competing traffic lanes in a system that very much resembles competing products on the same perfect market. Two-way roads are described in the mathematical model as separate one-way roads with one or several traffic lanes (Bede & Péter, 2012). In this model, a traffic lane segment is taken as a finite-length line, which is divided into equal segments the length of which is L (Figure 2).

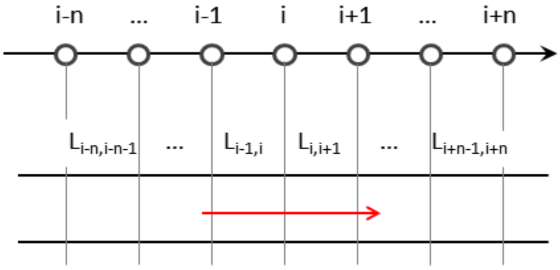

Figure 2. Transport flow model on a straight segment of a traffic lane
(*Source: Junevičius et al., 2011*)

The parameters of a road segment (traffic flow speed, traffic flow concentration or traffic flow intensity) can be measured at the end points. The point, which connects two adjacent segments, has a point common to both segments. Minimal and maximal values of traffic flow parameters for each road segment are set separately and may be different. Minimal values of traffic flow speed and concentration are usually equal to zero. Maximum possible speed is based on observations. Maximal permitted traffic flow concentration value may be calculated according to the following formula (1):

$$k = \frac{n_{auto}}{L_{i,i+1}}, \quad (1)$$

where

n_{auto} – number of vehicles in segment (units),

$L_{\text{i,i+1.}}$ – road segment length (m).

Let us suppose that a road segment cannot be overfilled. If the number of vehicles on a road segment reaches an upper boundary limit, more vehicles cannot enter this road segment. If a road segment is full, the value of vehicles‘ flow remains the same, increases or slightly decreases, but is insufficient and the road segment ahead remains overfilled, vehicles start accumulating on the road segment subsequent to the full road segment. Vehicle flow speed is limited as well. Each road segment has its own speed limit, which can differ.

Traffic lane segments split in the model are numbered $L_{i-1,i}$, $L_{i+1,i}$ when i = 1...n, i – road point number (Figure 3).

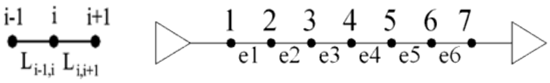

Figure 3. Description of elements of a straight road. a) two elements $L_{i-1,i}$ and $L_{i+1,i}$, are connected at point i; b) a straight road segment drawn from several road segments connected at points 1…7
(*Source: Junevičius et al., 2011*)

The first point of an element is equal to the last point of the preceding element, and the last point of an element is equal to the first point of the subsequent element (Junevičius et al., 2011). It is very important that no traffic can be added in the segment except at the beginning and end point. This theory provides advantages in using bridge pricing in order to reach optimal traffic flow.

3. Results

Different competing lanes have been investigated by the authors. Authors have assumed that not only the price of lanes but direction is also changeable. In a macro economical sense, those one-way lanes are competing with the other direction. In this case authors have investigated the very simple model of RLS in case of a bridge. Within these circumstances the optimizing this has to be decided between tolls level on the bridge and direction of the lanes in order to maximalize the revenues (3):

$$REV = \sum_{i=1}^{n} (k_i \cdot L_i \cdot p_i), \tag{2}$$

where

k_i – the number of vehicles in segment (PCU/m),

L_i – road segment length (m)

p_i – toll fee (€/ PCU)

In this article authors tried to build up a model of competing RLS in a bridge. Authors have assumed that competing RLS is behaving like a set of competing goods, therefore the basic macro-economical assumptions and rules were used. Practical uses of supply and demand analysis often centred around the different variables that change equilibrium price and quantity, represented as shifts in the respective curves (Figure 4). Comparative statistics of such a shift traces the effects from the initial equilibrium to the new equilibrium.

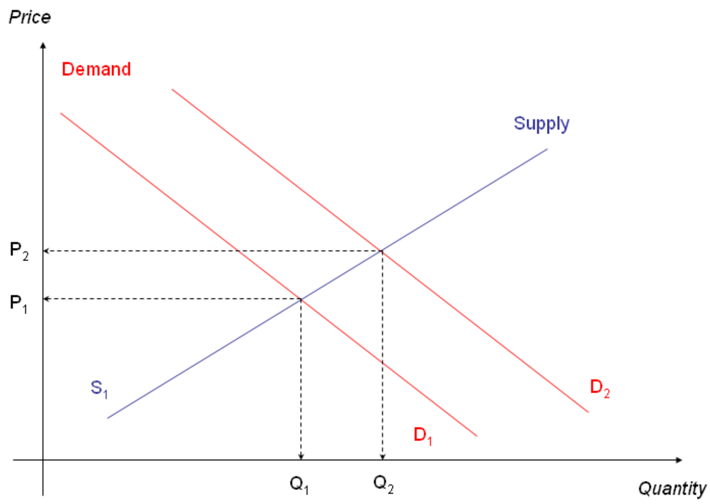

Figure 4. Change of demand curve
(*Source: Oscar R. Lange: Introduction to Economic Cybernetics*)

Authors have simulated an unwanted rightward shift in demand, increasing equilibrium quantity that increases price. At each price point, a greater quantity is demanded, as from the initial curve D_1 to the new curve D_2 (more and more people wanting to pass the bridge, for example). In the diagram, this raises the equilibrium price from P_1 to the higher P_2 in order to keep the balance and to control traffic flow. This raises the equilibrium quantity from Q_1 to the higher Q_2. Mathematically a linearised demand function can be described as (4):

$$x_t = a \cdot p_t + \alpha . \tag{3}$$

In the example above, there has been an increase in demand, which has caused an increase in (equilibrium) quantity. The increase in demand could also come from changes in the value of travel time. People sitting in congestion could pay higher fee for the bridge. This would cause the entire demand curve to shift, changing equilibrium price and quantity. The equilibrium quantity, price and demand are different from the previous balanced point. At each point, a greater amount is demanded (when there is a shift from D_1 to D_2).

The increased demand led to increased profit that, in turn, could shift the supply curve (Figure 5). For example, assume that some of the lanes on the bridge can be turned over – the direction can be changed (see Figure 1).

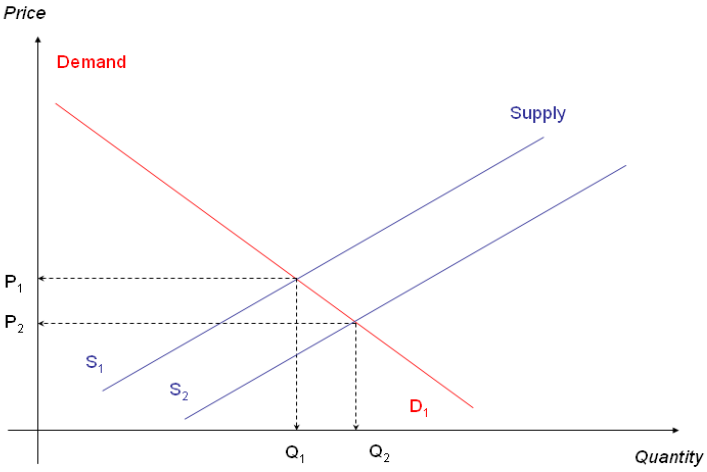

Figure 5. Change in the curve of supply
(*Source: Oscar R. Lange: Introduction to Economic Cybernetics*)

To put it another way, drivers will be able to use more lanes at every price and this shifts the supply curve from S_1 outward, to S_2 — an increase in supply. This increase in supply causes the equilibrium price to decrease from P_1 to P_2. The equilibrium quantity increases from Q_1 to Q_2 as the quantity demanded increases at the new lower prices. In a supply curve shift, the price and the quantity move in opposite directions. Mathematically the linearised supply function can be described as

$$y_t = \beta + b \cdot p_{t-1} . \tag{4}$$

It is well known that market equilibrium is when demand x_t and supply y_t are equal. For every time period *t* there is an equilibrium that can be described with

$$\begin{aligned} a \cdot p_t + \alpha &= b \cdot p_{t-1} + \beta \\ a \cdot p_t &= b \cdot p_{t-1} + (\beta - \alpha), \end{aligned} \tag{5}$$

where

$x_t = a \cdot p_t + \alpha$, as demand function

$y_t = b \cdot p_{t-1} + \beta$, as supply function

p_t – price in time *t*

market equilibrium is reached when $p_t = p_{t-1}$. Therefore

$$\hat{p} = \frac{\beta - \alpha}{a - b} \tag{6}$$

and the actual price differs from the market equilibrium price with

$$\tilde{p} = p_t - \hat{p} = p_t - \frac{\beta - \alpha}{a - b} . \tag{7}$$

At this time the market equilibrium can be described as:

$$\begin{aligned} a \cdot \tilde{p}_t &= b \cdot \tilde{p}_{t-1} \\ \tilde{p}_t &= \frac{b}{a} \cdot \tilde{p}_{t-1} . \end{aligned} \tag{8}$$

With the above-mentioned model (Figure 6) authors have tried to analyse the effects of changing lane direction on bridge tolling as a form of pricing method. Theoretical investigation shows that if it is technically possible to change lane direction (as extension of infrastructure) then such an action could lead to decreased prices.

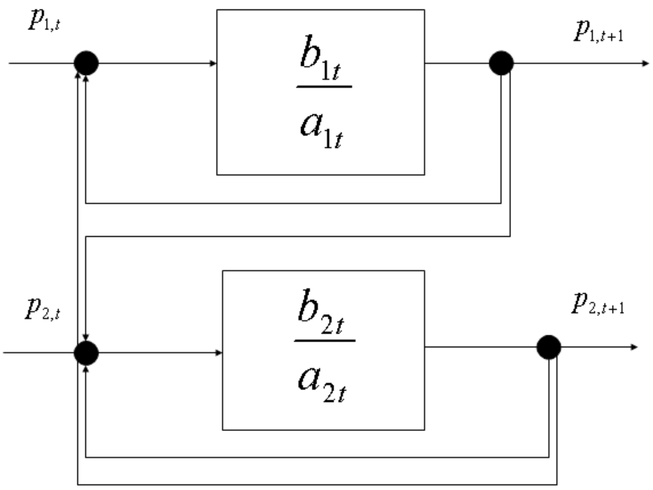

Figure 6. Cybernetic model of market equilibrium with two concurring group of lanes.
(*Source: Oscar R. Lange: Introduction to Economic Cybernetics, own research*)

4. Analysis and Discussion

The above-explained model can be extended by marginal social cost-based road pricing. In that case bridge tolling is not only a tool for controlling traffic flows, but to make users pay the cost of their externalities. In such a system, externalities can be estimated and be internalised in the pricing regime.

As Figure 6 shows, if a pricing regime controls the traffic flow then social marginal cost-based pricing can cause an unwanted shift in the balanced equilibrium point. Revenues cannot only be maximised through proper pricing but in some cases proper layout provides an opportunity to change lane direction. Keeping road safety in mind, more revenue can be generated with the use of variable lane direction.

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THE DIFFERENCES IN EFFICIENCY MEASURMENT: THE CASE OF EUROPEAN RAILWAYS

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In the world railways are organized in two ways. In one case, infrastructure management and organization of traffic and commercial activities are integrated at the level of one of the enterprise whereas in the other case the functions of the carrier and the manager of the infrastructure are separated. This article addresses approaches of different scientists and politicians on both forms. The analysis of the case of Lithuania has been carried out. The case of Lithuania is a typical one – historically the railways have had a monopoly with the infrastructure and transportation not separated. This article presents a critical view of theoretical pros and cons of both the models.

Keywords: railway liberalisation, infrastructure management, competition, transportation, state enterprise, market regulation

1. Introduction

In Europe for the past two decades there has been a debate between the railway companies, national governments, the European Commission and the researchers, whether the infrastructure should be separated from the carrier or integrated.

As for the benefits of the separation model, it is often argued that having separated the interests of the infrastructure manager and carrier, the development of the railways will be ensured and the efficiency will be raised only due to the resulting tension of interests, as both the infrastructure manager and carriers will attempt to work effectively. So far, the knowledge accumulated by the scientists is not yet comprehensive or complete, and the results are contradictory. So, what are they?

Ivaldi and McCullough (2006) demonstrated that the railway company which operates in accordance with the integration model (i.e. operating as not separated), has 20–40 per cent cost advantage compared to companies operating within the separation model – that is, in case of separation the costs increase.

Cantos et al. (2002), when investigating railway performance, concluded that the highest railway productivity was observed before the separation model was implemented and infrastructure was open for the carriers' competition. They analyzed the interaction between infrastructure costs and freight / passenger rail transport performance. According to them, the work by separation model implies inefficiency.

Asmild, Holvad, Hougaard&Kronborg (2008) shows that the separation at the level of accounts obviously contributes to improving the efficiency of rail operations. Although there are indications that rail efficiency grows after a full implementation of the institutional separation – the results are not statistically significant. So the question of whether the separation model promotes the efficiency of a railway sector remains unanswered. However, one can consider that the increasing rail efficiency after the implementation of separation model can actually be the result of separation of accounts that is occurring at the same time.

Friebel et al. (2004), Beria et al. (2012), Sánchez-Borràs (2010) examined the effectiveness of railway reform in the EU old member states. One of the factors the influence of which was attempted to be assessed by researchers was the separation effect on the efficiency of rail activity. Significant differences between integrated and separated enterprises were not detected. The separation model is not a prerequisite for efficient railway operations. In order to create a positive effect of the reform, it is necessary to carry it out by consecutive and separate phases – with the introduction of the full reform package the railway efficiency remains not only unchanged, but it could even decrease. This indicates that the rail sector's ability to absorb reform is limited: introducing reforms step by step allows the adjustment of further steps according to the needs and enables to abandon harmful moves.

Wills–Johnson (2008) came to the conclusion that the separation model in practice does not bring greater losses, partly due to the fact that integrated railway companies themselves are not very capable of optimally managing the wheel-rail interaction.

Calvo and De Oña (2012) raise a question if rail charges connected to costs in the light of monopoly approach.

What do these data show? Even if it would seem that the results show the benefit of the integrated model, all agree that the information leading to say that one or the other model is more effective, is missing. The observed results of the reforms offer a look at each rail system as a unique and specific arrangement; the same choice for one form of railways will prove to be successful, while for the others – devastating. However, these results should be seen as indication that the integrated railway company is more likely to deal with operational tasks more efficiently. Given that Lithuania made a decision on railway reforms without carrying out the economic justification of the reform, the possibility should be considered that Lithuania may be placed among those countries not being able to afford the separation model.

The EU railway reform goals are to create a single market for rail transport, increase the volume of rail operations (including their significances for other modes of transport), the efficiency and quality of services. None of the EU Directives requires a complete separation between the infrastructure and operations, and a consensus on the optimal organizational model on railway transport functioning is not made. It can be said that so far the greatest achievement of the discussion on "effective" and "ineffective" models is namely the perception that general guidelines on the realization of railway reform cannot be found, so it is increasingly being perceived that rail transport is a specific activity influenced by a number of factors – both as one of the network industries, and as one of the transport modes.

Therefore, it is also important to be aware of the source of ideas to reform the railway sector by applying a separation model. This idea – to dissociate the train traffic and infrastructure so that external carriers would be able to compete by using common rail, is related to telecommunication, electricity and other transport sectors. For example, road and air carriers have been continuously competing by using the infrastructure operated by infrastructure managers not associated with the carriers. However, practice has shown that the benefits of this model applied in a variety of networked industries also differ – it is associated with a higher success in one form of modes, whereas elsewhere – with less. For example, this model has proven to be successful and more adaptable in the electricity and gas sectors rather than in the telecommunication and rail sectors. Therefore, it is clear that the debate on rail reform successes and failures in various countries is questioning not only specific solutions and situations in various countries which led reforms, but also the idea of the applicability of such a reform in the railway sector.

As for the problems raised in this article, we would like to note that the discussions on the railway reform involve at least three different and not necessarily related railway reform components:

- Organization model (choice of either a separation model or the integrated model);
- Rail liberalization (to develop competition by giving an open access to all or to impose restrictions on potential market entrants);
- Form of ownership (privatization or maintaining public ownership?).

The main focus of this text is on the discussion of the arguments for and against each model. The separation of functions of the carrier and the infrastructure is identified by the term "separation model" ("vertical separation", "vertical unbundling"). The model of working without separation of these functions is identified by the term "integration model" ("vertical integration"). The issues of liberalization and the development of competition will also be reviewed in this discussion. However, the problem of privatization will not be addressed. Quite a number of commentators of the Lithuanian railway reform have expressed their belief that before taking further steps in the railway reform Lithuania has to gain knowledge of other countries' reform experience. This article attempts to discuss the experience of other countries although a list of "for" and "against" arguments found in the literature has been significantly narrowed.

The next section discusses the choices of the EU countries in reforming their own rail systems, which in its turn raises the awareness of a wider environment on which Lithuania focuses on priority basis today. The third section discusses the interaction of the organizational model and the development of competition: Which of these models facilitates the emergence of competition and consolidation?

Or maybe opening railways to competition does not mean that viable competition will appear naturally? The fourth chapter examines which model is more preferable in solving one of the crucial issues for Lithuania – investments in infrastructure and management of the infrastructure itself. This topic is extended in the fifth and final chapter, the purpose of which – to present the conclusions of a number of studies that have sought to evaluate the effectiveness of one or another model.

2. Railway Reforms in European Union Countries – Separation or Integration?

The railway reform goals and trends appear to be defined by the railway reform guidelines set by the EU directives and other documents as well as the attempts demonstrated by the countries themselves to integrate into the EU railway sector. The countries have the opportunity to carry out the reform with flexibility in finding the best individual solutions that will take into consideration their interests and specific needs. Therefore, it should be borne in mind that railway reforms in the EU old countries developed as an attempt to deal with the situations and problems of namely those countries. Consequently, the reform results should be considered by taking into account the fact that in every country, especially in post-communist European countries, the rail transport situation in general and the problems are different.

With regard to the EU requirement to separate infrastructure and transportation (at least in the accounts), the EU countries have chosen different reform paths. IBM (2007) study authors have divided the EU / EFTA countries into three main groups.

This classification reflects the real current rail organization in these countries in 2007, not the one declared or targeted to be achieved during the course of the reform. An example of another classification – "prospective" – is given by Nash, Matthews, Thompson (2005). This classification distinguishes four models in terms of what level of separation the parties decided to achieve: 1) Swedish Model (complete separation), 2) French model – separation of partial functions, 3) German model – holding 4) The Irish model – only accounts are separated, in other cases the integration is maintained. It is obvious that Lithuania intends to implement the Swedish model whereas our neighbours, Latvia and Poland, are planning to implement the German model.

Table 1.EU / EFTA countries by rail management models

Level of separation		
Complete institutional separation	**Functional, organizational, accounting and legal separation**	**Separation only at the account level**
Britain Bulgaria Denmark Spain Netherlands Norway Portugal Romania Slovakia. Finland Sweden	Austria Belgium Czech Republic Italy Poland Lithuania Germany Greece (not all functions) France (not all functions)	Ireland Estonia Luxembourg Latvia Slovenia Switzerland Hungary

Source: IBM (2007)

What do different classifications presented by various researchers mean? On the one hand, the situation in the European railways is rapidly changing even today – some countries have not yet achieved the objectives set by the reform, others have responded by improving their reforms. On the other hand, there is a difference between a formal, declared situation and the real situation. For example, some EU countries have reformed their railways only to the extent that does not breach the EU directives, but does not change anything. French and Spanish rail reforms are good examples. In these countries, an alleged mechanism was designed to ensure independent infrastructure management, but in fact the infrastructure manager is totally dependent on the state-owned railway company-carrier. This suggests only one conclusion: all EU countries in reforming their railway must take into account what environment and what set of factors are surrounding Lithuania. When inertia and reluctance to reform railways are observed in other EU countries, it is worth considering what consequences of Lithuanian railway reform implemented in such an environment could be possible? Isn't there a threat to give away everything, but to get nothing in return?

3. Towards Integration – Lithuanian Case

The literature on railway reform recognizes that the choice of either the separation or integration model inevitably means a compromise: on the one hand, the assumptions of rail competition are being strengthened (separation) or weakened (integration); on the other hand, the coordination efficiency is being strengthened (integration) or weakened (separation).

We have already discussed that the decision on the rail operations organization model is being discussed as a major tool to help achieve the objectives of the railway reform – to create a common market, to increase the service quality, the efficiency of railway operation and that of the whole transport system and so on. However, it is important to understand that the relationship between one or another organizational model and the achievement of the objectives of the reform, is not straightforward even at the conceptual level. For example, the logic of the argument constructed by a number of discussions and research papers on railway reform issues can be presented as a simplified sequence of actions and consequences:

Separation → competition → the desired results, but by means of a compromise (coordination) Integration → coordination → desired results, but by means of a compromise (competition)

*Figure 1.*Conditions of separation and integration

In other words, a separation model is a tool assisting to promote competition on the common rail, which in its turn will help achieve other objectives of the reform. Thus, a common answer to the question of why infrastructure management should be separated from transport operations is as follows: having implemented the separation model, a transparent and impartial mechanism is to be developed that will promote competition among the rail sector carriers and will help achieve a higher quality of service, perhaps even at a lower cost. According to this concept, the organization model and rail liberalization are closely related. True, it is worth noting that possible negative consequences of liberalization are also taken into consideration.

However, today there are already plenty of examples, even within the EU itself, where market liberalization is ensured and competition is promoted by implementing vertical separation as well as maintaining vertical integration. In other words, both separation and integration create pre-conditions to market liberalization and the development of rail competition.

Integration → competition and coordination → desired results

Figure 2. Integration by competition

When the separation model is implemented, coordination not only requires more effort and resources – it even decreases (newly introduced mechanisms are not always efficient, their development continues over time, and some of the functions are simply no longer carried out). Following „Deutsche bahn“ approach, the continuity of integration allows to reduce coordination costs incurred in implementing the holding model integrated institutionally, but broken into many layers, as well as having opened rail to the holding organizations, the major carriers in the German market carriers “strangers”, effectively managing their interaction.

Efficient distribution of functions within the holding means that the costs are “moved” from the holding to the overall rail system are much lower than those in case of the implementation of the separation model (then the costs would not be effectively absorbed within the system, but “moved” to the outside, for example, management of contracts and conflicts). So, following the experience of Germany, it is likely that the holding model with the infrastructure manager and at least one carrier working under one roof, will reduce the coordination costs attributable to all the rail system activities – their reduction will be directly related to the transportation market share associated with a specific carrier – the bigger the share – the lower the costs. It is obvious that without “bigger players” in the carrier market the implementation of separation will require a disproportionate growth of coordination costs. The question is whether the emergence of competing carriers is possible in the implementation of the integration model?

The reform leaders in Europe, assessed by all sections are mostly the same countries (except for Estonia in the last column). It is worth noting that according to IBM (2007) studies the countries' rankings are redistributed when analyzing the countries by the type of their transportation activities, for example by Liberalization index leading positions are taken by Germany only in passenger transport – and by Sweden – in Freight transport (Britain is pushed out of leadership positions).Table 2 is based on the IBM (2007).

Table 1. Rail liberalization index

	The liberalization of rail 2007 *			
Rank	**Liberalization** (Total index)**	**Regulation and organization**	**Access availability and barriers**	**Competitive dynamics**
1	Britain (827)	Britain (969)	Sweden (817)	Britain (793)
2	Germany (826)	Germany (905)	Germany (807)	Estonia (704)
3	Sweden (825)	Netherlands (865)	Netherlands (795)	Sweden (633)
4	Netherlands (809)	Sweden (857)	Britain (791)	Germany (555)
10	↓	Lithuania (820)	↓	↓
15	Lithuania (684)		↓	↓
16			Lithuania (650)	↓
20				Lithuania (184)

* The number of the collected points by ranking is given in parentheses next to the country name. Maximum number of points: 1000 points
** The liberalization index is calculated as that of the other two categories – Market regulation and Access availability – derivative. The last, the index of Competitive dynamics is not used in calculating the total Liberalization index

In order to assess which model of organization separation or integration – proved to be more appropriate in Europe, it should be noted that Sweden and Germany, prevailing leaders in the railway reform have implemented different organizational models (separation –Sweden, integration – Germany). Thus, despite the different organization models, both countries are among the four EU countries rated as leaders in the liberalization of rail – both in terms of various criteria and competition in the market. Reviewing the results, the authors of the IBM report note that countries with the most dynamic market and biggest competition (i.e., Great Britain, Estonia, Sweden, Germany and the Netherlands) apply different organizational models.

Germany separated the infrastructure and railway operations, forming the organization of a holding structure back in 1994. The carriers working in Germany complain of discrimination, although acknowledge that the conditions for their operation have improved in the last few years. However, the following fact must be taken into consideration – in 2007, 350 carriers were working in Germany (more than in all other EU countries combined). Germany's rail transport role in the total transportation activities has been stable for a long time, but has begun to grow quite rapidly in recent years, whereas in the passenger transport sector it has grown since the beginning of the reform. IBM report notes the success of the reform, as the indicators of the performance of the last year show that Germany's negative trends in the rail sector have finally changed towards growth.

Sweden completely separated their infrastructure and transportation activities in 2001. It seems that the creation of a separate infrastructure manager did not guarantee a non-discriminatory system. For example, IBM (2007) report presents the information that a number of carriers reported discrimination – just in 2006 there were three cases in which the decision was taken in favour of the carriers, rather than the infrastructure manager. By the way, in 2007 the number of carriers working in Sweden was significantly lower than that in Germany – eight carriers were working in passenger and 14 – in cargo transportation sectors. It is worth noting that in Sweden the "new" carriers, originating not from reformed "traditional" carriers play a more significant role rather than in Germany or in most other European countries.

Thus, based on these data, it can be said that both, the one and the other model have enabled the competition to develop. Yet, neither the one nor the other model eliminated discrimination problems. However, it is interesting to note that the "independent" operators play much a more important role in the Swedish rail transport activity. For example, Nash & Rivera–Trujillo (2004) describe the Swedish model as the most successful in Europe. However, the Swedish achievements could be explained not only as a result generated by the separation model but as a consequence of a specific Swedish transport system (e.g., a simple railway network, standardized wheel–rail interaction and not overloaded traffic, a small intermodal transport competition (Ksoll, 2004).

Observation of the rail reform process in different countries shows that both models can be associated with positive outcomes. It is important to emphasize that market liberalization and competition can also be ensured within the framework of the integrated model. The World Bank's position is also similar: it is recognized that the separation could contribute to the fact that the competition in the given market would be "fairer", but the separation is not a prerequisite in order to create competition. The establishment of a separate infrastructure manager is associated with a situation of mistrust that regulatory mechanisms will be created to ensure non-discriminatory access to infrastructure. However, the separation itself does not mean that regulation issues have become obsolete. On the contrary – after the separation of activities a complex regulatory mechanism is required. Also, the separation and the consecutive demand to ensure the activities of the whole railway system are associated with increasing costs that even by proportion are not likely to outweigh the benefits generated by the separation model. It should be added that in the context of global practices a separation model has proven to be not the most successful way to develop competition, even though the EU countries have experienced varying success in promoting competition, so far the results are described as disappointing. Why? Transportation market liberalization in Europe is associated not so much with the newly evolved market players as with the development of the activities of existing companies operating in other territories, most often with the railway companies of different countries entering the markets of other countries. It seems that even given open access to the infrastructure to other carriers, competition may not appear due to the specifics of the railway system. For example, there are indications that rail operations cannot fundamentally be cost-effective either in case of separating the wheel-rail interaction (separation model), or in case of specializing the activity and thus breaking the benefits generated by the scope economy. By the way, the decision to create competition within the rail may be unnecessary and inefficient, if the competition occurs between different railways. In addition, the railways face other modes of competition.

Assessing the "Lithuanian Railways" in terms of the international context, particularly from the perspective of post-Soviet countries, it is obvious that already today the Baltic railways compete with each other. Taking into account the discussed above development of competitive rail business in Europe, it is evident that the EU rail market can develop in a similar direction – only in this case the activities of the carriers will develop moving on both, their own and foreign rails.

One of the negative consequences of the separation model discussed in literature is the declining incentives to invest. However, it is recognized that this problem is decreasing in the context of increasing market competition: if an investor sees that there are a few carriers competing for the deployment of a service, he will be interested to invest, because it guarantees a stronger negotiating position. On the one hand, opening up the market to competition, but without developing the infrastructure as Estonia's experience has shown, can be problematic. Russian carriers started to work actively on the Estonian market which greatly disturbed the politicians and the public. One explanation why the EU carriers do not rush to the Estonian market is technical incompatibility of rail systems.

As for the benefits of the separation model, it is being emphasized that separation will enable to completely and certainly refuse cross financing and transparency will be created in handling costs and revenues. This, for example, will allow governments to decide on the expediency of investment by carrying out an informed cost-benefit analysis of investment projects. Based on the Swedish experience, it could be argued that effect generated by the model results in creating a favourable investment climate for government investment. For example, the Swedish government is investing more in infrastructure development being sure that the funds allocated for the infrastructure opportunities development will not "be eaten" by inefficient transportation activities. Of course, it is reasonable to raise the question: Are there any other possible measures to eliminate opportunities for cross-financing? The Germans, for example, solved this problem by regulatory mechanisms.

On the other hand, it is important to emphasize that in the rail sector neither the carrier nor the infrastructure manager can make investment decisions independently of one another's interests and plans, for example, how high-speed trains would be used if there are no tracks suited for them and vice versa? From the German point of view, the success of investment decisions can only be assured by an integrated model, because it means a long-term, reliable relationship between rail transport participants – a stable relationship that is necessary for the vast majority of investment decisions in the railway sector.

Lithuania, despite aspirations to integrate into the EU's rail system still holds the marginal position between the two technical (1435 mm and 1520 mm) systems and remains strongly associated with post-Soviet space. Among its crucial questions remains the implementation of investments in order to upgrade dilapidated railway infrastructure and reliable investment projects that would assist JSC "Lithuanian Railways" "to move" from the marginal position between the two railway systems to an intermediate position. However, neither the reformers working by a separation model nor the reformers promoting an integration model so far managed to create an investment environment that would successfully promote private sector investments. Nor the “independent” infrastructure manager is able to ensure the function in question.

In fact, a number of indications can be found in the literature that separation by itself already means rail performance growth, but the use of infrastructure becomes less efficient. For example, the depth study was carried out in Dutch port of Rotterdam seeking to evaluate the efficiency of rail operations at the port after the railway reform. The researchers came to the conclusion that the reform, particularly the appeared competition between carriers is associated with a number of positive results – improved quality of services, decreased costs. But they acknowledge that the reform did not help to optimize resource management – even the opposite trend is observed. Most importantly, the perspective of the system has disappeared – companies are handling issues in accordance to their own interests, which ultimately comes down to the inefficient use of infrastructure.

In addition, the debate on rail reform often presents an argument is that the relationship between the train wheels and the rail is much better managed through a single entity whereas the separation of wheels and rail creates a situation where the carrier loses the incentive to optimize this relationship. For example, the literature deals with the situation where there is no incentive for the carrier to grind wheels. Considering the fact that for wheel grinding the carrier spends 2 million a year, the company will save only \$ 1 million for performing this work. However, not ground wheels may cause 10 million dollars in damage for railway track. In theory, the infrastructure charging mechanisms should be able to solve this problem, but in practice this has not yet been achieved.

4. EU Policy Implication. Case of Lithuanian Railways

For example, Lithuanian railways which are basically run by the integrated model are often described in reports as ineffective, as limiting competition, as one of the most expensive in terms of the use of infrastructure. The proponents of the separation model make use of these as their basic arguments. However, when one looks at the deeper reasons or evaluates the external circumstances, such negative assessments can be rejected, what is more, completely different conclusions may be provided.

One of the most important issues in rail efficiency is the fact that 50 per cent of all freight in Lithuania is transported by rail, while the EU average is less than one fifth. In this regard modal distribution in Lithuania is much more efficient, and more secure to the environment than that within the EU.

Furthermore, it should be noted that Article 6 of the Directive 91/440/EEC regulates the transport infrastructure and accounting separation, the separation of essential functions of the infrastructure, and Paragraph 2 of Article 6, provides for the possibility to manage the infrastructure either by establishing a separate division in a company or establishing a separate entity. Neither this Directive nor any other EU legal act requires a complete separation of infrastructure and operations.

Listed below are some examples of when the Lithuanian Railways are accused of ineffectiveness and reasoned explanation of the situation is provided.

The European Commission’s second report to the Council and the European Parliament on the rail market development monitoring SEC (2009) 1687 (hereinafter – the Report) emphasizes that Lithuania’s rail market is to be considered as the most close.

Source of Fig. 3 is Questionnaire of the European Commission’s second report to the Council and the European Parliament on rail market development monitoring {SEC (2009) 1687 completed by the EU members of May–June 2009.

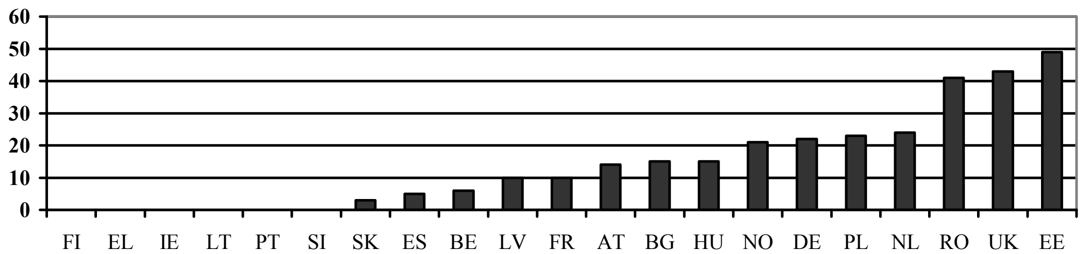

Figure 3. Market Share (%), belonging to the new rail freight operators in late 2008

Even though there is a relatively considerable number (24) of the licenses issued in Lithuania, the actual freight service providers – carriers were not indicated on the filled in questionnaire of the Lithuanian report, consequently, Lithuania is regarded as a country with a de facto monopoly situation in the railway market. A relatively significant number of licensed companies are determined by the requirements of the legal framework of Lithuanian Republic. According to the Lithuanian legal framework even companies that perform manoeuvring tasks (wagon pulling / pushing on its territory, access roads and marshalling yards) by their own manoeuvring locomotives, are required to obtain carrier license issued by the State Railway Inspectorate. This resulted in a relatively large number of licensed carriers.

This resulted in a relatively large number of licensed carriers. The majority (17 of 24) of licensed companies are cargo owners or owners' representatives (based on various agreements – trade, expeditions or capital ties). Today these companies for shipping make hiring contracts with JSC "Lithuanian Railways". The companies that aim to become carriers can be naturally associated with the desire to carry their own load. The goals of these companies to become carriers can be inspired by the expectation to transport their cargo themselves. These goals may be related to their expectations to perform transportation by themselves which is more cost-effective compared with the current cost of hiring JSC "Lithuanian Railways".

A more detailed analysis of licensed companies shows that by using licenses companies only ship carriages from the train station (or access road) to the loading / unloading location, i.e., are involved in the manoeuvring traffic. Freight contracts with customers are made only by JSC "Lithuanian Railways" (other licensed transportation companies do not perform freight operations). In most cases in Lithuania the companies that took out licenses do not have defined plans to carry freight business, but only: (a) carry out manoeuvres (such as "Akmenes cementas", "Lifosa", "Žvyrokarjerai"); (b) carry out the rail infrastructure repairs (e.g. "Geležinkelio tiesimo centras", "Alkesta", "Vitras").

This situation resulted from licensing procedures applied in Lithuania. According to EU directives a licensed railway enterprise is the one that carries out transportation of freight or passengers. While according to the Railway Transport Code of the Republic of Lithuania, freight contract shall come into force in the primary station and expires in the terminal; access roads for freight are not mentioned. In Lithuania's case, many licensed companies are from the field of industry, for which manoeuvring locomotive operations comprise only part of their technological process. They do not provide freight services. Some companies use their manoeuvring locomotives to perform slight work for other companies, yet the State Railway Inspectorate treats these activities as those of a railway operator that requires a license. However, pushing wagons in access roads or yards should not be considered as cargo transportation. Some of the companies by means of their transport access the station paths (repair companies –sub-stations) while SRI's position is that one cannot enter into public infrastructure without a license. Any entrance to the station road or sub-station is considered by the SRI as the use of public railway infrastructure and is based on Code of Railway Transport, Article 28, which specifies the right to use public infrastructure granted to licensed companies. According to the data of report SEC (2009) 1687 in Lithuania one of the largest infrastructure access charges are applied.

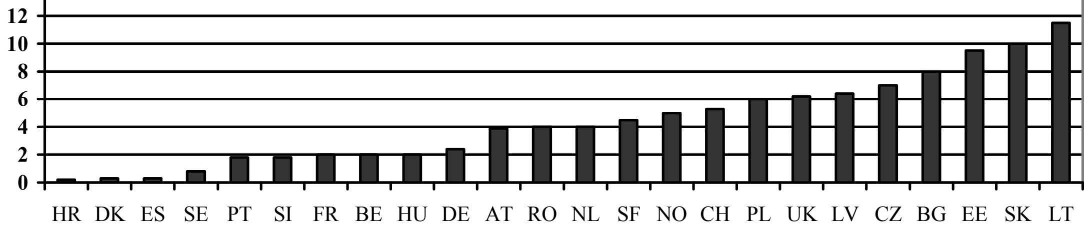

Figure 4. Charges for the use of railway infrastructure applied for the standard 2000 gross tons of freight trains (Euro / train-km)

Source: ITF, Report on the charges for the use of railway infrastructure, 2008

However, it should be noted that in Lithuania, apart from the EU funds, the infrastructure by100 percent is kept, maintained and restored by the company JSC "Lithuanian Railways" that includes all of these costs in the infrastructure rate. In accordance with UIC data, in 2008 Sweden allocated

2.9 billion Euros for rail infrastructure maintenance, in 2009 Great Britain – for their infrastructure – over 4 billion Euros.

It is obvious that the European countries where the railway infrastructure is largely maintained by taxpayers (data are presented in Annex 10), the infrastructure charges are lower than those in Lithuania. Western Europe rail infrastructure maintenance is financed with taxpayers' money due to the fact that the EU's transport policy is targeted to the transfer of cargo from road to rail. In the EU only 17 percent of goods are transported by rail. It causes huge traffic jams on the roads. In Lithuania rail transport accounts for about half of all cargo transported. In addition, 2/3 of the total freight traffic is transit cargo from foreign (Eastern) countries. If the Lithuanian tax payers contributed to rail infrastructure maintenance (as is done in the EU), there would be a real opportunity to reduce infrastructure cost, thus to create and an opportunity for the coming private operators. However, there is a real question whether Lithuanian taxpayers at their own expense should support business of foreign operators who carry goods in transit through Lithuania. The objective data on rail infrastructure fee justification or unreasonableness can be obtained only having conducted a detailed JSC "Lithuanian Railways" analysis in terms of its structure of cost and its reduction.

In summary, the use of railway infrastructure is regulated by several European Union directives. Article 5 of Directive 2001/14/EC establishes a right of access to infrastructure objects and Annex II of Directive 2001/14/EC specifies lists of services provided by the infrastructure managers. JSC "Lithuanian Railways" ensures access to infrastructure under these directives.

In the same report the Lithuanian railways are named as closed, because there are no active foreign operators. Yet, the reasons why there are no foreign operators should be taken into account. Western rail width is 1435 mm, while in Lithuania there is the so-called "Russian" gauge (1520 mm of width). "RailBaltica", European gauge construction project that was supposed to start in 2007, to reach Kaunas in 2010 and later be extended to Riga and Tallinn, has been significantly delayed. At the end of 2010 only about 6 miles from the border with Poland were built. The difference between the Russian and European gauge systems is not only in the width of gauge, but also in transport technology schemes, vehicles, traffic management and automation. Western rail operators today do not have appropriate technical feasibility to enter into the Lithuanian rail transport market.

Western rail operators are interested in Lithuanian railways. Foreign operators' expectations are associated with the European gauge and RailBaltica project. The interest focuses on the connection between Germany and Lithuania. After constructing RailBaltica to Kaunas and building an intermodal terminal a realistic chance would appear for this section to be used by foreign operators.

JSC "Lithuanian Railways" have signed a cooperation agreement with the German company CargoBeamer AG, which has developed a semi-trailer reloading on rail technology, has installed its first prototype terminal and made its first test shipments within Germany for company "Volkswagen". The development of this technology has been contributed a lot by the German national railway company Deutsche Bahn, which has still been actively supporting the project. There is already a large customer base focused and waiting when they will be able to move their trailers to carry via "East-West" rail corridor through the Baltic countries and especially Lithuania. The planned corridor is Rotterdam–Kaunas with 3–5 trains per day. There is already Deutsche Bahn Group-owned company "Schenker" operating in Lithuania. Companies of Deutsche Bahn Group as well as the companies under its influence – potential rail operators in Lithuania and their activity is likely to come true after the implementation of the project RailBaltica.

„Lithuanian Railways" has entered into an agreement with a subsidiary of Rail World – Rail Polska concerning cooperation in gauge conversion system Talgo trial in Lithuania.

JSC "Lithuanian Railways" and the German logistics company DB Schenker enterprise DB Schenker Rail has signed a letter of intent on DB Schenker freight train traffic from the Polish border to Mockava.

Latvian railway companies (as well as the national carrier LDZ Cargo) take an active interest in the availability terms of the safety certificate in Lithuania; several meetings with the State Railway Inspectorate were held.

Railway operators of eastern countries are basically the national carriers of those countries: Russian Railways, Belarusian Railways, Ukrainian Railways, Kazakhstan railways and so on.

The interests of Russia and its government and business groups to participate in Lithuanian economic processes are justifiable (e.g., energy resources supply, distribution and sales). Russia's interest in the railway sector in the Baltic States is proved by Estonia's practical example. Among the Lithuanian firms that have obtained licenses are those that are large-scale Russian industry (e.g. steel) export freight forwarders (transport and trade brokers), or their direct or indirect representatives. In addition, because it is irrelevant whether the license is obtained in Lithuania or in another EU country (e.g. Latvia, Estonia), the Eastern capital firms with licenses from any EU country, may transport goods by Lithuanian railways (although for the capital firms from Eastern countries, assessing the costs and risks, today it is easier to make contracts with JSC "Lithuanian Railways").

The Lithuanian operators' access to the market is prevented by the amount of initial deposit of infrastructure fees and the size of the investment required. The basic fee paid for the Freight Directorate of JSC "Lithuanian Railways" depends on the reserved train kilometres and actual gross kilometres, whereas for the levied fees the carrier is given the minimum access package (reservation of train lines and availability of these lines; traffic management and organization; document management; information provision; access to path stations; objects of infrastructure). The fact that the initial deposit of the main fee is about 15–20 per cent of the total fee can be seen as a barrier to enter the market for smaller companies that lack of working capital.

JSC "Lithuanian Railways" can be considered as monopoly in the Lithuanian rail transport market. The conducted analysis shows that currently all shipments are made by JSC "Lithuanian Railways" and licensed rail transport companies mainly are cargo owners or owners' representatives and in order to carry out transportation they make contracts of employment with JSC "Lithuanian Railways". Freight contracts with customers are made only by JSC "Lithuanian Railways".

JSC "Lithuanian Railways" faces competition in international transportation area. International shipments cover 2/3 of the JSC "Lithuanian Railways" market where the competition is observed not within the country but with Latvian, Estonian, Russian railways.

Domestically, JSC "Lithuanian Railways" compete with other modes of transport.

The comparison of the specifics of Lithuanian railways with the structures of Western and Central European countries shows significant differences. Lithuanian railways features which are incompatible with the current operating structure of the integral rail division are as follows:

- Most of the trains in the infrastructure are freight trains (2/3 train kilometres, more than 90 percent of gross km) and over 90 per cent of the income earned from freight;
- Two thirds of freight revenue earned from transit cargo of third countries;
- Infrastructure integrated into the CIS rail network;
- Joint fleet of wagons with the CIS countries;
- Highly flexible freight train traffic schedule, the ride of freight trains planned for about 6 hours before. This is due to the arrangement specifics of traffic crossing the Russian–Belarusian border, unpredictable work of Klaipeda port loading companies;
- Trains are selected, wagons are formed in distribution stations not according to individual clients or the type of the cargo, but according to the destination of transportation, which allows to reach the maximum exploitation of the available infrastructure and the fleet of vehicles;
- Passenger transportation activity is not subsidized by state funds as it is opposite in many EU countries (Nash 2010);
- Rail infrastructure is not financed by the state (with the exception of the EU funds for development projects).

Structure of charges for the use of railway infrastructure. Although the charges (fees) for the use of railway infrastructure in the country are among the highest in Europe, these fees are paid by freight carriers, rather than from the national budget, as is the case in most Western European countries. In this case, Lithuania implements the principle of "user pays". From this point of view, JSC "Lithuanian Railways" can be seen as an efficient railway company that, without receiving the state funding, is able to operate profitably, maintain rail infrastructure and the loss in passenger traffic. The only fee payer in Lithuania is Freight Directorate of JSC "Lithuanian Railways" which pays this fee for Infrastructure Directorate of JSC "Lithuanian Railways" (customers just pay the freight rates for Freight Transportation Directorate).

Infrastructure charge (fee) on all roads (busy and no-load) is the same. Only the corridor from Kena to Klaipeda and the branch to Kaliningrad can be called as busy sections. This represents only a quarter of the total railway network. The infrastructure charge collected from busy sections ensures stable maintenance of the network. Non-loaded regional sections help to keep small industrial enterprises. The decision to dismantle non-loaded sections and stay with the development of only busy sections would conflict with the principles of regional development.

Network problem. Actually, the Lithuanian railway infrastructure does not involve alternative routes (parallel lines, bypasses) and the need for the application of different rates in lines for redistribution (optimization) of train traffic (for example, in case of a very loaded line to divert trains to another line). There are no objective (unambiguous) economic arguments for “increasing” or “decreasing” rates of certain lines: (1) with the reduced infrastructure charges on busy traffic lines (Corridor IX), the rest of the lines for carriers will be significantly more expensive; to organize local transportation would be inefficient and regional lines would have to be maintained from the state budget or closed; (2) with the increase in the rates of infrastructure charges on lines of busy traffic (Corridor IX) shipments to the port of Klaipeda would become more expensive, the carrier acting in intense lines would subsidize the maintenance of regional lines, for which the carriers carrying transit cargo should be able to reasonably make a claim.

A high price charged by the Lithuanian railway infrastructure can have a negative impact on the export competitiveness of the products made in Lithuania because the component part of the transport price in the field of heavy industry (construction, chemicals, and petroleum) is significant and may result in a general increase in product prices. However, cargo transport rate should not be confused with the infrastructure fee. Not the infrastructure charge but the freight carrier’s tariff charged on cargo is important for the economy (customers). Though European countries have lower infrastructure charges, the freight rates in these countries are not smaller.

Lithuanian railway efficiency is determined not only by the issues of the company’s organizational level and relationships with customers and other operators, but also the problem of Lithuanian rail system network. Lithuanian railway network was constructed and configured as part of the former USSR network, with the main unit and the control centre in Riga. The network was configured for (1) freight transport (mainly strategic cargo such as liquid energy products and military equipment), and for (2) the service of industry developed in Lithuania. After the collapse of the USSR most of the industrial enterprises that had rail sidings, collapsed or their volumes were significantly lower than the capacity proposed by rail. Current freight flows are formed exclusively in the two corridors directed to Klaipeda and Kaliningrad.

Russia’s policy of the last decade led to the formation of the main cargo flow by mainline leading to the Kaliningrad port. A large part of the infrastructure network remains unexploited, and some – heavily loaded. JSC “Lithuanian Railways” has to maintain the whole rail infrastructure, even in case if it is very little used. This is one of the reasons why the cost of infrastructure use is so high.

5. Conclusions

1. The choice of the separation or integration model inevitably means a compromise: on the one hand, the pre-conditions of rail competition are being strengthened (separation model) or weakened (integration model), on the other hand, the coordination efficiency is being enhanced (integration model) or weakened (separation model).

2. The establishment of a separate infrastructure manager is based on the expectations that the rail market liberalization objectives will be achieved more efficiently having set up an institutional mechanism that maximizes the possibility that the infrastructure manager is not interested in a particular carrier’s success. The experience of railway reforms in different countries that implemented both integration and separation models, shows that opening access to the rail does not guarantee the emergence of competition between carriers or resulting service selection, quality increase and cost reduction.

3. The separation model is implemented at the expense of scale economy specific to integrated rail. The determination to implement the separation model does not generate any stimulating investment environment as an infrastructure manager, without performing any transportation activity himself, is more interested in collecting the largest possible infrastructure fee with the lowest possible cost. However, if the infrastructure manager sees a few carriers competing for the deployed service he will be interested to invest, because it guarantees a stronger negotiating position.

4. The improvement of transportation performance indicators does not necessarily mean an efficient and sustainable use of the infrastructure.

5. Transportation market liberalization in Europe is associated not so much with the newly evolved market players as with the expansion of the activities of the existing companies to other territories, most commonly with the railway companies of certain countries entering the markets of other countries. Even given open access to the infrastructure for other carriers, competition may not appear due to the specifics of the railway system itself.

6. The separation of functions of the carrier and the infrastructure is identified by the term vertical separation or vertical unbundling. The model of working without separating these functions is identified by the term vertical integration. The integration model has several variants, such as holding or fully integrated model (the current case of Lithuania). In case of holding the infrastructure is managed by a separate legal entity which, as well as companies providing transportation service, belong to the same group, but must offer non-discriminatory conditions for all carriers for access to the infrastructure. Market liberalization and competition can be ensured not only within the framework of a separated model but also of the integrated model. Separation could contribute to the fact that the competition in the given market would be "fairer", but the separation is neither a necessary nor a sufficient condition to create competition.

7. The use of railway infrastructure is regulated by several European Union directives. Article 5 of Directive 2001/14/EC establishes the right of access to the objects of infrastructure and Directive 2001/14/EC Annex II presents lists of services provided by the infrastructure managers. JSC "Lithuanian Railways" provides access to infrastructure under these directives. True, there is the question of the validity of the size of the infrastructure charges.

8. In Lithuania in 2010 there were 24 licensed rail transport companies, but all operations have been carried out by JSC "Lithuanian Railways". Licensed rail transport companies are mostly cargo owners or owners' representatives (based on various agreements – trade, expeditions or capital ties) and for transportation make contracts of employment with JSC "Lithuanian Railways". It is, therefore, appropriate to consider the change in licensing procedures so that only cargo carriers would have to take out licenses, rather than industrial enterprises for their manoeuvring in access roads and yards or railway repair enterprises. Otherwise, when transportation is carried out by only one of the 24 licensed companies, it is natural that the sector will be negatively evaluated by the efficiency assessment methodology.

9. The rail transport market share of JSC "Lithuanian Railways" can be valued as a monopoly (all shipments are carried out by JSC "Lithuanian Railways"). However, it should be kept in mind that JSC "Lithuanian Railways" competes not only at international level (internal transportation is only a small part of the total freight traffic) but also with the road transport. In this competitive context the company shows comparatively significant results. Yet, the fact that JSC "Lithuanian Railways" charge levied for the use of railway infrastructure is one of the largest in Europe reveals the potential for economic inefficiency. However, for economy (customers) not the infrastructure charge is the most important but the carrier's freight rate, which is not higher than the rates used in European countries.

10. The majority of rail network managed by JSC "Lithuanian Railways" is low loaded and the passenger transportation operation suffers large losses. On the other hand, those circumstances that at first sight could be considered as economic inefficiency have both, social and economic justification.

11. The availability of low-crowded stretch and unprofitable passenger services are needed in the context of regional policy. Consideration can be given to solve the question of passenger transportation by rail demand and subsidizing by including local governance in subsidizing regional routes (changing the legal base).

12. The key market entry barrier to Western operators is the difference between Russian and European gauge systems, which results not only as a gauge, but as differences in technological transportation schemes, vehicles, traffic management and automation. Western rail operators today lack the technical capacity to join the Lithuanian rail transport market. After having built RailBaltica to Kaunas and constructed an intermodal terminal (in which the containers shipped would be reloaded from one platform to other platforms or trucks or by rail brought trucks continue to further run by road), there would be a real possibility for this segment to be exploited by foreign operators.

13. The fee for the use of railway infrastructure in Lithuania is one of the largest in Europe. However, these fees are paid solely by cargo carriers, rather than from the national budget (as it is in the case of most Western European countries). In this respect, JSC "Lithuanian Railways" can be seen as an efficient railway company, since it is able to operate profitably, to maintain the railway infrastructure and the loss-making passenger transportation. Not the infrastructure charge but the freight rate applied by the carrier is the most important factor affecting Lithuania's economy. In European countries the infrastructure charges are lower while the transportation rates are higher.

14. Infrastructure charges could also decrease if part of the infrastructure maintenance costs were covered not by JSC "Lithuanian Railways", but from the state budget. However, in view of the fact that currently two thirds of all freight traffic is transit cargo from foreign (Eastern) countries, moving this burden on the Lithuanian tax payers does not seem justified. This would mean that the Lithuanian tax

payers at their own expense would have to maintain business operators from third countries (non-EU member states) that would carry goods in transit through Lithuania.

15. The infrastructure charge collected from busy stretches ensures stable maintenance of the network. Although the decision not to dismantle non-overloaded stretches is based on regional policy purposes, however, it is appropriate to consider a possibility to introduce an alternative transport in not loaded stretches.

16. The justification of both, separation and integration (holding or full integration) differs from country to country. Therefore, it is necessary to have a comprehensive economic justification before conducting structural transformations in JSC "Lithuanian Railways". There are no EU legal requirements introduced for structural adjustment of the current system. It should be noted that currently one of the major issues of the sector's efficiency – high infrastructure charges. These charges depend on the network maintenance costs so the potential structural changes are not likely to affect its size. The potential reduction in infrastructure charges should be based on the network maintenance cost analysis, the aim of which would be – to answer – whether the infrastructure is managed efficiently.

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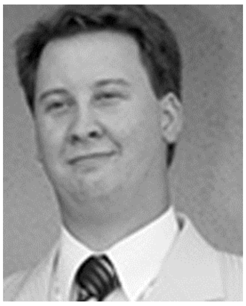

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CUMULATIVE INDEX

TRANSPORT and TELECOMMUNICATION, volume 15, no. 2, 2014 (Abstracts)

Chowdhury, Md. S. A., Haque, Md. B., Sarwar, G. Traffic Information Interface Development in Route Choice Decision, *Transport and Telecommunication*, vol. 15, no. 2, 2014, pp. 91–96.

In this paper, a method has been developed based on historic traffic data (vehicle speed), which helps the commuters to choose routes by their intelligence knowing the traffic conditions in Google maps. Data has been collected on basis of video analysis from several segments between Tuker Bazar and Bandar Bazar route. For each of the video footage, a reference length has been recorded with measurement tape for use in video analysis. Software has been also developed based on Java language to get the traffic information from historic data, which shows the output as images consisting of traffic speed details on the available routes by giving day and time limit as inputs. The developed models provide useful insights and helpful for the policy makers that can lead to the reduction of traffic congestion and increase the scope of intelligence of the road users, at least for the underdeveloped or developing country where navigation is still unavailable.

Keywords: traffic speed, speed interface, route choice, Google maps, Java, Kinovea

Grakovski, A., Pilipovec, A., Kabashkin, I., Petersons, E. Weight-in-Motion Estimation Based on Reconstruction of Tyre Footprint's Geometry by Group of Fibre Optic Sensors, *Transport and Telecommunication*, vol. 15, no. 2, 2014, pp. 97–110.

The problem of measuring road vehicle's weight-in-motion (WIM) is important for overload enforcement, road maintenance planning and cargo fleet managing, control of the legal use of the transport infrastructure, road surface protection from the early destruction and for the safety on the roads. The fibre-optic sensors (FOS) functionality is based on the changes in the parameters of the optical signal due to the deformation of the optical fibre under the weight of the crossing vehicle. A fibre-optic sensor responds to the deformation, therefore for WIM measurements it is necessary to estimate the impact area of a wheel on the working surface of the sensor called tyre footprint. This information is used further for the estimation of the vehicle wheel's speed, contact width, length, and, finally, axle's weight while in motion. Recorded signals from a truck passing over a group of FOS with various speeds and known weight are used as an input data. The results of the several laboratory and field experiments with FOS, e.g. load characteristics according to the temperature, contact surface width and loading speed impact, are provided here. The method of initial signal deconvolution on symmetric and asymmetric components provides the chance to approximate geometric size of tyre surface footprint as well as calculate weight on each wheel separately. The examples of the estimation of a truck speed, tyre contact surface footprint parameters using FOS signals are discussed in this article.

Keywords: transport telematics, weigh-in-motion, fibre-optic sensor, tyre footprint

Kirillova, Y. V., Meleshenko, Y. S. Justification of Financial Safety Analysis Approach in Cargo-and-Passenger Ferry Operations Management**,** *Transport and Telecommunication,* vol. 15, no. 2, 2014, pp. 111–119.

Currently, ferry services are widespread in Europe, the Baltic States, the CIS and they continue to progress rapidly despite the unstable global economy. An activity of modern cargo-and-passenger fleet is based on nevertheless the perspective of stable profit generation. In conditions of ferry market instability, the important task is to ensure the break-even analysis in operation of vessels and justification of relevant quantitative indicators. At the same time, when managing the production activity of the ferry operators and, in particular, when analysing the ferry operation the indicator of its financial safety factor is of great importance.

This paper refines static indicators and determines dynamic indicators of critical quantity of cargoes and passengers in ferry loading; gives analytical method of its justification; develops analytical method and presents graphical method of financial safety factor estimation when loading of cargo only or boarding of passengers only, as well as performing composite actions – loading of cargoes and picking up passengers.

Keywords: ferry transportation, cargo-and-passenger ferry, dynamic indicators, critical loading, financial safety factor

Lukinskiy, V., Lukinskiy, Vl., Churilov, R. Problems of the Supply Chain Reliability Evaluation, *Transport and Telecommunication, Transport and Telecommunication,* vol. 15, no. 2, 2014, pp. 120–129.

Reliability is one of the most important characteristics of the functioning of supply chains. The carried out analysis have shown that, despite some progress, a number of questions remain open, in particular, the terminology, the selection of key indicators and methods of their calculation as well as there is no economic evaluation of redundant and restorable supply chains.

The paper presents a formed conceptual apparatus of logistics systems' reliability theory, the discrete-continuous model of the simple supply chain's functioning as well as it contains the proposal to assess the reliability not only with the help of faultlessness but as well by using the leading function of costs associated with the maintenance of supply chains' operability.

Keywords: reliability, supply chains, terminology, methods of analysis, models of failures

Garcia-Castro, A., Monzon, A. Homogenization Effects of Variable Speed Limits, *Transport and Telecommunication, Transport and Telecommunication,* vol. 15, no. 2, 2014, pp.130–143.

Changing factors (mainly traffic intensity and weather conditions) affecting road conditions require a suitable optimal speed at any time. To solve this problem, variable speed limit systems (VSL) – as opposed to fixed limits – have been developed in recent decades. This term has included a number of speed management systems, most notably dynamic speed limits (DSL).

In order to avoid the indiscriminate use of both terms in the literature, this paper proposes a simple classification and offers a review of some experiences, how their effects are evaluated and their results.

This study also presents a key indicator, which measures the speed homogeneity and a methodology to obtain the data based on floating cars and GPS technology applying it to a case study on a section of the M30 urban motorway in Madrid (Spain). It also presents the relation between this indicator and road performance and emissions values.

Keywords: Effectiveness indicator, variable speed limits, dynamic speed limits, GPS application, speed management, floating car data

Bede, Z., Torok, A. Theoretical Investigation of Traffic Equilibrium on Bridges, *Transport and Telecommunication, Transport and Telecommunication,* vol. 15, no. 2, 2014, pp. 144–150.

Road traffic flows on a straight road segment such as bridges are modelled in this article. The mathematical model of traffic flows has been constructed by using the method of lumped parameters. Changeable lane direction and road pricing has been theoretically investigated in order to understand the shifting in supply and/or demand curves of traffic participants in equilibrium. The article presents assumptions for constructing the mathematical model. Demand can be influenced by road pricing, in its turn, supply can be influenced by extension of infrastructure with reversible lanes.

Keywords: traffic flow, mathematical modelling, supply and demand curve, bridges

Jaržemskis, A., Jaržemskis, V. The Differences in Efficiency Measurment: the Case of European Railways, *Transport and Telecommunication*, **,** vol. 15, no. 2, 2014, pp.151–163

In the world railways are organized in two ways. In one case, infrastructure management and organization of traffic and commercial activities are integrated at the level of one of the enterprise whereas in the other case the functions of the carrier and the manager of the infrastructure are separated. This article addresses approaches of different scientists and politicians on both forms. The analysis of the case of Lithuania has been carried out. The case of Lithuania is a typical one – historically the railways have had a monopoly with the infrastructure and transportation not separated. This article presents a critical view of theoretical pros and cons of both the models.

Keywords: railway liberalisation, infrastructure management, competition, transportation, state enterprise, market regulation

TRANSPORT and TELECOMMUNICATION, 15. sējums, Nr. 2, 2014 (Anotācijas)

Čodhuri, Md. Saidul Azam, Heig, Md. Baširul, Sarvar, G. Satiksmes informācijas interfeisa attīstība maršruta izvēlē lēmumā, *Transport and Telecommunication*, 15. sēj., 2. nr., 2014. g., 91.–96. lpp.

Šajā rakstā ir izstrādāta metode, pamatojoties uz satiksmes vēsturiskiem datiem (transportlīdzekļa ātrums), kas palīdz darbiniekiem maršrutu izvēlē, zinot satiksmes apstākļus pēc Google kartēm. Dati ir apkopoti, pamatojoties uz vairāku segmentu starp Tuker Bazar un Bandar Bazar maršrutu video analīzi. Katram no video kadriem, references ilgums ir ierakstīts ar mērīšanas lenti, izmantojamu video analīzei. Programmatūra arī ir izstrādāta, pamatojoties uz Java valodu, lai iegūtu satiksmes informāciju no vēsturiskajiem datiem, kas parāda iznākumu kā attēlus, kas sastāv no satiksmes ātruma informācijas pieejamajos maršrutos. Izstrādātie modeļi sniedz noderīgas atziņas, kas savukārt ir noderīgas politikas veidotājiem, kas var novest pie satiksmes sastrēgumu samazināšanas un palielināt darbības jomu satiksmes dalībnieku izpētē, vismaz mazattīstītās vai jaunattīstības valstīs, kur navigācija joprojām ir pieejama.

Atslēgvārdi: kustības ātrums, ātruma interfeiss, maršruta izvēle, Google kartes, Java, Kinovea

Grakovskis, A., Pilipovecs, A., Kabaškins, I., Pētersons, E. Svara-kustībā novērtēšana, pamatojoties uz riepu nospiedumu ģeometrijas rekonstrukciju ar optiskās šķiedras sensoru grupu, *Transport and Telecommunication*, 15. sēj., 2. nr., 2014. g., 97.–110. lpp.

Autotransporta līdzekļa svara-kustībā (*angl.* weight-in-motion (WIM)) mērīšanas problēma ir svarīga pārslodzes realizēšanā, ceļu uzturēšanas plānošanā un kravas kolonnas vadīšanā, tiesiskās transporta infrastruktūras lietošanas kontrolē, ceļa virsmas aizsardzībā no priekšlaicīgas iznīcināšanas, kā arī ceļu drošībā. Optisko šķiedru sensoru (*angl.* fibre-optic sensors (FOS)) funkcionalitāte ir balstīta uz optiskā signāla parametru izmaiņām sakarā ar optiskās šķiedras deformāciju zem šķērsojoša transportlīdzekļa svara. Optisko šķiedru sensors reaģē uz deformāciju, tādēļ WIM mērījumiem ir nepieciešams novērtēt riteņa iedarbības zonu uz sensora darba virsmu, ko sauc par riepu nospiedumu. Šī informācija tiek izmantota tālāk, lai novērtētu transportlīdzekļa riteņa ātrumu, kontakta platumu, garumu, un, visbeidzot, ass svaru, esot kustībā.

Piemēri kravas automašīnas ātruma novērtēšanā, kā arī riepu saskares virsmas nospiedumu parametri, izmantojot FOS signālus, tiek apspriesti šajā rakstā.

Atslēgvārdi: transporta telemātika, svērt-kustībā, optisko šķiedru sensors, riepu nospiedums

Kirilova, V. V., Meļešenko, J. S. Finanšu drošības analīzes pieejas pamatojums kravas un pasažieru prāmju operāciju vadībā, *Transport and Telecommunication*, 15. sēj., 2. nr., 2014. g., 111.–119. lpp.

Pašreiz prāmju pakalpojumi ir plaši izplatīti Eiropā, Baltijas valstīs, NVS un tie turpina strauji attīstīties, neskatoties uz nestabilitāti pasaules ekonomikā. Mūsdienu kravas un pasažieru flotes darbības pamatā tomēr perspektīvā ir stabilas peļņas paaudze. Prāmju tirgus nestabilitātes apstākļos, svarīgs uzdevums ir nodrošināt bez-zaudējumu analīzi kuģu darbībā un attiecīgo kvantitatīvo rādītāju pamatojumu. Tajā pašā laikā, pārvaldot prāmju operatoru ražošanas aktivitāti, un, jo īpaši, analizējot prāmju operāciju, finanšu drošības faktoru rādītājam ir ļoti liela nozīme.

Šis raksts precizē statiskus rādītājus un nosaka kravu kritisko daudzumu dinamiskus rādītājus un pasažieru daudzumu prāmī; sniedz tās pamatojuma analītisko metodi; attīsta analītisko metodi un sniedz finansiālās drošības faktoru grafiskās metodes novērtēšanu.

Atslēgvārdi: prāmju pārvadājumi, kravas un pasažieru prāmis, dinamiski rādītāji, kritiskā slodze, finansiālās drošības faktors

Lukinskis, V., Lukinskis, Vl., Čurilovs, R. Piegādes ķēdes drošuma vērtēšanas problēmas, *Transport and Telecommunication*, 15. sēj., 2. nr., 2014. g., 120.–129. lpp.

Drošība ir viens no svarīgākajiem parametriem piegādes ķēžu darbībā. Veiktā analīze liecina, ka, neraugoties uz zināmu progresu, vairāki jautājumi paliek atvērti, jo īpaši, terminoloģija, galveno rādītāju atlase un to aprēķinu metodes, kā arī nepastāv ekonomiskais novērtējums liekām un atjaunojamām piegādes ķēdēm.

Raksts atspoguļo loģistikas sistēmas uzticamības teorijas' izveidoto konceptuālo aparātu, vienkāršu piegādes ķēžu funkcionēšanas diskrēto nepārtraukto modeli, kā arī tas satur priekšlikumu,

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The paragraphs continue from here and are only separated by headings of first, second and third levels, tables, images and formulae. The section headings (T&T_Heading1) are arranged by numbers, using Times New Roman bold and 11pt, with 12pt spacing before and after. The section text (T&T_body text) should be Times New Roman 10pt. Section headings should be numbered consecutively, starting with the Introduction.

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The sub-section headings (T&T_Heading2) should be arranged by numbers and sub-numbers, using Times New Roman 10pt and, bold, with 12pt spacing before the heading and 6pt spacing after.

Files should be in MS Word format only and should be formatted for direct printing. Figures and tables should be embedded as close as possible to their references in the text and should not be submitted separately.

Attention! First name, last name, the title of the article, abstract and keywords must be submitted in the English and Latvian languages (in Latvian it is only for Latvian authors) as well as in the language of the original (when an article is written in different language).

The text should be in clear, concise English (or other declared language). Please be consistent in punctuation, abbreviations, spelling (English UK), headings and the style of referencing.

Follow this order for your manuscript: Title, Authors, Author's information, Abstract, Keywords, Introduction, description of the research (including figures and tables), Conclusion, Acknowledgements and References. Add acknowledgements in a separate section at the end of the paper; do not include them on the title page or as a footnote to the title.

Bulleted lists may be included and should look like this:

- First point
- Second point
- And so on

After bulleted lists, be sure to return to the 'T&T_body text' style (Times New Roman 10pt), without spacing before and after. This is the style that should be used for large blocks of text.

Please do not alter the formatting and style layouts which have been set up in this template document. Papers should be prepared in single column format. Do not number pages on the front, because page numbers will be added separately for the *Transport and Telecommunication*.

All of the required style templates are provided in this document with the appropriate name supplied, e.g. choose T&T_Heading1 for your first order heading text, T&T_abstract for the abstract text etc.

1.2. Format of formulas and figures

Format of formulas. The third level Headings – 'T&T_Heading3' style

The set of formulas and equations on application of fonts, signs and a way of design should be uniform throughout the text. The set of formulas is carried out with use of editors of formulas MS Equation 3.0 or MathType. The formula with a number – the formula itself should be located on the left edge of the text, but a number – on the right one. Font sizes for equations are the following: 11pt – full, 7pt – subscripts/superscripts, 5pt – sub-subscripts/superscripts, 16pt – symbols, 11pt – subsymbols.

$$\sqrt{a^2 + b^2} \qquad (1)$$

Equations should use the style 'T&T_equation'

Format of figures

All figures must be centred. Figure number and caption always appear below the figure ('T&T_figure_caption' style, Times New Roman 8pt with 6pt spacing before and 12pt after).

Figure 1. This is figure caption

Diagrams, figures and photographs must be of high quality, in format *.TIFF, *.JPG, *.BMP with resolution not less than 300 dpi. Also formats *.CDR, *.PSD are possible. Combination of figures in format, for instance, *.TIFF with elements of the in-built Figure Editor in MS Word is prohibited.

1.3. Format of Tables

Table Number and Title should be placed above tables, Alignment left, with 12pt spacing before and 6pt after ('T&T_table_head' style, Times New Roman 8pt).

Table 1. This is an example of a Table

Heading	Heading	Heading
Text	Text	Text
Text	Text	Text

Insert one line after the table (if not a heading). The table style should be 'T&T_table_text' Times New Roman 8pt.

1.4. Format of references

References and citations should follow the Harvard (Autor, date) System Convention. As example, references should be identified in the main text as follows:

- The results (Vroom, 1960) were quite striking.
- In recent studies by Smith (1999a, 1999b, 1999c)…
- Earlier (Vroom and Jago, 1988) we described a systematic evaluation ...

Besides that, all references should be cited in the text. No numbers with or without brackets should be used to cite or to list the references.

References should be listed at the end of the paper and should first be arranged alphabetically and then in chronological order if there is more than one reference for a given set of authors. More than one reference from the same author(s) in the same year must be identified by the letters "a", "b", "c", etc., placed after the year of publication.

The correct format for references is the following:

1. *Book*: Author(s). (Year of publication) *Book title (in Italics)*. Place of publication: Publisher.

Example: Kayston, M. and Fried, W. R. (1969) *Avionic Navigation Systems.* New York: John Wiley and Sons Inc.

2. *Conference Proceedings:* Author(s). (Year of publication) Title of an article. In: *Conference name*, Date, Place of publication: Publisher, Page range.

Example: Gibson, E.J. (1977) The performance concept in building. In: *Proceedings of the 7th CIB Triennial Congress*, Edinburgh, September 1977. London: Construction Research International, pp. 129-136.

3. *Journal article:* Author(s). (Year of publication) Article title. *Journal Title,* Volume (issue), range of pages. DOI.

Example: Nikora, V. (2006) Hydrodynamics of aquatic ecosystems. *Acta Geophysica,* 55(1), 3–10. DOI:10.2478/s11600-006-0043-6.

4. *Report:* Author(s). (Year of publication) *Title*. Place of publication: Publisher. (Report number).

Example: Osgood, D. W. and Wilson, J. K. (1990) *Covariation of adolescent health problems*. Lincoln: University of Nebraska. (NTIS No. PB 91-154 377/AS).

5. *Government publication:* Institution name. (Year of publication) *Title.* Place of publication: Publisher.

Example: Ministerial Council on Drug Strategy. (1997) *The national drug strategy: Mapping the future*. Canberra: Australian Government Publishing Service.

2. Conclusions

Conclusion section (this is mandatory) – should clearly indicate on the advantages, limitations and possible applications.

Acknowledgements (‘T&T_Heading_nonum’ style)

The Acknowledgements and References headings should be in bold but without numbers, using the style ‘T&T_Heading_nonum’.

Acknowledgements (if present) mention some specialists, grants and foundations connected with the presented paper.

References (‘T&T_Heading_nonum’ style)

1. Gibson, E.J. (1977) The performance concept in building. In: *Proceedings of the 7th CIB Triennial Congress*, Edinburgh, September 1977. London: Construction Research International, pp. 129–136.
2. Kayston, M. and Fried, W. R. (1969) *Avionic Navigation Systems.* New York: John Wiley and Sons Inc.
3. Ministerial Council on Drug Strategy. (1997) *The national drug strategy: Mapping the future*. Canberra: Australian Government Publishing Service.
4. Nikora, V. (2006) Hydrodynamics of aquatic ecosystems. *Acta Geophysica,* 55(1), 3–10. DOI:10.2478/s11600-006-0043-6.
5. Osgood, D. W., and Wilson, J. K. (1990) *Covariation of adolescent health problems*. Lincoln: University of Nebraska. (NTIS No. PB 91-154 377/AS).

The references style should be ‘T&T_references’ Times New Roman 10pt.

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