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ACOUSTIC SIGNALS PROCESSING AND APPLIANCE FOR THE PROBLEM OF TRAFFIC FLOW MONITORING

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The increase of road traffic in the European Union focuses for creating intelligent transportation systems of traffic control in local, urban and regional level. The possibility of using acoustic sensors for traffic intensity measurements are discussed in this article. Acoustic signal detector, such as an ordinary household microphone, is used as the most inexpensive sensor version for stationary and mobile traffic surveillance systems. The examples of the acoustic signals records from different types of road vehicles in various weather conditions are described here. The simplified modification of acoustic microphone’s signals spectral processing algorithm and noise filtering are solved. Detection of moving road vehicles results, using records for their acoustic signals, is also discussed. The restrictions of using acoustic sensors to estimate traffic parameters are established.

Keywords: intelligent transport system, transport flow surveillance, vehicle detecting, acoustic signal, digital signal processing

1. Introduction

In the contemporary world the volume of traffic transportations has become one of the indicators of growth and regional development level. Due to this, the number of transport vehicles on roads is persistently increasing and the capacity of roads cannot cope with traffic, creating hours-long traffic jams. The permanent increase in the traffic intensity in urban areas leads to fading traffic flows, thus entirely paralysing the segment or the whole transport network. In order to solve this problem it is necessary to modernize the transport infrastructure (add an extra traffic lane or increase the width of the road), but this is often practically impossible because of the presence of a large number of closely located buildings, for example, in the historical centre of Riga (Fig. 1).

Figure 1. Traffic jam

At a first glance, it seems that the situation is completely desperate. However, this problem can be solved by creating new intelligent transportation systems of traffic control [1], but, for this purpose, a detailed analysis of traffic flows in real-time mode under any weather conditions should be carried out, after which vulnerabilities in the transport network should be detected and eliminated. Structurally, these systems include networks of sensors of primary and indirect measurements of traffic flow parameters, controlling centre and the network of executive elements (traffic lights, managed road signs, reversible lanes etc.). The wider the network of sensors is, the more complete information is available for the intelligent control.

Currently, video surveillance, laser, radio, inductive and press-button sensors are mainly used as sensors of intelligent transport systems. The expansion of the network of such sensors requires considerable financial resources and sometimes even additional construction works. Installation, maintenance and protection of the network of costly sensors and their connection channels make the creation of full-scale intelligent transport systems rather expensive, which often cannot be financed by state.

With the development of methods and means of digital signal processing, an opportunity of using acoustic signals for detection of a passing-by transport vehicle appeared. This allows using a usual household microphone as a sensor, which makes possible to expand the acoustic network with minimum financial costs.

On the basis of spectral analysis of real records of acoustic signals of the transport vehicles passing by under different weather conditions, an algorithm of filtering noise components (wind gusts) and getting the useful signal letting to define the amount, speed and type of the vehicle (motor car, public or freight).

2. The Study of Intelligent Transport System's Sensors

As noted earlier, there are a large number of sensors, which have a number of significant advantages and disadvantages relative to each other. Use them in every segment of the transport network must be considered separately, and in some cases altogether excluded because of inability to properly fulfil the stated objectives [2].

2.1. Radio radars

Radio radars use the Doppler Effect and have a second name – Doppler radars. This radar measures the change in frequency of the signal reflected from the object. By changing the frequency of the signal, the radial velocity of the object (the projection of velocity on the straight line passing through the object and the radar) is calculated. Doppler radars are widely used in various fields: for determining the speed of aircraft, ships, cars, hydrometeor and other objects [2].

A major disadvantage of the radar is the feature that the speed of one moving vehicle only can be detected each time. Therefore, it is impossible to use the radio radar as traffic counter.

2.2. Laser radars

Laser radars, as well as radio radars, are used to determine the speed of vehicles. Abbreviation of the name is called as LIDAR [3]. LIDAR is the technology of obtaining and processing the information about remote objects by means of active optical systems utilizing the phenomenon of light reflection and dispersion in transparent and translucent media.

LIDAR is significantly smaller than traditional radar, but less reliable in determining the speed of modern cars: reflections from the inclined plane of complex shape distorted signal to the receiver LIDAR.

Disadvantages of laser radars are similar to radio radar.

2.3. Photo radars

Photo radar has a number of opportunities for the registration of moving vehicles. This is the best method for measuring traffic flows and speeds. This type of radar can store information in some cases to pass this information via radio to a remote mobile post. There are problems with taking pictures at night, but the problem is solved by using infrared illumination.

In the second generation of photo sensors installed new hardware and software that solves the problem of mathematical processing of data from radar and cameras, image analysis and pattern recognition to personnel numbers, self-diagnostics, climate control, and performs communication functions. As a result of data processing and image analysis photo sensor gives one fixed frame with the velocity and recognized car number [2].

Despite the large number of possibilities, this method has its own disadvantages. To obtain a clear picture visibility and wet weather should be moderate. It is also possible to solve problems with the fixation of several vehicles simultaneously. These photo radars are not designed to count the number of vehicles, but could be upgraded. The processing of acoustic signal can be added to it. Photo radar is inherently unidirectional, meaning it can fix the vehicles in both directions.

2.4. Induction sensors

Inductive sensors are designed to detecting the moving vehicles. Proximity sensors are designed to control the position of objects made of metal (other materials are not case sensitive); performed with normally open or normally closed contact [4].

In a simplified form the inductive sensor is a wire which is placed under the asphalt surface and is connected to the controller. The sensor works on the principle of inductance while driving the car through it. The signal is processed by the controller and at the same counter the number of vehicles increases. In order to be able to determine the direction it is necessary to use two wires. Depending on which of them will cross first, the direction of car is determined [4].

The disadvantage of this method is that it requires the destruction of the road surface for laying inductive loops. It requires special permission and time.

2.5. Pressure sensors

Pressure sensors are composed of two screw elements, which are separated by some distance. Once the transport front wheels crossed the first push element, the receiver gives the signal of start of timer. Once the front wheels reached the second transport screw element, the receiver command is ending the countdown. At the time and known a certain distance between sensors it is simply to calculate the values of a passing transport. It may be the speed, quantity and direction [4].

The disadvantage of such sensors is that not any road surface can be installed. Most of these installations can be found at the entrance/exit to/from the car parking. From other hand, the sensors of this type very quickly become clogged, and it can lead to their frequent breakdowns.

2.6. Sensor's network combination

For the full solutions of increasing transportation problems should be combined and set a large number of sensors on one segment of the transport network that leads to processing of huge amounts of data, thereby reducing the reliability of the system.

It is becoming actual problem of minimizing the number of sensors using alternative methods of traffic flows monitoring. One such a method is based on digital processing of acoustic signals from passing vehicles, but at first we consider the most common types of acoustic sensors.

3. The Use of Acoustic Sensors

It is possible to use one of the 3 types of microphone (ribbon, dynamic or condenser), which the best solution to the task of sound record.

The principle of the ribbon microphone consists of the following: a very thin aluminium tape almost freely suspended in a magnetic field. Its fluctuations depend on the sound pressure on both sides.

Dynamic microphones are composed of membrane and attached to it a small coil placed in the field of a permanent ring magnet. Membrane, oscillating under the influence of sound pressure moves the coil, which when crossing the sound of magnetic field lines are the currents corresponding to the sound vibrations. These microphones are easy to assemble, inexpensive, accessible and perfectly suited to the role of the acoustic sensor.

Condenser (capacity) microphone consists of a very thin membrane and located very close parallel to the electrode. In order for this system has become a capacitor, the power supply is needed. Fluctuations of the membrane lead to changes in the capacity of the condenser and the appearance of the signal. This signal is weak, and the built-in preamplifier is need for the signal increasing [5]. The membrane is very thin and agile, so condenser microphones are more sensitive than dynamic. They need their own power supply. Condenser microphones are usually more sensitive than dynamic microphones; there is less resistance against mechanical damage. These microphones are mainly used in recording studios and are not suitable for recording the signal on the street.

4. Development of Moving Road Vehicles Algorithm Detections Using Digital Processing for Its Acoustic Signals

To develop the algorithm for detecting road vehicles was used the real acoustic signal recorded from the streets of Riga (Fig. 2).

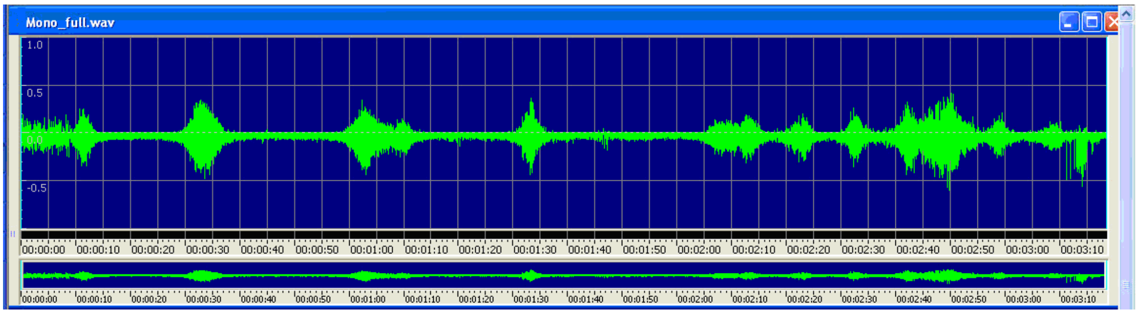

Figure 2. Example of acoustic signal

In areas where the signal increases and then decreases, there is passing road vehicles, after that these areas are cutting out and using for calculations.

During the experiment, acoustic signals were recorded under different weather conditions (Fig. 3-6). Analysing the Figures 3-6 we can conclude that each signal has its own specific form. Road vehicles have a common feature: the increasing signal, and then gradually decreasing. At last acoustic signal is clearly observed chaotic bursts indicating the noise which should be filtered. All these signals brings together that their maximum is attained at the points from 0.4 to 1. Moreover, the maximum mark of the road vehicle is in the range from 0.5 to 0.6 and 0.5 to 1 for wind.

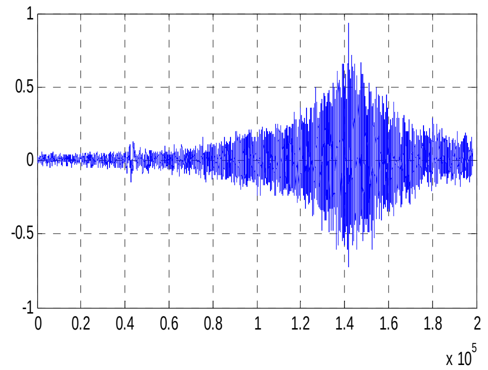

Figure 3. Car signal

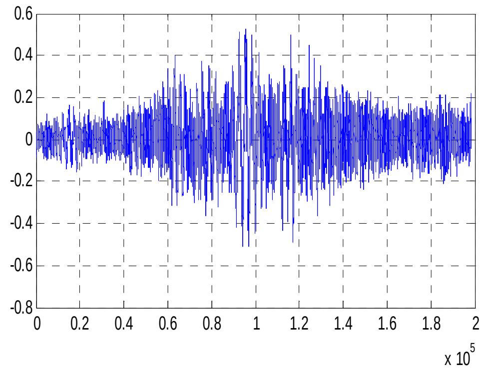

Figure 4. Signal of public transport

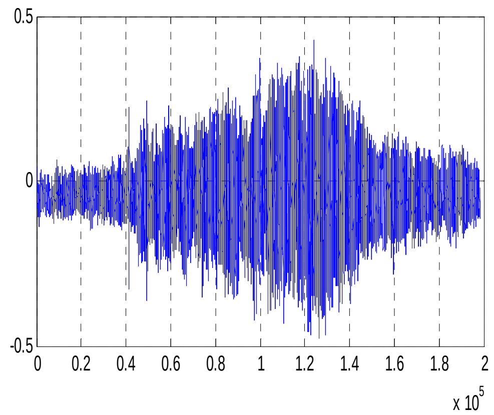

Figure 5. Car signal at rain

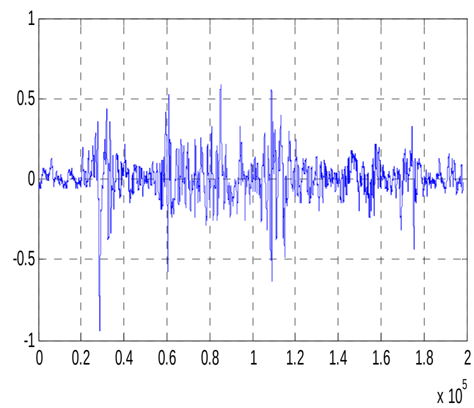

Figure 6. Wind signal

Each record was divided into fragments of 5 seconds length, since all the pulses of signals from vehicles travelling at a speed of about 60 km / h, fit in this time period (Fig. 2). The peculiarity of acoustic recording is almost three times the redundancy of the sampling frequency: quantization and recording occur with a maximum sampling rate of 44100 Hz and a microphone used in the experiment has a bandwidth of only 16000 Hz. To eliminate redundancy and reduce the processing time the quantization of the signal has been carried out with a frequency corresponding to the conditions of registration (microphone), i.e. 16 kHz. The result has been obtained as discrete sequence of 80000 samples length.

Then the signal was subjected to decimation, where every tenth sample was kept, retaining the basic properties of the signal unchanged, resulting in a signal of 8000 samples length.

On the basis of numerous of experiments it is established the optimum in terms of minimum-time of data processing, as the acoustic signal processing algorithm. It consists of 3 stages:

- Filtering in the spectral domain [6] for lower and upper frequencies of the acoustic signal using the function developed by ***filtering (x, lb, ub)*** in the Matlab software. The parameters of function are: ***x*** – input array of points of the signal, ***lb*** – lower limit of the filter, ***ub*** – upper limit of the filter;
- Square power of the filtered signal;
- Calculation of the moving average of the window length 8000 points, with a given step 10 samples with the help of the developed functions ***mean_vals (x, winSize, step)*** in the environment of Matlab. The parameters of function are: ***x*** – input an array of the signal, ***winSize*** – the length of the window, ***step*** – step.

The example of block diagram of an acoustic signal of the car (Fig. 7) and wind (Fig. 8) phase-out processing is presented below.

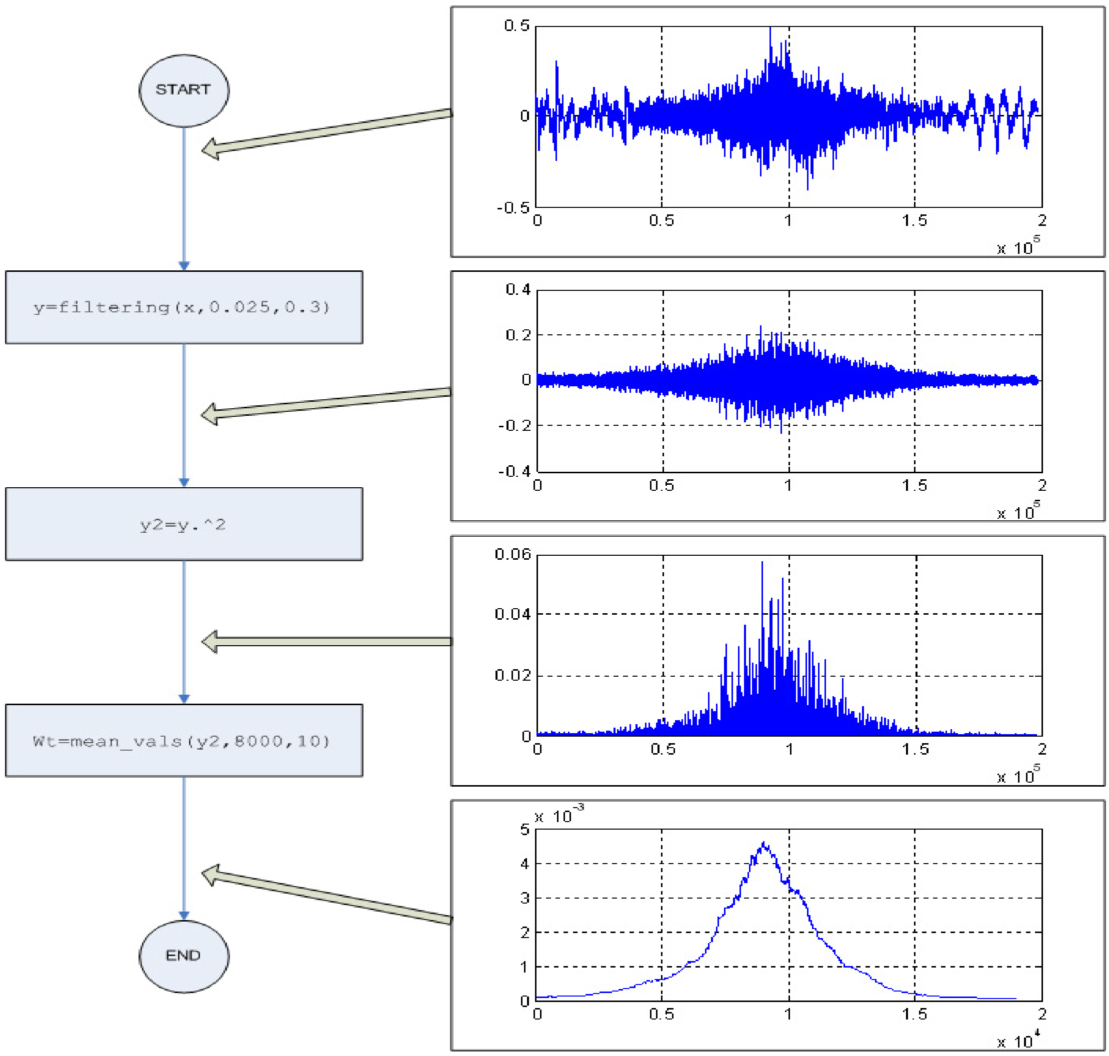

Figure 7. Block-scheme of acoustic car signal processing

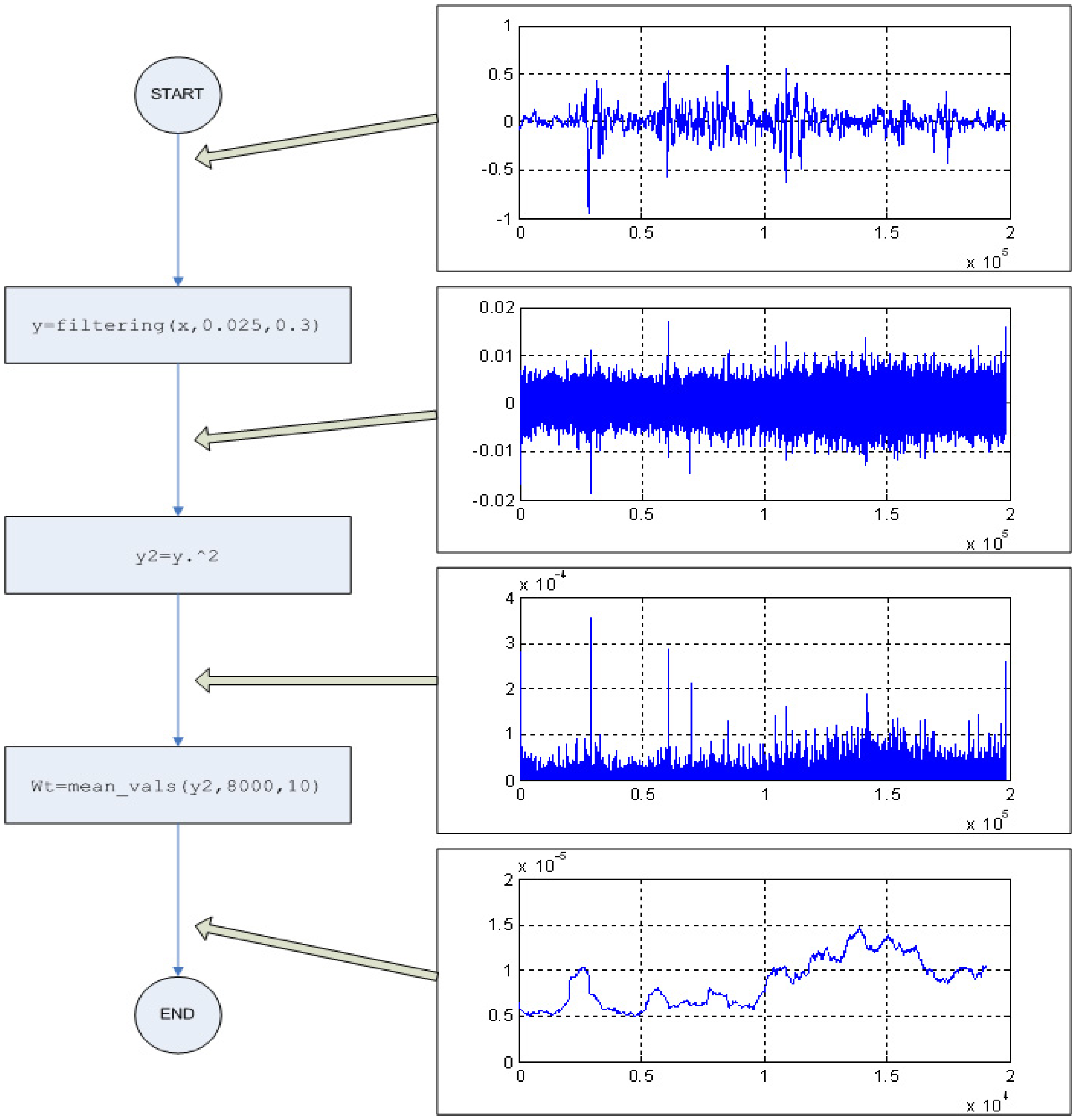

Figure 8. Block-scheme of acoustic wind signal processing

After performing such operations the ratio between the signal of wind and the signal of the car has very low settings, though the pulse of the wind signal before the processing is several times greater. Maximum of signal of the car is now 300 times higher than the highest point of the wind that makes it possible to state certainly the presence or absence of a vehicle in the segment of the transport network, i.e. use the elementary amplitude detector.

We must pay attention to the fact that the signals have been registered in the absence of pedestrians on the free stretch of road one-way traffic, where vehicles are moving at the maximum permissible speed. The effects of extraneous sources of sound, motion with low velocity dense mass of vehicles in traffic “bottleneck” and the noise from vehicles in opposite directions – these all are the factors of effectiveness of the acoustic method, which is expected to detail study in future.

5. Conclusions

As the result of studies it has been found that the acoustic method can be used for detecting of moving vehicles, therefore, the algorithm for determining the moving vehicles based on digital processing of acoustic signals is useful for surveillance. The advantages of this method are as follows:

- Low cost of equipment, what helps to minimize the financial cost for full-scale implementation;
- Autonomy of the system;
- Mobility and flexibility of the system;
- Ability to work in all weather conditions.

Unfortunately, this method is working well on the road with one lane in only one direction at absence of interferences. The most perspective creation of mobile and low-cost measurement system is a combination of acoustic sensors, longitudinal and transverse directions with observation data from WEB-camera making an additional influence research of various interferences. Also, the entire system must be completely manipulated (with the possibility of full control), which requires additional studies to determine the necessary protection level of data and all transmission channels.

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URBAN TRANSPORT ECOLOGY FACTORS, ECOLOGICAL PROJECTS, AND THEIR IMPACTS ON THE ECOLOGICAL SITUATION IN LATVIA

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Transport and industry are among the most important factors influencing the contemporary ecological situation. The analysis of this influence is impossible without monitoring the conditions of change in the environment. In different countries, measures of ecological regulation have been undertaken. These require significant expenditure. One of the most interesting projects concerning ecological regulation and the comparative analysis of ecological risk is 'The Californian project'. In this project, proposals on the economic criteria for evaluating the measures of risk reduction have been developed.
Attention is drawn to different programs used to monitor the ecological situation in Latvia. In the research the analysis of 10-12 years of statistical data is carried out. Data analysis suggests a tendency towards an improvement in the ecological situation. In Latvia, the mechanisms for financing ecological programs, which are aimed at decreasing the levels of harmful pollution in the atmosphere, are based on the experience of the USA and European countries. This research evaluates the relationship between the financing of ecological programs and the ecological situation in Latvia.

Keywords: ecology, environment pollution, ecological laws, ecological statistics for Latvia, analysis of statistics

The research of Academician Vernadsky has shown that life on Earth is concentrated in a thin layer of biosphere within which all components are connected into a single global system. A leading thinker at the end of the 19th century wrote: “Let's not flatter ourselves too much with our victories over nature. It revenges every victory.” Mankind has had to find a way out different ecological situations at different stages of development. For example, extermination of many species of mammals as a result of hunting more than 25 thousand years ago made people turn to farming and cattle breeding. Nowadays the essential factors of influence on the ecological situation are transport and industry.

1. The Influence of Transport and Industry

The negative consequences of transport and industry development (use of resources, up to their exhaustion) can be considered in the three aspects [1, 2, 3] shown in Table 1.

Table 1.

Consumed resources	Ecological factors	Social factors
Energy. Material. Land. Water. Air.	Construction of new projects: pollution of land, water, atmosphere, changes to the existing ecosystem, destruction of natural habitats, reduction in living space, threats to biodiversity. Transport streams: noise and vibration, exhaust fumes, expense, road accidents	Death, serious injury and poisoning of people and other living organisms. Increased levels of stress experienced by road users Occupational illnesses of drivers. Increased taxation and expenditure related to transport, including effects on the family budget. Hypodynamia.

According to the United Nations, transport and industry produce approximately equal amounts of environmental pollution. The percentage produced by transport is presented in Table 2 [3].

Table 2.

Factors	Transport percentage, %
Consumption of natural resources	20-32
Pollution of atmosphere	50
Water pollution	5
Use of land	30
Noise	60-80
Accidental deaths	46

91.3% of this air pollution results from road transport activities, 3.7 % from railways, 2.7 % from maritime transport, 0.9 % from river transport and 1.4 % from air transport. According to USA data, road transport produces 60.6 % of air pollution, industryproduces16.2 %, heating produces5.6 %, waste incineration produces 3.5 %, power stations produce 14.1 %.

The impact of CO on the human organism is shown in Figure 1.

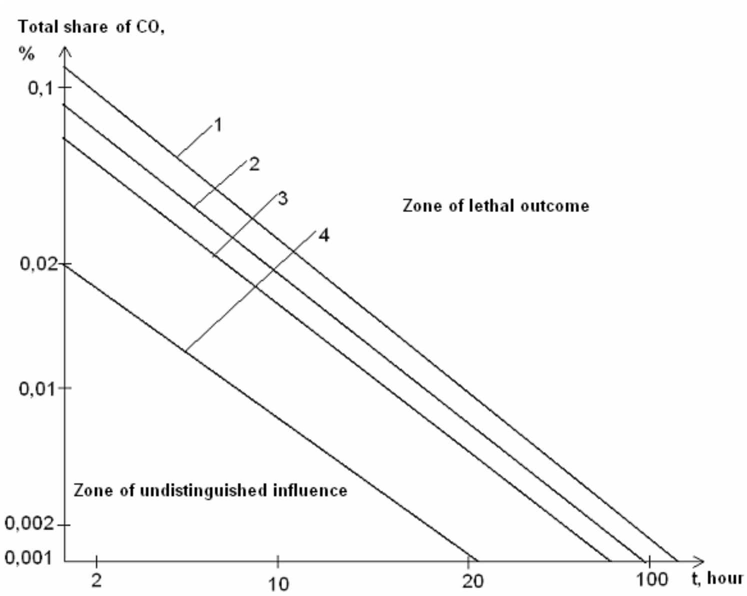

Figure 1. CO Impact on a human organism:
1 – deadly danger; 2 – headache, nausea; 3 – the beginning of toxic effects; 4 – noticeable effect.

It is noticed that the careful regulation of traffic, for example in tunnels, leads to a decrease in levels of CO (as overtaking is often forbidden and speeds are lowered). The concentration of CO in pedestrian tunnels, as a rule, is several times less than in adjoining streets (this difference is greater when a tunnel is well-ventilated). On a 900 km journey a car uses as much oxygen as a person does in a year.

Many hazardous substances connected with transport activities can dissipate into the atmosphere. For example, nitrogen oxide is transferred over 10 km in 1 hour, and carbon dioxide can travel over 100 km in 48 hours. The effects of lead, iron, copper, zinc can be seen on plants. Growth is slowed down, and leaves develop yellowness and can die off.

Noise has been called an invisible poison. It leads to emotional disorders, gastric diseases, loss of hearing and other illnesses. Transport produces 45 % of city noise, aircraft produce up to 2 %, industry produces up to 30 %.

Electromagnetic radiation is produced by various devices and equipment that may be installed in a road vehicle. At the present time electromagnetic radiation is not regulated. The electrostatic potential of a body and the intensity of an electromagnetic field in a vehicle should be subject to regulation.

The manufacture of vehicles requires large quantities of materials, which leads to a large consumption of natural resources. It is necessary to implement energy-saving technologies and technologies which do not produce waste, and also secondary raw materials processing technologies. It is very important to monitor how the environment changes. All of this requires expenditure.

2. Ecological Risk and 'The Californian Project'

Expenditure on environmental protection is significant. For example, in the USA the passing of basic ecological legislation at federal level has put into place the basis of a rigorous system of regulation. No state is permitted to pass any legislation which is less rigid than the federal measures [4]. The Environment Protection Agency (EPA) is responsible for implementing environmental legislation. In the USA there is an assumption that if businesses are better informed about ecological regulation measures, the costs they will incur in realizing the main objectives of ecological policy will be lower. A local general plan of nature use usually serves as the basis for managing the ecological conditions in regions (municipalities). The financing of ecological programs through special taxes has become widespread over recent years. Some states have undertaken more detailed projects to produce comparative analyses of ecological risk. The largest project is known as the Californian [4].

The Californian project was an attempt to answer some questions of national value. One key issue concerned disagreement over the policies of the EPA regarding the use of risk estimations in determining regulation priorities. The opinion was expressed that the risk estimation itself should not dominate the decision-making process. Attention focusing on quantitative aspects of risk does not give sufficient information on qualitative aspects, which can be very important. For example, questions concerning whether the risk is voluntary is or not, whether it is distributed uniformly or if it mostly concerns certain groups of the population cannot be described within quantitative parameters. Moreover, risk estimation is not an 'exact science' in the strict sense, as it inevitably includes some assumptions and expert estimations. In addition there is a high degree of uncertainty in risk assessment and it is considered that comparative analysis of risk often ignores social values and the role of society.

Due to discussions at a national level, the Californian project paid particular attention to these questions. For example, equality was one of the criteria that were used for ranging. Questions of 'flashpoints'; places where the most vulnerable groups in the population were exposed to the greatest risk, were considered. The critical analysis of risk estimation models included the analysis of factors which influence or should influence the extent of risk and decision-making on environmental issues.

Special attention in the project has been paid to the questions of the participation of the community in decision making. One of the most efficient methods to ensure this occurs is to assign adequate technical assistance to the inhabitants at the local level. For example, the EPA provides grants so that the local residents would have the means to hire a consultant or to conduct a study. Many states follow this policy. Grants are assigned also to assist the conduct of negotiations concerning the solution of conflict situations.

One of the most important aspects of the Californian project is the development of proposals which concern taking economic factors into account when seeking solutions to ecological problems. Practically for the first time in this type of project there are not only carefully formulated parameters, but also attempts to put the ideas into practice. From the point of view of economic analysis, the ideal selection is making the kind of decision which ensures the greatest risk reduction under a given level of expenditure. Within the framework of the project, four economic criteria for evaluating the measures of risk reduction have been developed: 1) the economic effectiveness (it assumes that the expenditure must bring the greatest benefit); 2) the distribution of expenditure and benefits; 3) the uncertainty (results depend not only on decisions taken concerning the environment, but also on many other variable factors); 4) factors of time (in terms of risk reduction this means deciding to take immediate action, or waiting until the necessary information has been acquired.

The elements of the Californian project can be used for the solution of the problems of ecology in the field of transportation and the analysis of ecological statistics.

3. Data analysis relating to hazardous pollution in Latvia

In Latvia, taking into consideration measures in the EU countries and the USA, steps have been taken to improve the ecological situation nationally, in regions and in cities.

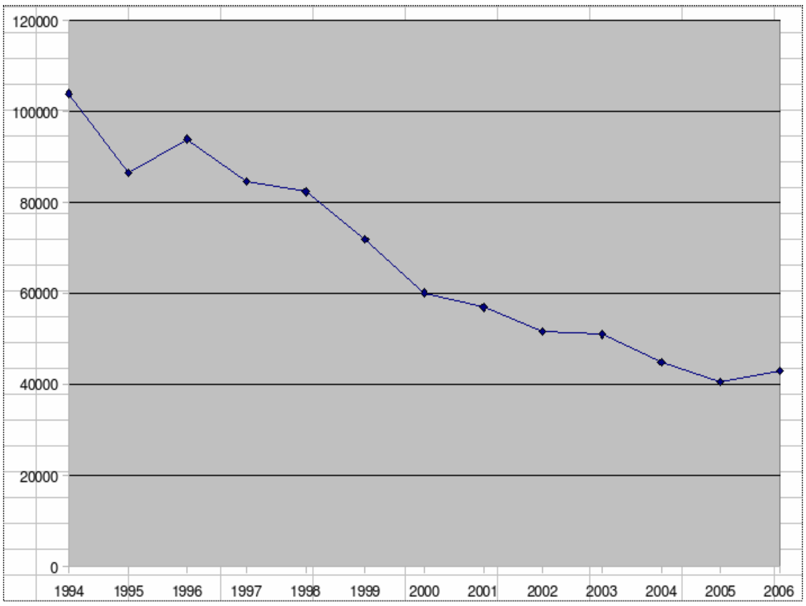

Figure 2. Level of hazardous pollution in tonnes by year

The realization of measures concerning environment protection, ecological regulation and the performance of corresponding programs demands considerable material inputs. In the article, a large volume of data received from the Statistical Bureau of the Republic of Latvia has been analysed [5]. These data contain information on the financing of programs and the volumes of different kinds of pollution.

In order to understand the relationship between the financing of ecological programs and the ecological situation in Latvia, a correlation analysis is used in the study [6].

In Latvia different programs concerning the ecological situation have been developed. Statistical data are accumulated and published annually [3-14]. As a result of the variety of measures taken in the last 10-12 years, the ecological situation has gradually improved. This trend is shown in Figure 2. It displays the volume of hazardous pollution in the atmosphere between 1994 and 2006.

Table 3 displays statistical data concerning the levels of different hazardous pollutants in tonnes between 1994 and 2006.

Table 3. (In tonnes)

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
NOx	10281,1	7913,2	8654,3	9513,5	9288,7	8203,8	8314,7	8808,8	9273,2	10285,2	8920,9	9743,2	10561,1
SO2	51598,6	38074,7	44930	33821	31735,9	23352,2	12038,1	8866,6	7773,1	5886,8	4534	3214,2	2078,7
CO	24723,9	23425,2	23768,4	23950,9	25375,3	25290	24997,8	24802,7	21609,6	22633,5	18766,9	15176,5	16608,6
GOS	1771,5	1689,1	1750,1	2136,7	2490	3607,8	3929,2	4263,6	4607,3	4516	4496,3	5101,3	4202,5
other	13178,9	12465,4	11829,8	12320,7	11123	9999,2	9500,2	8553,8	4343,4	4140,9	6263	5481	5951,5
misc.	2289,9	2866,8	2856	2757,9	2279,2	1330,3	1220,8	1487,6	3932,5	3466,3	1785,4	1781	3517,2
Total	103843,9	86434,4	93788,6	84500,7	82292,1	71783,3	60000,8	56883,1	51539,1	50928,7	44766,5	40497,2	42919,6

Figure 3 displays the reduction in levels of different hazardous pollutants (in tonnes) by year. The displayed levels of the different pollutants show a downward trend, although this is not the case with NO_2.

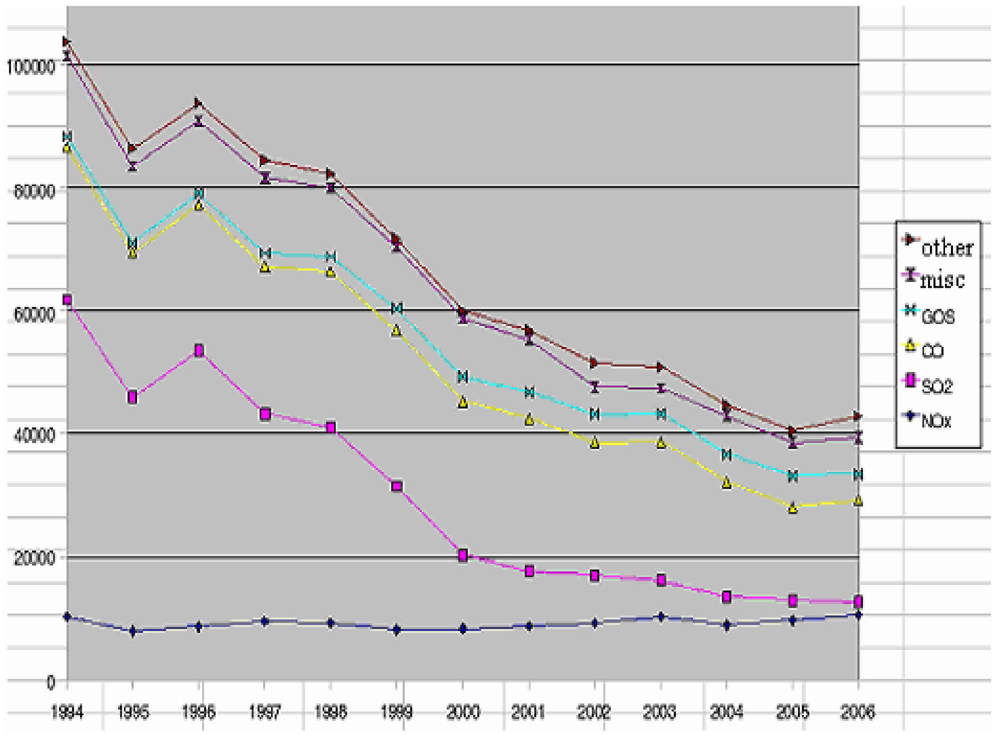

Figure 3. Levels of different hazardous pollutants in tonnes between 1994 and 2006

Figure 4 displays the proportions of the different hazardous substances for each year between 1994 and 2006. There is a clear reduction in the level of SO_2 although the levels of NO_x, CO and GOS increase significantly over the period. There is no significant change in the levels of the other substances.

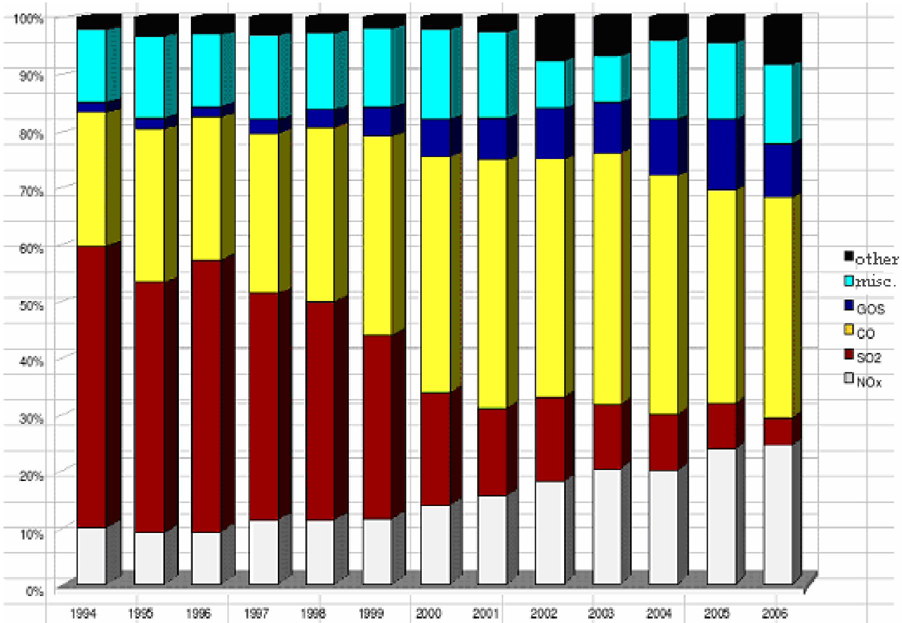

Figure 4. Levels of different pollutants expressed as a percentage of the total for each year between 1994 and 2006

Table 4 shows the level of atmospheric pollution in Riga compared with the total from other cities in Latvia (in tonnes) between 1996 and 2006.

Table 4.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Riga	15106,2	12920,7	11376,3	8900,4	9372,4	8869,9	6991,9	6843,4	5190,2	6437,1	7286
Others	78682,4	71580	70915,8	62882,9	50628,4	48013,2	44547,2	44085,3	39576,3	34060,1	35633,6
Total	93788,6	84500,7	82292,1	71783,3	60000,8	56883,1	51539,1	50928,7	44766,5	40497,2	42919,6

Figure 5 shows that the levels of hazardous pollutants in Riga comprise between 12% and 18% of the totals of these substances in Latvia these pollutions in Latvia (depending on the calendar time).

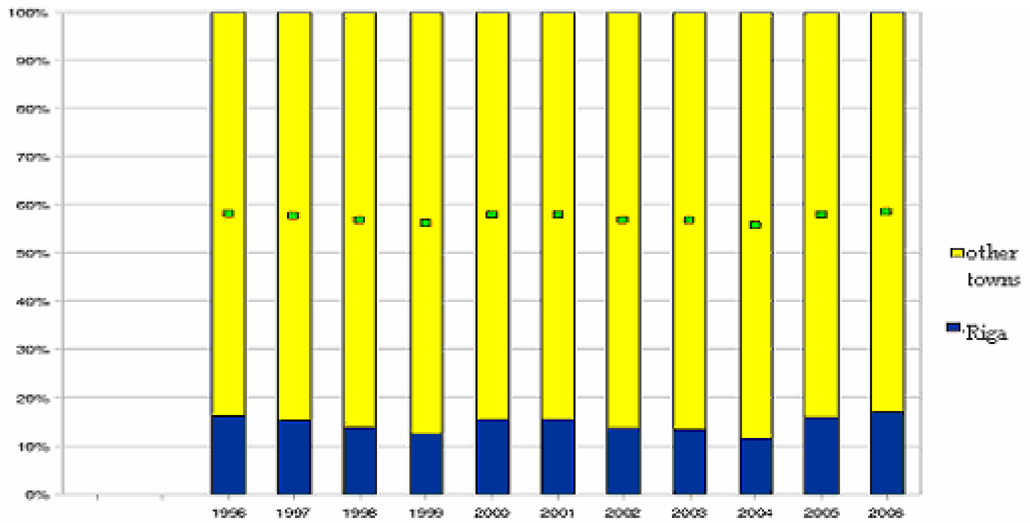

Figure 5. Pollution in the city of Riga as a proportion of the total for Latvia

Figure 6 shows the reduction in the levels of hazardous pollutants between 1996 and 2006. The proportion of these substances in Riga is smaller than 10 years ago.

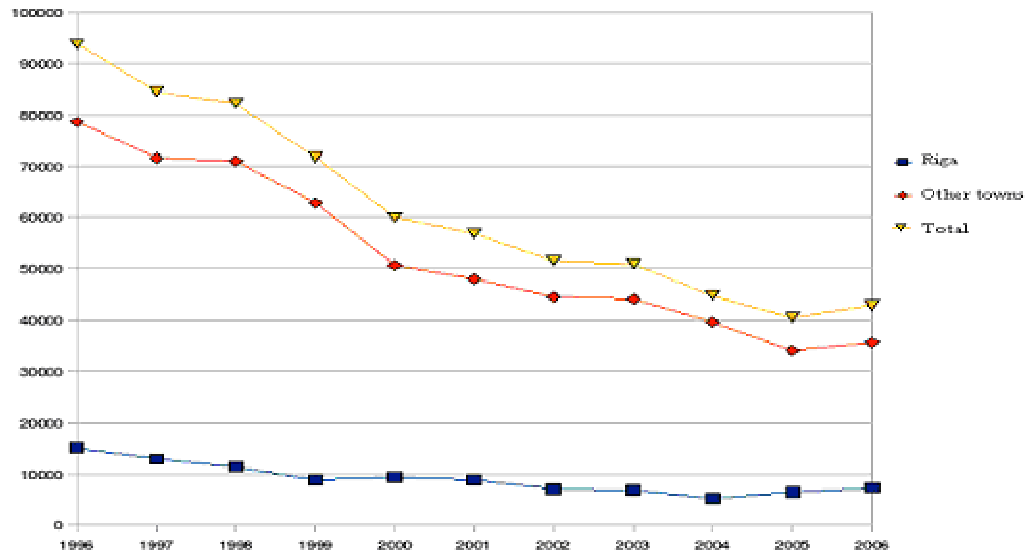

Figure 6. Volume of hazardous pollutants in Riga, other Latvian cities, and the total for Latvia between 1996 and 2006.

4. Directions in the financing of ecological programs in Latvia

Based on the experience of the USA and other European countries, there are mechanisms for financing ecological programs to reduce the levels of harmful substances in the atmosphere in Latvia. As in similar programs in other countries, the distribution of funds is directed first of all towards those cities and regions which are most exposed to the pollution. This principally applies to the city of Riga. Table 5 shows the trend in the dedicated financing of anti-pollution measures. The increase in this funding can be clearly seen.

Table 5.

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Riga			368,9	350,1	298,2	188,1	117,7	239,7	1604,7	2423,2	1182,4	3090,9	5873,1
Other	1216,3	2078,6	815,2	2044,2	3518,8	1661,6	1017,8	2525,6	4190,9	3095,7	3642,6	4263	5356,1
Total	1216,3	2078,6	1184,1	2394,3	3817	1849,7	1135,5	2765,3	5795,6	5518,9	4825	7353,9	11229,2

If years in which there were reduced levels of finding of air pollution reduction measures are not taken into account, the overall trend shows an increase in funding. It is evident that the level of funding in Riga has increased, as it has in Latvia as a whole. (Figure 8).

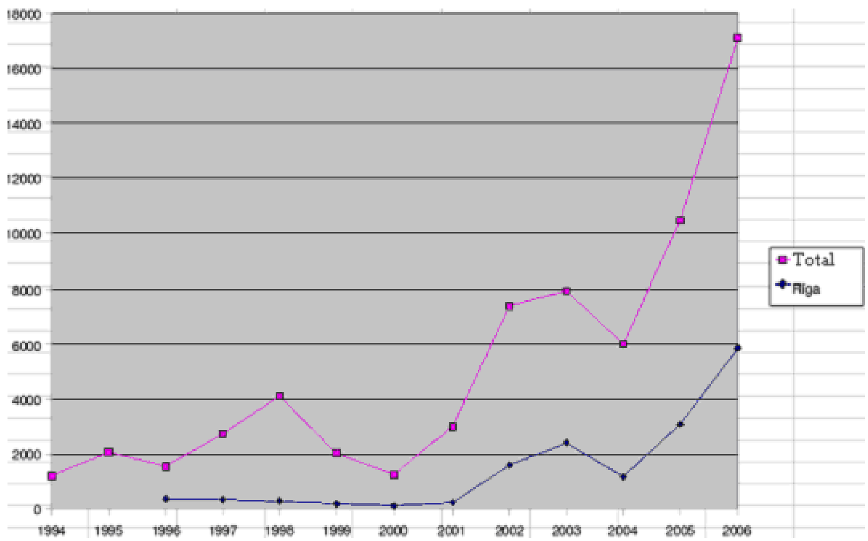

Figure 7. Financing of ecological programs between 1994 and 2006.

Figure 8 shows the share of ecological program funding spent in Riga, and the combined share spent in the other main towns in Latvia between 1994 and 2006 in

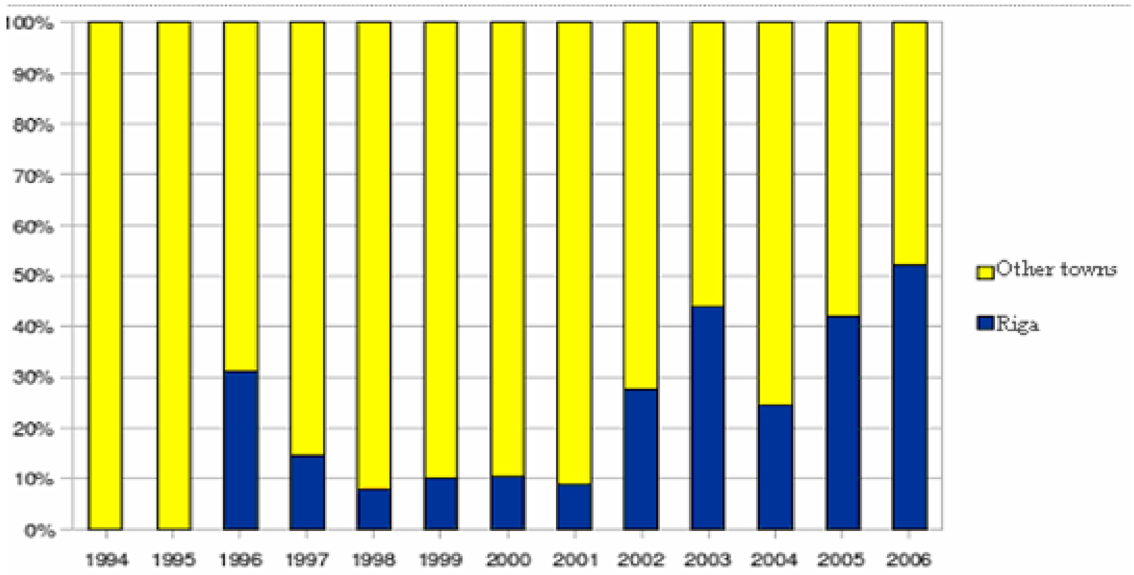

Figure 8. Share of ecological program funding in Riga and the rest of Latvia

5. Evaluation of the relationship between the financing of ecological programs and the ecological situation in Latvia

In order to evaluate the relationship between the financing of ecological programs and the ecological situation in Latvia it is expedient to use a correlation analysis. Using statistical data it is possible to calculate that the selective paired correlation coefficient, which characterizes the tightness of the relationship between values x and y is $\rho(x, y) = -0.73$. Since it is negative and close to -1, it means that there is a close inverse relationship between the ecological situation and the expenditures connected with the ecological programs. An increase in the level of funding for ecological programs tends to lead to a decrease in the levels of hazardous substances. A notable feature of the financing of ecological programs in Latvia (1994-2006) is the fact that they are targeted at decreasing the impact of stationary sources of pollution. It is not assumed that they are targeted at mobile sources of pollution such as transport.

On the basis of the regression estimators, the degree of influence of the enclosed resources (funds) on the ecological programs can be determined. For this purpose it is necessary to use an estimation of the regression equations [4]. The result of the calculations (according to all the available statistical data) is as follows:

$$\hat{y} = \text{-0,008754+4521,6} \cdot \text{x} .$$

From the equation (5) it is seen that with each increase of one thousand LVL in the financing of the ecological the level of air pollution in Latvia reduces by 4521.6 tones.

Calculating the elasticity coefficient (defined under the formula $e_1 = b_l \frac{\bar{x}}{\bar{y}}$), shows that e_1=-0.15. It shows that with a 1% increase in financing, pollution levels fall by 0, 15 %.

6. Conclusions

Transport and industry are among the most important factors which influence the contemporary ecological situation. The analysis of this influence is impossible without monitoring the conditions of change in the environment. In different countries measures of ecological regulation have being undertaken in recent years. These require significant expenditure. One of the most interesting projects concerning ecological regulation and the comparative analysis of ecological risk is "The Californian Project". In this project proposals on the economic criteria for evaluating the measures of risk reduction have been developed.

Attention is drawn to different programs used to monitor the ecological situation in Latvia. In theses programs the analysis of 10-12 years of statistical data is carried out. Data analysis suggests a tendency towards an improvement in the ecological situation improvement. In Latvia the mechanisms for financing ecological programs, which are aimed at decreasing the levels of hazardous pollution in the atmosphere are based on the experience of the USA and European countries. This research evaluates the relationship between the financing of ecological programs and the ecological situation in Latvia.

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A FUZZY APPROACH AND MODELLING OF SERVICE ESTIMATIONS FOR DRUGS FREIGHT TRANSPORTATION

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Expedience of quality estimation of transport service in the conditions of narrow-mindedness, unclear, incompleteness of information and competition environment at the market of transport services on the basis of fuzzy sets is grounded. The parameters of quality of implementation of freight transportations are certain. The two-tier model of determination of integral quality of freight transportations on the basis of unclear design is built. The computer's realization of the fuzzy approach and correspondent model with the use of expert's fuzzy estimations is performed by facilities of the software environment MATLAB fuzzy logic toolbox.

Keywords: drugs freight transportation, fuzzy modelling, transport service quality, MATLAB fuzzy logic toolbox

1. Introduction

Swift development of manufacture and market of drugs, pharmaceutical and medical production setting conduces to intensification and growth of transport streams in particular automobile drugs freight transportation and raw material. In such terms the performer of transport services must as good as possible perform the requirements of clients and, at the same time, properly to provide the own interests.

Progress of work of cargo enterprises, transport divisions of production and intermediary enterprises, in a transport system depends on increase for quality of their services.

The maintenance of service level needs permanent internal self-control of production activity on the basis of the proper scientifically methodological and practical providing.

Many publications at last time past was devoted both directly to quality of transportations and to consideration of this question among other tasks of perfection of a transport service on the whole [1–4].

Thus the problem of transportation's technologies and service's upgrading is thoroughly probed as well as it separate constituents.

The row of methods for estimation of transportation quality is developed, but unique, the universal does not exist.

Substantial complication is that row of indexes for transportation quality are difficultly to obtain numerical estimate or it is in general impossible to exactly numeral estimations in practice. Often basic attention is focused to separately indexes, but not – to generalized quality transportation's estimation.

Researches of quality of a transport service testify that at its practical estimation there are concepts with diffuse limits, assertions which have a linguistic specification of parameters, unclear relations between component parts [4–6].

Therefore it is necessary to apply the proper mathematical methods which are based on the methods of fuzzy sets theory [7]. The last allows probe features which are difficult to take into account in classic approaches, namely: fuzzy estimations, fuzzy advantages, fuzzy information about events, terms, limitation and others parameters of transportation.

The evaluation tasks on a few parameters have the special importance for the improvement of a transport service. They make possible the determination of integral result on a few separate technical, technological, other indexes (parameters). Thus activity of cargo enterprises passes in the different level of vagueness conditions, when initial parameters and results are estimated a few unclear criteria.

It is difficult to estimate the row of transportations parameters in number. The vagueness are related with impossibility of receipt of reliable information, with a refuse to give this information from participants of transportation's process (they explain it by a desire to keep a commercial secret, hide information from competitors, supervisory organs and others).

It confirms the necessity of the use of fuzzy sets theory for the design of constituents of a transport service. Therefore the purpose of the article is a decision of scientific and technical task from development practically oriented tool for determination, control and monitoring of quality level of freight transportations (in particular, estimations of trips quality) by creation and realization on a computer the proper model on the basis of methodology of fuzzy sets and fuzzy logic.

2. Methodology, Data and Model

The first stage of research is establishment of parameters, which determine quality of freight trip. Fact data (Table 1) are got on a production and wholesale-intermediary pharmaceutical enterprises by questioning of specialists, accountable for implementation orders of clients, technical providing of separate trips, technical state of car's park.

Table 1. Parameters of freight trips and average estimations of their levels

Parameter	Levels (limits)		
	high	middle	low
1. Delay to the client (delivery or serve, hours)	1	4	6
2. Safety (an amount of travelling and transport incidents for a year)	1	3	5
3. Maintenance of loads (% damages from a general volume, cost)	1	5	10
4. Claims of client (% from the incurrence of orders for a year)	5	10	30
5. Time mode (% violations of time-of-flight control points)	5	15	30
6. Speed mode (% to motion with a considerable over speed)	5	20	35
7. Expense of fuel (% overruns of fuel from planned on a trip)	10	30	45
8. Readiness (time of car preparation after previous trip to the following, days)	2	4	8

It is appeared, that transportation's managers, specialists of technical service readiness, safety inspectors are interested about parameters and estimations of trips from the point of observance of exploitation, motion and road safety, implementations of schedules of drugs delivery at observance of rules of its transportation.

We will consider every parameter from the point of expedience of its including in the model. Delay is one of major parameters of delivery quality that is why it must be in a model. Safety is a stable parameter, which has constant character of change for one trip therefore it is not necessary to include this parameter to model. Maintenance parameter also is permanent for one trip that is why we don't examine it too. Claims of client are required by the accumulations of statistics on a few trips for certain time period. That is why (for a separate trip) they are not in-out parameter and eliminated from model. In general they can be united with maintenance at the analysis of a few transportations quality for period.

Inhibition of the motion (traffic) mode is an important parameter for control of a trip. The timely passing of control-temporal points testifies to high qualification of drivers, rightness of choice of route and determination of his parameters by managers which planned transportation. Right speed mode is the condition of transportation safety, maintenance of cars, prevention of emergency situations and fines that is why for the estimation of separate trip it is sufficiently important.

An expense of fuel also is an important parameter which characterizes quality of trip from view of working of driver. It is expedient to examine it consonant with the speed and motion modes. Together these three parameters almost full characterize work of driver in a trip. Parameter of car readiness to the next trip is important too. That is time, which necessary for car technical preparation to next (after previous) trip. A parameter has technological validity and economic consequences. It is attitude of drivers characterizes, among other, the maintenance of car during a trip.

The analysis of selected parameters and previous models of quality estimation for freight transportations (developed before) on the basis of approach, which is based on the fuzzy sets theory testifies about expedience of construction of two-tier model (Fig. 1).

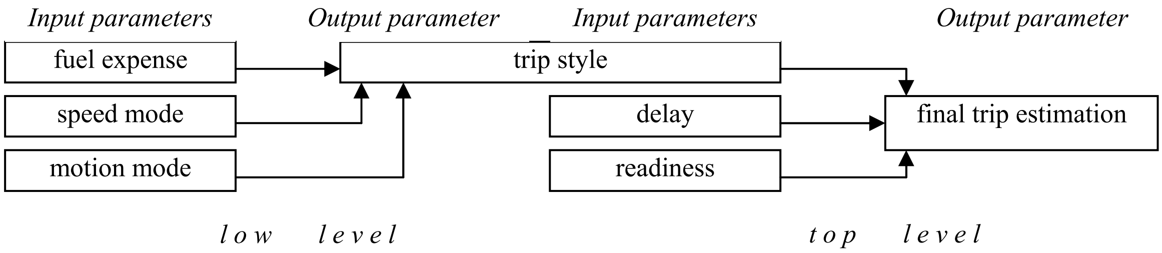

Figure 1. Structure of two-tier model of trip quality

It is thus possible to examine in-out parameters, each of which is determined as a set of three linguistic terms with the linear (triangular and trapezoidal) membership functions. At top level of entrance variables is a delay, readiness and trip style. Last is defined as output parameter for the motion mode, speed mode, fuel expense – three input parameters at lower level of model.

For this purpose we fill tables for each of three input parameters (variables) and output parameter and build the proper membership function. Thus, membership function for input parameter "motion mode" depending on the amount (%) of deviations from the passage schedule of the control points is resulted in Table 2. Membership functions for parameter "speed mode", which is a percent of trip time with excessive speed also resulted in a Table 2.

Table 2. Parameters of membership functions "motion mode "and "speed mode of movement"

Motion mode		**Speed mode**	
good	Function "good motion mode" is evened 1 (rejection from 0% to 2%). Diminishing from 1 (rejection 2%) to 0 (rejection 5%). Value is 0 (deviation from 5% and more)	good	Value of function the "good speed mode" is 1 (rejection from 0% to 1%). Diminishing from 1 (rejection 1%) to 0 (rejection 5%). Value is 0 (deviation from 5% and more)
middle	Function "middle motion mode "has the value 0 (deviation from motion schedule from 0% to 3%). Growth from 0 (rejection 3%) to 1 (rejection 8%). Value is 1 (rejection from 8% to 12%) Diminishing from 1 (rejection 12%) to 0 (rejection 15%). Value is 0 (deviation from 15% and more)	middle	Value of function the "middle speed mode" is 0 (rejection from 0% to 2%). Growth from 0 (rejection 2%) to 1 (rejection 10%). Value is evened 1 (rejection from 10% to 15%). Diminishing from 1 (rejection 15%) to 0 (rejection 20%). Value is 0 (deviation from 20% and more)
bad	Value of function the "bad motion mode" is 0 (at a rejection from 0% to 13%). Growth from 0 (rejection 13%) to 1 (at a rejection 30%). Value is1 (at a rejection more than 30%).	bad	Value of function the "bad speed mode" is 0 (rejection from 0% to 16%). Growth from 0 (rejection 16%) to 1 (rejection 35%). Value is 1 (at a rejection more than 35%).

Graphics of these functions, resulted on Figure 2, are (as well as in future) the screen copies and got directly during realization of model in the fuzzy-logic toolbox modelling component of MATLAB.

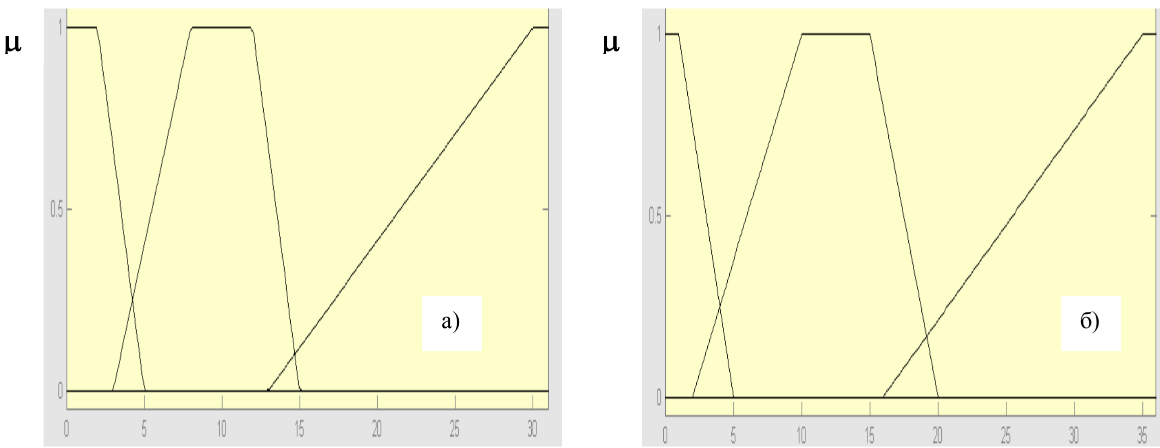

Figure 2. Sets of membership function for entry parameters "motion mode"(a) and "speed mode"(b)

It is like possible to present gradations (Table 3) and membership function (Fig. 3a) for an entry parameter "fuel expense" (% of its overruns over planned on a trip). Output variable of lower level "trip style" will define as set (Table 3) from three membership function of triangular kind (Fig. 3b) with estimation by 10-ball scale.

Table 3. Numerical intervals for the membership *functions* of linguistic variables " fuel expense" and " trip style"

Fuel expense		**Trip style**	
norm	Function "norm fuel expense" is 1 (rejection from 0% to 5%). Diminishing from 1 (rejection 5%) to 0 (rejection 10%). Value is 0 (rejection 10% and anymore).	bad	Value of function "bad style" is 1 (estimation is 0 marks). Diminishing from 1 (estimation is 0 marks) to 0 (estimation is 5 marks). Value is 0 (estimation is 5 marks and more).
exceeding	Function "expense is exceeded" is 0 (rejection from 0% to 6%). Growth from 0 (rejection 6%) to 1 (rejection 14%). Value of function is 1 (rejection from 14% to 20%). Diminishing from 1 (rejection 20%) to 0 (rejection 30%). Value is 0 (rejection more than 30%)	middle	Value of function "middle style" is a 0 (estimation is from 0 to 3 marks). Growth from 0 (at estimation 3 marks) to 1 (at estimation 5 marks). Diminishing of function "style trip is middle" from 1 (at estimation 5 marks) to 0 (at estimation 8 marks). Value of function "style is middle" is 0 (an estimation is 8 marks and more)
surplus	Function "surplus expense of fuel" is 0 (rejection from 0% to 23%). Growth from 0 (rejection 23%) to 1 (rejection 45%). Value is 1 (rejection more than 45%).	good	Value of function "good style of trip" is 0 (at estimation from 0 to 6 marks). Growth of function "good style of trip" from 0 (at estimation 6 marks) to 1 (at estimation 10 marks).

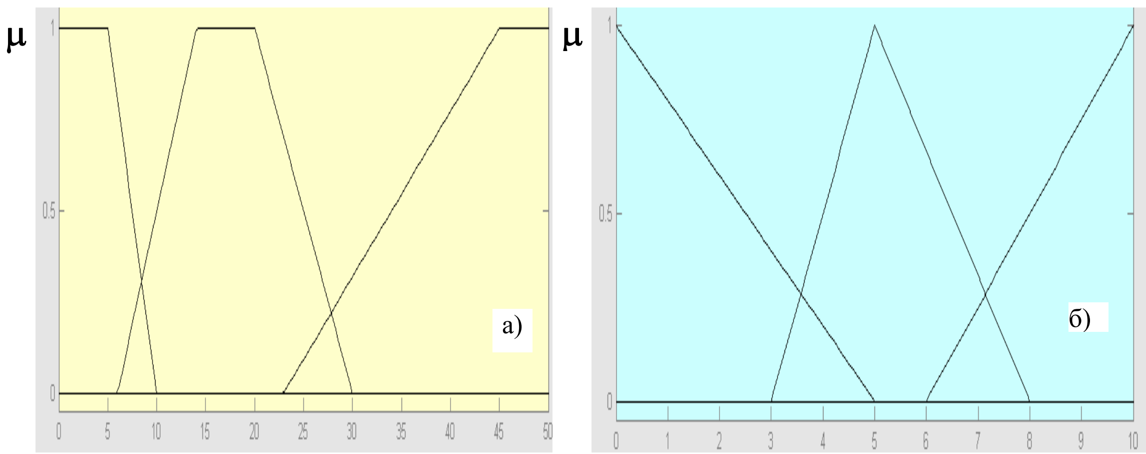

Figure 3. Sets of membership functions for parameters "fuel expense" (a) and " trip style" (b)

For the lower level of model certainly rule fuzzy conclusion, resulted in a Table 4.

Table 4. Fuzzy rules (conclusion) for the lower level of model (determination of trip style)

Rules:	**If ... motion mode is…**	**And speed mode is…**	**And fuel expense is…**	**Then trip style is…**
rule 1	Good	Good	Norm	Good
rule 2	Good	Good	exceeding	good
….....	……………	…………..	……………..	…………
rule 15	middle	Middle	surplus	bad
rule 16	middle	Bad	Norm	middle
………	……………	…………..	……………..	…………
rule 26	bad	Bad	exceeding	bad
rule 27	bad	Bad	surplus	bad

We conduct the construction of top level of model an analogical method; accordingly we describe three inputs and one output parameters with the triangular membership functions.

First of input parameters is an output variable of lower level – "trip style". The second input parameter is a "delay" (in hours) of arrivals cars to clients at delivery drugs or serve of car for loading (Fig. 4a). The third parameter is "readiness" that is time (days), which is necessary for preparation of car after the previous trip to the following one (Fig. 4b).

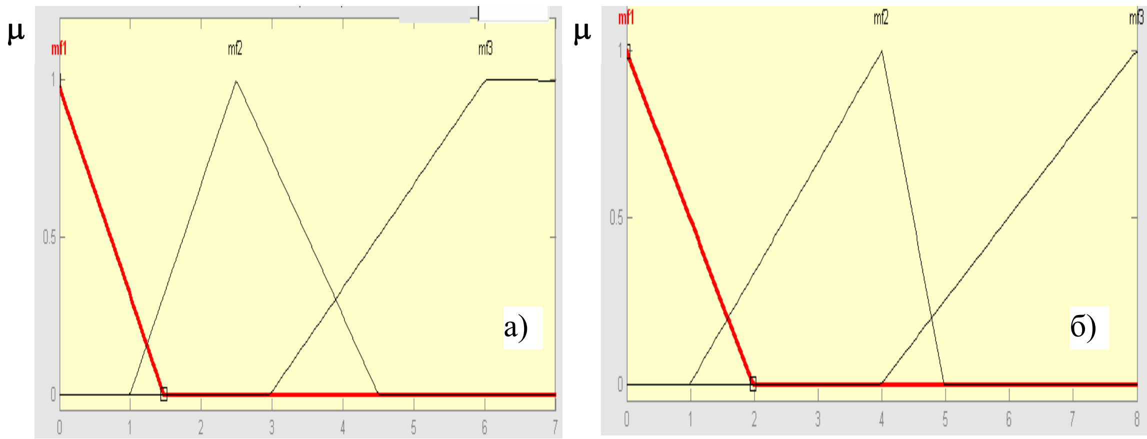

Figure 4. Functions of top level parameters "delay" – in hours (a) and "readiness" – in days (b)

Final resultant parameter (integral quality of trip) is estimated in marks from 1 to 10.

For it the proper membership function is built by analogical method with attributes "bad", "middle" and "good".

The rules of fuzzy conclusion for the model top level are built on the basis of expert estimations (like resulted in a Table 4 for a lower level). Their visualization after an input in the Matlab interface of model is represented by Figure 5 (a fragment of computer screen).

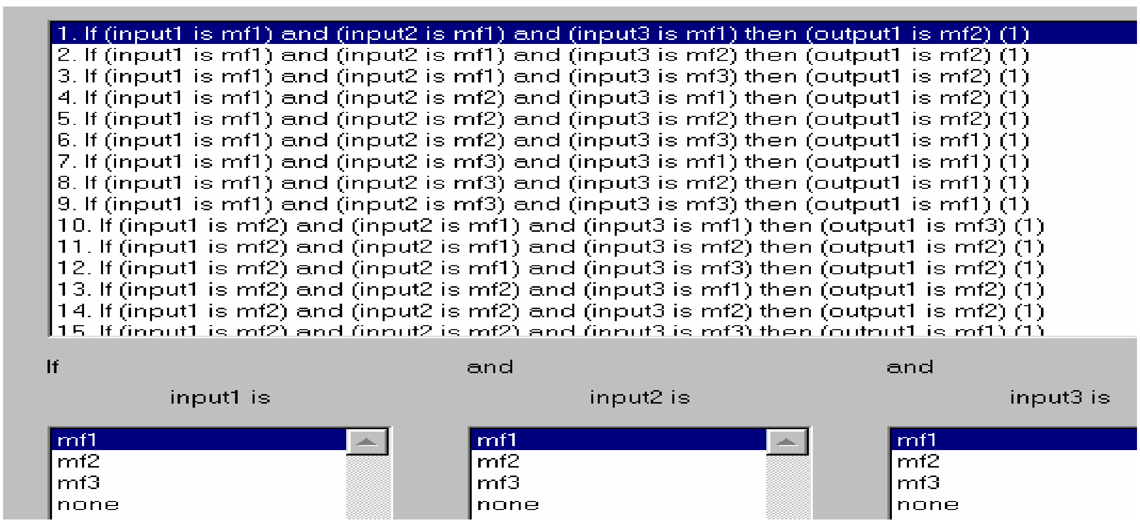

Figure 5. Fuzzy rules (conclusions) for the top level of model (fragment, 14 rules from 27)

Graphic interpretation for interaction of fuzzy conclusion rules and sets of membership functions in the process of estimation's calculation of trip quality is presented on Figure 6.

For every level of model it is possible to build the surface of fuzzy conclusion (Fig.7).

It evidently represents dependence of output variable on the change of input parameters that allows easily analysing the built model. It is possible to find out areas, where the insignificant changes of input data are given by the strong vibrations of results and vice versa, to set the ranges of input values, which has a little influence on the end-point result (output parameter). If a few input parameters are presented, it is expedient to analyse such surfaces for every pair from them.

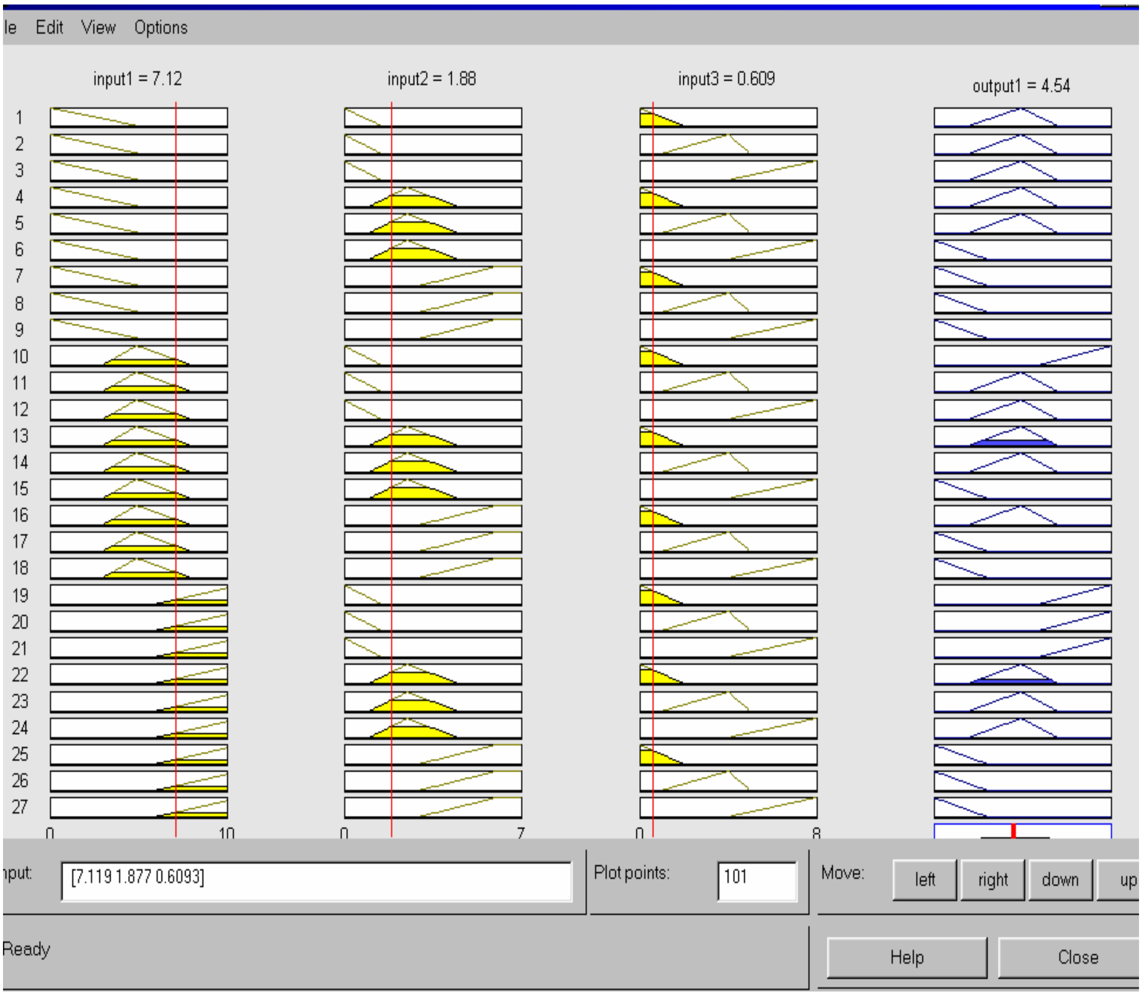

Figure 6. Interaction of decision rules and fuzzy membership *functions*

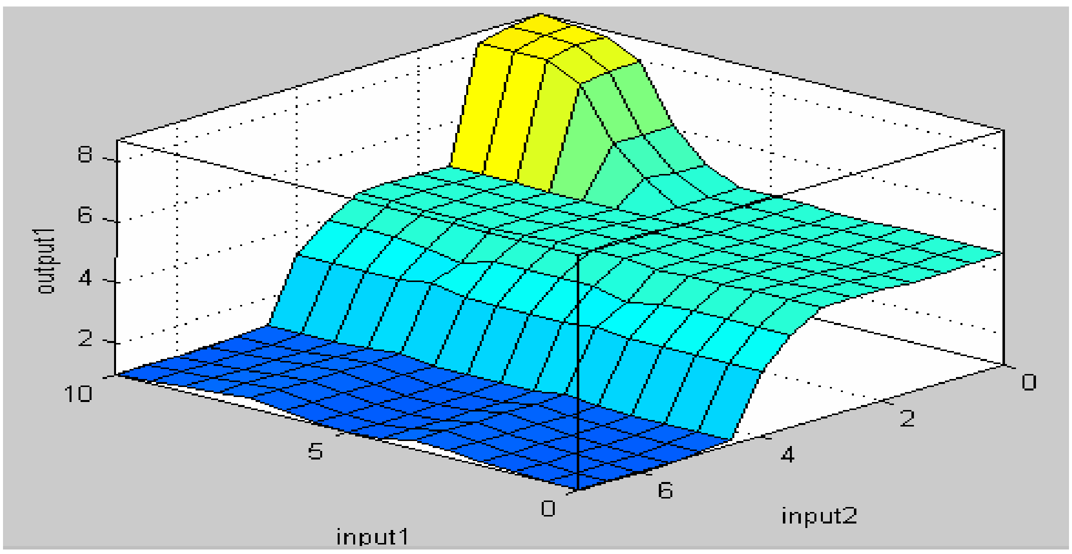

Figure 7. Fuzzy conclusion surface for the top level of model

The analysis of such surfaces shows that they exactly sufficiently represent interdependence of different parameters in their general influence on the integral estimation of transportation quality both in a separate trip and at the estimation of transportations on the whole (for several times period, groups of trips, directions, clients-customers).

In this case especially important is a construction of membership function, what exactness of estimations depends on. The correct construction of fuzzy logical inference rules is also needed. This procedure must be realized on the basis of experience of persons, which make decisions such as managers, specialists of transportations, motion safety, providing of the technical state and readiness of cars which are used.

At practical application of model it is desirable to adhere following next recommendations. At first, it is necessary to accumulate a full database on each of input parameters. Secondly, it follows to accumulate information and organize it on such signs: driver (estimation of his work), car (an estimation of its fitness to transportations, technical state), directions, clients (clarification of normative indexes and parameters for trips in different directions), distances of transportations, etc. Thirdly, it is necessary, the adaptation (clarification and correction) of model (kind and parameters of membership functions, rules for decision making) on the stage of model's introduction.

Thus, some duplicate rules can be eliminated (corrected). Also may be needed the change of composition and amount of entry parameters for the quality estimation of freight transportation.

3. Conclusions

A necessity, expedience and efficiency of application of fuzzy modelling methodology for determination of integral quality of freight transportations has been confirmed. Thus, two-tier model for the trip integral estimation during realization of freight transportations is first built.

On the basis of application of MATLAB (multifunction environment for engineering's calculations) the realization of model on computer is executed. As the results of verification in production terms, the recommendations for practical application for the trips estimation with the purpose of system improvement of freight transportations quality are given.

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IMPROVEMENT OF RAILWAY SAFETY BY APPLYING THE ADVANCED TECHNOLOGIES

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Only modern transport can reliably perform cargo and ensure efficiency and total safety of the economic process. Information technologies provide us with new possibilities in organizing transport work.

Information systems can be used for electronic data registration of cargo. The necessity of mobile transport systems analysis is base on globalisation and integration process: interconnection of various types of vehicles and their management in order to obtain more effective, safe and mobile freight monitoring and it is the creation of intelligent transport sector.

Keywords: information technologies, mobile transport system, railway traffic management, control and security systems

1. Introduction

By the development of advanced transport technologies it is very important to accelerate the integration of the Lithuanian transport system into the economic community of Europe and of other countries of the world, it is necessary to create the information infrastructure of the Lithuanian transport system that optimally functions both internally and externally.

The information infrastructure of the transport system is understood as an integrated aggregate of informatics and communication means, standards, technical regulations and organisational procedures that enables electronic accumulation of major information resources of the transport system, their processing in a coordinated way and, with the help of computer communication means, immediate provision of reliable summarised information of different nature, form and purpose, which is necessary for technological activities of companies, comprehensive accounting, as well as for decision-making by the authorities of companies or a transport system.

2. Estimation of Advanced Transport Technologies Approach of Long-Term Development Strategy of the Lithuanian Transport System

Creation of the information infrastructure is understood not as the creation of one huge computerised information system but as the creation of the environment for the functioning of information systems of companies.

The purpose of the information infrastructure of the transport system is the efficient and optimal informational maintenance of functioning of the Lithuanian transport system. Such an information infrastructure will allow the following:

- acceleration and optimisation of the movement of material and information flows through computerisation of functioning of its elements that control the above-mentioned movement;
- integration of the Lithuanian transport system into the European transport network;
- integration into the European transport service market.

To create information infrastructure of the transport system, it is necessary to take into account the general European requirements and multilateral agreements with neighbouring countries.

The following measures in the field of advanced transport technologies development should be mentioned:

1. Development and introduction of a transport network system of traffic and user information management and control in order to optimise the use of the infrastructure;
2. Modernisation of railway transport data transmission and traffic management system, assurance of its compatibility with those of neighbouring countries;

3. Drafting of a programme for transport system management and rearrangement of information technologies and telecommunication structure of individual transport branches, also for development of intelligent transport systems while integrating the Lithuanian transport system into the EU transport information technologies and telecommunication systems;
4. Development and introduction of a computerised system that enables automatic control of a technical state of road transport, drivers' work and rest schedule, information on freight being transported;
5. Introduction of an integrated information system that would embrace all activities of the railway sector and assure an effective management of the total railway transport system. Introduction of this information system could be followed by: rational use of the available system capacity, launching of freight flows across the territory of Lithuania at the lowest cost and in the shortest period of time; rational planning and implementation of maintenance and repairs of mobile and stationary objects of the railway transport system; its connection with information technologies systems of other transport modes and its organic integration into the information system of all transport sector of Lithuania.

3. Evaluation of Information Systems (IS) Selection and Implementation in Railways

For the successful creation of Information Systems the following factors are particularly important: user's workplace, ergonomics of IS, operational convenience of the system, amount of errors and other aspects of the workplace. User's workplace often needs to meet the requirement for possibilities to reflect a large amount of information. Therefore modern systems are usually created in the Windows environment by application of graphic means for reflection of data and actions. For this reason persons working in subdivisions of management of different business sectors often use even several monitors reflecting different information necessary for decision-making. Application of typical solutions for data picturing and attraction of attention enables a significant enhancement of efficiency, speed and comfort ability for the user.

In the course of IS development the cooperation of IS and functional staff becomes particularly complicated. In the integrated case the requirements for systems and their functionality are created by functional units responsible for the reaching of business goals – IS is an instrument for improvement of delivery of services and reaching the aims. In a defined way provider is selected in the railway terminals and the system starts to be implemented. In this period appears the railway terminal's IS division staff, which has to take care of the system's integrity, its availability for operation and further maintenance and development. After implementation of the system it is transferred to IS subdivision for taking care of maintenance. Often proposals for further IS development are provided by IS subdivisions, which are also taking care of the stability and development of the system, as well as of the maintenance and administration of users, and communication with providers.

Best practices of IS management occur in transport company, however it is also purposeful to use the best global practices that have proved as successful and that are constantly being improved. One of such practices is the so-called "Information Technology Infrastructure Library", which in the period of system's existence comprises the following processes: on tactical level and operational level.

Tactical level:

1. Management of services standards;
2. Management of accessibility;
3. Management of resources volumes;
4. Management of succession;
5. Management of finances.

Operational level:

1. Management of configurations;
2. Management of prompts registration service;
3. Management of incidents and problems;
4. Management of modifications;
5. Management of versions.

The above-mentioned processes are not all required and not for all transport institutions prises necessary – however each of them can also be used for the management of a concrete system. The following scheme is required for the attainment of desirable state of the system (Fig. 1).

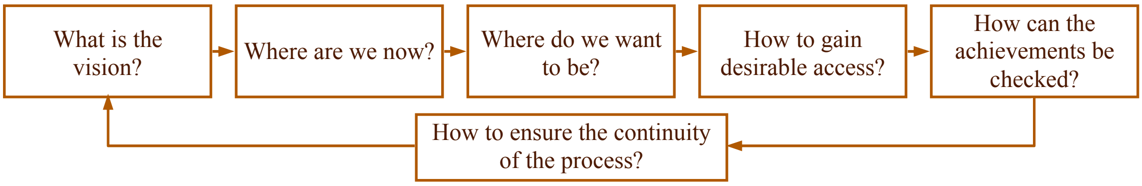

Figure 1. Scheme is required for the attainment of desirable of the system

This process includes several the above-indicated stages – identification of vision, short description of existing situation, definition of directions, action plan and creation of system for checking of condition.

4. The Application of Technologies in Traffic Management and Control in Railways

Perspective technological solutions should be first of all implemented on the main railway sections thus enabling the reduction of amounts of road installations on side tracks and allowing maximum use of microprocessor equipment at stations and locomotives, meeting European requirements, ISO and other reliability and safety standards. This should enable a centralised management basing on the implementation of a computer network and data transmission system, the use of discrete information transmission channels, including the optical fibre and radio communication. For the replacement of the old equipment it is necessary to:

- implement European traffic management and safety systems by leaving the existing automatic locomotive signalling code transmission track road system (TTRS);
- semiautomatic blocking (SAB) installed on certain rail road sections by automatic blocking (AB) in the entire railway sector. The AB should improve the control of train movement between stations on side tracks, provide quicker possibility for restoring normal train traffic after rail road equipment disorders (damages), increase passing capacity of trains – in fact the passing capacity on double-track lines with automatic blocking and electric centralisation of switches at stations should increase up to 220 couples of trains per 24 hours, which is by 2.5 times more than with the semiautomatic blocking.

For the evaluation of AB advantages over the SAB, regarding the passing capacity, certain methods can be applied. Limitary passing capacity of single track side track section between stations in case of semiautomatic blocking is calculated by the following formula:

$$\Pi = v/(L+l), \tag{1}$$

where v – the average speed of the train between stations, km/h; L – the length of the stretch between stations, km; l – the average length of the train, km.

In case of double-track railway road the passing capacity increases twice as much.

The increase of passing capacity of three-digit automatic road blocking is calculated by the following formula:

- for double-track side track section between stations:

$$\Pi = 2(v/(2L_{BR}+l)); \tag{2}$$

- for single track side track section between stations:

$$\Pi = 2(vn/(2L_{BR}(n-1)+l+L)), \tag{3}$$

where n – the number of trains starting one by one in the same direction (the traffic of opposite direction trains being stopped); L_{BR} – the length of blocking section of side track in AB case.

These formulae are correct under the condition that side track roads are divided into blocking sections of equal length. If these lengths differ, then in the formula (3), instead of $2L_{BR}$, is inscribed the largest length of two the nearest adjacent blocking sections of the side track. Then the formula (2) will be as follows:

$$\Pi = \left(v/\left(L_L + l\right)\right) + \left(v/\left(L_N + l\right)\right), \tag{4}$$

where L_L and L_N – the maximum lengths of two adjacent blocking sections on rail roads of odd and even routes.

5. The Application of Technologies in the Field of Traffic Safety

The research deals with the implementation of one of the traffic safety and control systems – the locomotive safety system – in traction force operating at Lithuanian railways. This is the Locomotive safety system ALSN. Table 1 presents the main functions of ALSN system.

Table 1. Functions of the ALSN system

1) reception of codes of road light signals
2) reiteration of signals by the locomotive light signals
3) drivers watchfulness control
4) indication of time
5) factual speed of the locomotive, km/h

With ALSN system implemented, such registration is performed with the help of 3SL-2M speed-indicator, contact and registration equipment. This speed-indicator is electromechanical.

The equipment of speed-indicator is applied during the movement of locomotive for the registration of the following components:

- on/off electric air valve (EAV) condition;
- the moment of applying the warning handle;
- reading of locomotive light signals;
- speed of the locomotive;
- time.

Grounding of implementation of new technologies and expected economic and social effect. The main objective of implementation of new technologies in railways means not only the economic efficiency, but also the improvement of traffic safety and traffic management, due to the fact that Lithuania is obliged to reach EU standards in the field of traffic safety and traffic management.

Modernisation of telecommunications, signalling and electric supply in Lithuanian railway network will enhance the supply for railway transport. Together with the change in supply, the demand tends also to change and influence the traffic in the following way:

- the transit mode to which investment is made acquires increased demand among people that are not using transport at all;
- users that are using other transport modes are attracted to the railway transport. The demand for railway transport is influenced by as follows: transportation (travel) costs, quality and travel time.

Demand for freight transportation is influenced by the following factors: tariffs, travel time, value-added services.

Modernisation of railway network boosts transport capacities and reduces travel/transportation time, as well as extends traffic flows, which results in the growth of revenues from transportation tariffs.

Benefits of implementation of new technologies:

Direct benefit

1) Railway tariffs.

Due to investments, the enhanced passing capacity of main railway corridors will enable delivery of better quality services.

2) Economy of expenditure on staff maintenance.

Railway modernisation will enable reorganisation of labour force both in stations and other railway units, and will allow the discharging of unnecessary staff.

Because of the high level of the technologies a demand will grow for more qualified labour force.

Indirect benefit

1) Reduction of freight transportation time; the reduction of transportation time contributes to the growth of traffic intensity.

2) Reduction of time intended for freight transportation influences cost of production: storage will need less warehousing of goods and less time, which will result in more efficient reaction to market demands; decrease of railway traffic accidents.

6. Conclusions

1. The article shows that for the successful creation of Information Systems the following factors are particularly important: user's workplace, ergonomics of IS, operational convenience of the system, amount of errors and other aspects of the workplace.
2. The analysis made in the article shows that perspective technological solutions should be first of all implemented on the main railway sections thus enabling the reduction of amounts of road installations on side tracks and allowing maximum use of microprocessor equipment at stations and locomotives, meeting European requirements, ISO and other reliability and safety standards.
3. For the evaluation of automatic blocking advantages over the semiautomatic blocking, regarding the passing capacity, certain methods can be applied. Limitary passing capacity of single track side track section between stations in case of semiautomatic blocking is calculated by the following formula: $\Pi = v/(L + l)$.
4. The main objective of implementation of new technologies in railways means not only the economic efficiency, but also the improvement of traffic safety and traffic management, due to the fact that Lithuania is obliged to reach EU standards in the field of traffic safety and traffic management.

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EXPERT SYSTEMS FOR EVALUATING THE AIRCRAFT POWER PLANTS' TECHNICAL CONDITION

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In the given paper there are considered some types of diagnostics systems: mathematical, stochastic and logical, which can be used in developing expert systems for evaluating the aircraft power plants' technical state as demonstrated by the engines TB-3-117 and PS-90A

Keywords: air gas-turbine engine, technical maintenance, control of parameters, automated diagnostics system, expert system, decision-making system, diagnostics matrix

1. Introduction

The specific features of modern air gas-turbine engines (GTE) are the complexity of their construction, wide application of automated electric systems, of developed mechanization and of sophisticated laws of control for achieving the required characteristics. Also these modern engines are expected to demonstrate high results in resource, reliability, flights safety and economic efficiency at minimum maintenance expense and labour consumption.

In the process of its exploitation, an engine may appear in one of the multitude of its technical states but the only acceptable state in which it should stay during the flight is that of a good working order. Failures of the technical means of aviation depend on many reasons, which cannot be interpreted as major or minor ones in advance. It makes us to treat failures and the time of their occurrence as random factors and values, which depending on the case, may be different and we cannot know this difference beforehand. The process of failures' development, occurrences of defects and faults present some random function and the character of the failure manifestation may be continuous, sudden, and the most dangerous case is when continuous manifestation immediately changes into sudden. The nature of the failures' occurrence is complicated enough because, as a rule, it is the result of coincidence of several unfavourable factors – overloads, deviation from the programmed modes of performance, outside conditions and the like, all of which are characterized by different casual relationships of different degree and nature resulting in sudden overloads, which greatly exceed the programmed values [1]. Such character of the failures' manifestation complicates their forecasting.

High sophistication of the aviation technical means suggested a great variety of the methods of controlling and diagnosing GTE, both instrumental and mathematical methods included.

For measuring the engine technical status condition, there are also used automated onboard and ground systems of controlling and diagnosing the engine parameters. Diagnosing by the thermo-gas-dynamic parameters (temperature, air consumption, pressure, etc.) is one of the most widely used and efficient methods of measuring the engine status condition since the relationship of the measured thermo-gas-dynamic parameters with the engine modules' characteristics is determined and can be described in terms of either physical or statistical models of different sophistication level. In the systems of automated diagnosing GTE [2] there are traditionally applied the algorithms of mathematical models' identification for detecting faults in the get flowing part of the engine and the algorithms of trend-analysis for defining the tendencies of the measured parameters time changes. Identification of a mathematical model is determining the discrepancy between the parameters' measured and programmed values. Application of the trend-analysis procedure to the parameters deviation from the programmed ones allows determining the regularities of their change with the account of random measurement errors.

In modern practice of analysing and processing information, the majority of diagnosis tasks is sorted out by a human operator, who takes decision about the status condition of the aircraft system and its system management in the course of exploitation judging by the results of comparing the received measurements based on either flight or ground data with the set values of the controlled parameters change. All this requires from the specialist deep knowledge of the engine and its control systems. Actually, the experience of a highly qualified specialist allows to take the decision about the engine status condition. Knowledge of highly qualified specialists, experts in their sphere, may be set in the expert systems (ES). But we cannot solve the task diagnostics completely using only the experts' knowledge of ES.

One of the promising trends of the GTE effective control and diagnostics is application of complex intellectual computer technologies, namely, the systems based on different knowledge of hybrid ES [3]. Hybrid ES present different types of knowledge, such as conceptual, expert and fact-graphic, and the corresponding methods of their processing.

The main task in developing hybrid systems is to find the best combination of different forms and methods of knowledge processing in the process of taking decisions of the diagnostics ES, that is the actual task of the present paper is research of an optimal combination of different mechanisms for processing knowledge with the aim of increasing quality, mobility and efficiency of ES in solving the tasks of the GTE diagnostics and control under the condition of uncertainty.

Integration of the ES in the onboard system of the engine control and diagnostics and in the ground automated control systems allows efficient evaluation of the GTE status condition in the current moment and revealing the correspondence of its parameters to the tactical-technical requirements, and working out recommendations for its further exploitation if necessary.

Development of information technologies of monitoring and managing the GTE exploitation is the process suggesting some particular methodology of using the a priori and a posteriori information about the object, measuring, computing and corporate means making up the resources of the monitoring information technologies and different mathematical methods of solving the tasks of processing and analyzing the information about the engine status condition as well as of taking decisions to achieve the aims of monitoring and its exploitation management [4].

2. Requirements to the Expert System of the Air Engine Diagnostics and Control

One of the promising means of providing the GTE effective control and diagnostics is application of complex intellectual computer technologies, namely, the systems based on different knowledge of hybrid ES, including such knowledge as: conceptual knowledge saved in conceptual knowledge base (CKB); experts' knowledge saved in expert knowledge base (EKB) and precedents (scenarios of behaviour) saved in precedents knowledge base (PKB).

A hybrid ES should include the following functional parts:

- A database storing pattern and actual data about the process, the results of their comparison, GTE conceptual, info-logic an physical models;
- Knowledge base (KB): statistic (knowledge is stored in the form of expert knowledge (product) and formulas, facts, dependencies, tables of notions of a particular subject sphere), dynamic (knowledge is stored as combined models in the form of pattern dynamic processes with the account of partial or complete uncertainty of the diagnostics parameters);
- A mechanism (machine) of logical deduction based on algorithm of generating causal relationship events in the functional-structural model;
- An adaptation mechanism coordinating the performance of the data bases (DB and KB) in the process of logical deduction depending on the situation;
- A mechanism of explanation which is actually the interpretation of the logical deduction process;
- A planner coordinating the process of solving tasks;
- A decider which allows finding effective decisions in the direct, reverse and mixed order of tasks.

Content, forms and algorithms of presenting information in a hybrid ES may vary according to the complexity of the modelled situation, specifics and individual characteristics of the user. Figure 1 presents the structure of the ES interaction with the object of diagnostics: air engine and expert (a person making final decision).

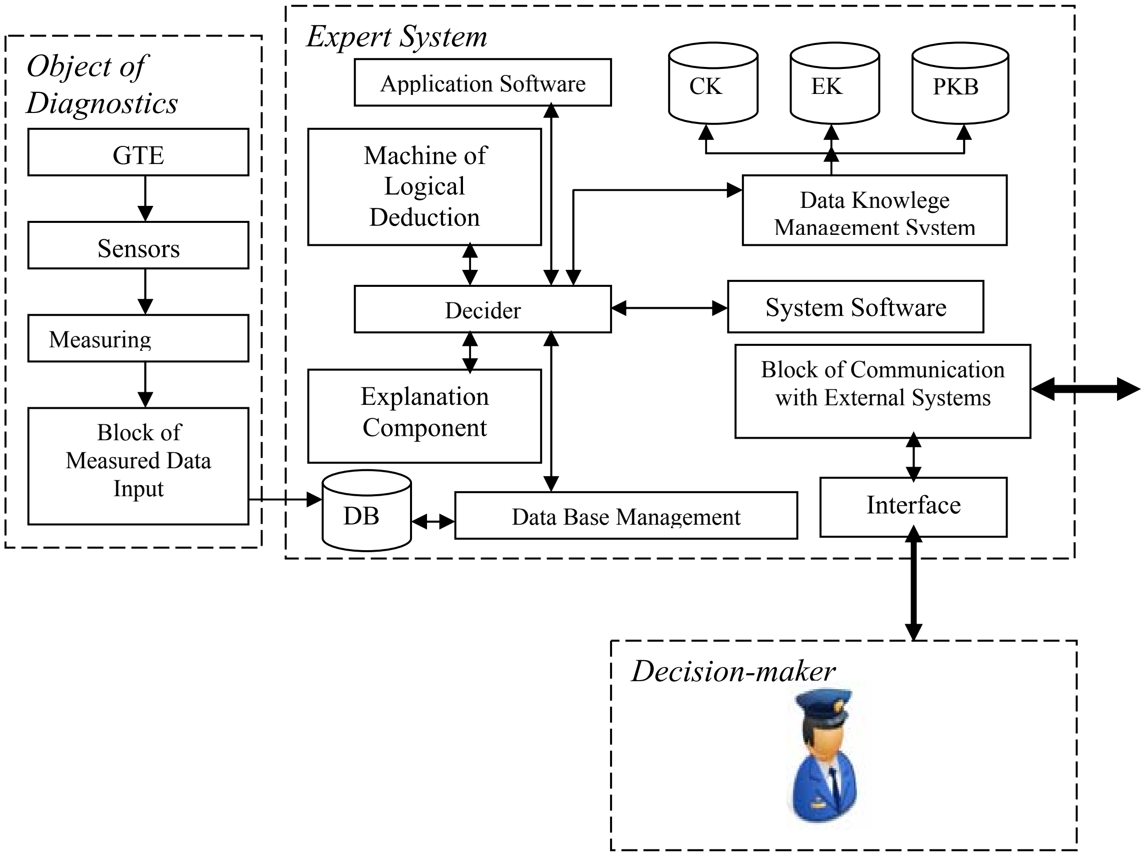

Figure 1. Structure of the expert system of monitoring the GTE status condition

A diagnostic task, in its general case, is the task of revealing the degree of correspondence of the technical object to the necessary requirements and we can differ between two main tasks: a direct diagnostic task or the task of controlling the technical condition and a reverse diagnostic task or the task of detecting the fault.

A diagnostic model is any knowledge used in the process of solving a diagnostic task and presented in a particular form. Each diagnostic model used to reveal the defect is required for:

- building the algorithms of diagnosing;
- building a pattern model of the diagnostics object.

In solving a reverse task, which is search and detection of the defect, the knowledge base should normally include three types of knowledge [3] considered above.

Knowledge of possible defects, of their causes and of their direct and indirect indicators. A separate defect is not an isolated phenomenon; therefore, in a multitude of possible defects there exist different relations which are of a casual relationship and time character.

Knowledge of the structural organization of the diagnostics object. This is knowledge of the functional processes occurring in the object of diagnostics. Functional processes describe the dynamics between the elements of the diagnostics object.

Knowledge of the possible diagnostics experiments. A diagnostic experiment is the process of evaluating the diagnostic indicators (DI*)* under the preset conditions with the aim of localizing defects. The main ways of measuring DI: measurement, control, replacement of the suspected elements in the diagnostics object for the a priori reliable ones, check of the suspected elements on the a priori reliable object, monitoring the object of diagnostics reaction in exerting a managing impact, etc.

Unfortunately, it is actually impossible to formalize all the three types of knowledge in one diagnostic model, that’s why we use some particular models. These are models in which the volume of one of the types of diagnostic knowledge is incomplete. Thus, in ES, there are used some particular models to present all the three types of knowledge.

3. Diagnostic Models in an Expert System

Let us consider some particular diagnostic models, which are used in ES. If there are given the identifiers of possible defects, there is admitted the existence of the method of measuring the DI vector and there are specified the required a priori probabilities, then for searching we can use Bayes' scheme according to which the decision about the current single defect is taken on the biggest value of the a posterior probability.

Bayes' formula for a set of attributes looks as follows [4]:

$$P(D_i / K^*) = \frac{P(D_i)P(K^* / D_i)}{P(K^*)}, \tag{1}$$

where *P(Di / K*)* – the probability of diagnosis D_i after the results of examination by the set of attributes *K* have become learnt; $P(D_i)$ – a preliminary probability of diagnosis *Di* (by the prior statistics). Formula (1) refers any of the n possible conditions (diagnoses) of the system.

To determine the probability of diagnoses by Bayes' method, it is necessary to build a diagnostic matrix (see table 1, which is formed on the basis of the prior statistics. This table contains the probabilities of the attributes' grades under different diagnoses.

Table 1. Diagnostic matrix by Bayes' method

D_i	Attribute k_j									$P(D_i)$
	k_1			K_2				K_3		
	$P(k_{11}/D_i)$	$P(k_{11}/D_i)$	$P(k_{21}/D_i)$	$P(k_{21}/D_i)$	$P(k_{22}/D_i)$	$P(k_{23}/D_i)$	$P(k_{24}/D_i)$	$P(k_{31}/D_i)$	$P(k_{32}/D_i)$	
D_1	0.8	0.2	0	0.1	0.1	0.6	0.2	0.2	0.8	0.3
D_2	0.1	0.7	0.2	0	0	0.3	0.7	0.1	0.9	0.1
...	...	...	...	...	...	...		...	...	...

The diagnostic matrix (DM) includes the diagnoses' a priori probabilities. The process of learning by Bayes' method is the DM formation. It is important to envisage the possibility of précising the table in the process of diagnosing. For this, the computer memory should store not only the values *P* (k_{js} / D_i) but the following values as well:

- N – total number of objects used for building the DM;
- N_i — number of objects with diagnosis D_i;
- N_{ij} – number of objects with diagnosis D_i examined by attribute k_j.

When a new object with diagnosis D_{μ}, enters we perform correction of the previous diagnoses' a priori probabilities like follows:

$$P(D_i) = \begin{cases} \dfrac{N_i}{N+1} = P(D_i)\dfrac{N}{N+1}, \; i = 1,2 \ldots n, \quad i \neq \mu \\ \dfrac{N_\mu + 1}{N+1} = P(D_\mu)\dfrac{N}{N+1} + \dfrac{1}{N+1}, \; i = \mu \end{cases}$$

Further corrections are made for the attributes' probabilities. Let a new object with diagnosis D_μ reveal the *r* grade of attribute k_j. Then for further diagnostics, we admit new values of the probability of intervals for attribute k_j under diagnosis D_μ:

$$P(k_{js} / D_\mu) = \begin{cases} P(k_{js} / D_\mu)\dfrac{N_{\mu j}}{N_{\mu j} + 1}, \; s \neq r \\ P(k_{jr} / D_\mu)\dfrac{N_{\mu j}}{N_{\mu j}} + \dfrac{1}{N_{\mu j} + 1}, \; s = r \end{cases}$$

Conditional probabilities of attributes under other diagnoses do not need correction.

Another scheme of the defects' search and localization uses diagnostic methods. DM are built on the basis of the engine mathematical model, which is received by the method of small deviations [5]. The paper [5] shows the possibility of diagnosing the TB7-117C engine free turbine by the thermo-gas-dynamic parameters with the help of diagnostic matrixes. A diagnostic model includes the list of possible defects and the decision on defect presence is made by comparing the pattern vector of diagnostic parameters (engine in good order) with the current vector of the engine diagnostic parameters.

These models describe the first and the third type's knowledge suggesting that the second type knowledge is known. The main efforts in developing these models are connected with solving the tasks of the role of the diagnostic parameters' vector elements. The vector must be such that it could provide the level of the defects' differentiating. This causes the necessity of examining the engine performance peculiarities in good and faulty orders.

To analyse and determine the engine status condition, there are built **logical models** of diagnosing the air engine built on the principle — "combination of elementary failures"→ "change of the system condition characteristic value" and "elementary failure"→ "change of values of the system condition characteristics' set".

Let us take as an object diagnosing the air engine PS-90A. For the characteristics of its condition, it would be reasonable to choose the following diagnostic attributes: z_1 is efficiency (E) of the ventilator; z_2 — efficiency of the low pressure compressor; z_3 — efficiency of the low pressure turbine; z_4 — efficiency of the high pressure turbine; z_5 — efficiency of the low pressure turbine; z_6 — efficiency of burning; z_7 — area of the first contour nose device; z_8 — area of the second contour nose device; z_9 — area of the jet nose; z_{10} — loss factor of full pressure; z_{11} — air collection; z_{12} — factor of providing full pressure in the combustion chamber; z_{13} — degree of the compressor compression; z_{14} — capacity of the high pressure turbine; z_{15} — temperature of the high pressure turbine; z_{16} — temperature of the low pressure turbine; z_{17} — capacity of the low pressure turbine; z_{18} — working pressure; z_{19} — thrust; z_{20} — factor of the jet nose losses; z_{21} — factor of the burning completeness.

Experience shows that the most frequent failures, which occur in the engine PS-90A, are the following: obstructions *(X_1);* change of geometric characteristics *(X_2),* change of the surface condition (X_3); chop offs (X_4); tear offs (X_5); burn down (X_6); destructions (X_7); soiling (X_8); change of the surface roughness *(X_9);* damages *(X_{10});* change of the letting in section area *(X_{11});* extra coking *(X_{12}).*

The subsystems of the air engine PS-90A as of the diagnostics object are the following places of failures occurrence (breaks, faults): The ventilator blades (c_1); blades' profile of the ventilator working wheel (c_2); blades' profile of the ventilator guide apparatus (c_3); ventilator rotor (c_4); ventilator stator (c_5); blades profile of the low pressure compressor (c_6); blades profile of the high pressure compressor (c_7); blades of the low pressure compressor (c_8); blades of the high pressure compressor (c_9); blades profile of the high pressure turbine nose apparatus (c_{10}); working blades profile of the high pressure turbine (c_{11}); blades profile of the low pressure turbine nose apparatus (c_{12}); working blades profile of the low pressure turbine (c_{13}); working blades of the high pressure turbine (c_{14}); blades of the high pressure turbine nose apparatus (c_{15}); working blades of the low pressure turbine (c_{16}); blades of the low pressure turbine nose apparatus (c_{17}); walls of the combustion chamber (c_{18}); sprayers (fuel burners) *(c_{19});* combustion chamber (c_{20}); labyrinth condensations and communications of the cooling air collection and supply (c_{21}); jet nose (c_{22}); letting in section of the outside contour (c_{23}).

To give simplicity and objectivity to the logic models of diagnosing, we are going to introduce the following conditional designations of the air engine condition characteristics' changes: ↓ — decrease; ↑ — increase; ↓↑ — deviation from the pattern level in this or that direction.

With the account of the fact that one and the same combination of elementary failures may result in simultaneous change of values of several diagnostic attributes of the air engine, a logic model built on "combination of elementary failures" → "change of values of the system condition characteristics", can be presented as follows:

$$X_1(c_1) \vee X_2(c_2) \vee X_2(c_3) \vee X_3(c_4) \vee X_3(c_5) \to D(z_1, \downarrow);$$
$$X_2(c_6) \vee X_4(c_8) \to D(z_2, \downarrow);$$
$$X_2(c_7) \vee X_4(c_9) \to D(z_3, \downarrow) \wedge D(z_{13}\ \downarrow\uparrow);$$
$$X_2(c_{10}) \vee X_2(c_{11}) \vee X_5(c_{14}) \vee X_5(c_{15}) \vee X_8(c_{19}) \to D(z_4, \downarrow) \wedge D(z_{14}, \downarrow) \wedge D(z_{15}, \uparrow);$$
$$X_2(c_{12}) \vee X_2(c_{13}) \vee X_5(c_{15}) \vee X_5(c_{16}) \vee X_5(c_{17}) \to D(z_5, \downarrow) \wedge D(z_{16}, \uparrow) \wedge D(z_{17}, \downarrow);$$
$$X_8(c_{19}) \vee X_{12}(c_{19}) \to D(z_6, \downarrow) \wedge D(z_{18}, \downarrow);$$
$$X_2(c_{10}) \vee X_8(c_{19}) \vee X_9(c_{20}) \vee X_{12}(c_{19}) \to D(z_7, \downarrow);$$
$$X_2(c_{11}) \vee X_2(c_{13}) \vee X_8(c_{19}) \vee X_9(c_{20}) \to D(z_8, \downarrow);$$
$$X_2(c_{13}) \vee X_5(c_{14}) \vee X_5(c_{15}) \vee X_5(c_{17}) \to D(z_8, \uparrow);$$
$$X_{10}(c_{22}) \to D(z_9, \downarrow) \wedge D(z_{19}, \downarrow) \wedge D(z_{20}, \downarrow\uparrow);$$
$$X_9(c_{23}) \vee X_{11}(c_{23}) \to D(z_{10}, \downarrow) \wedge D(z_{19}, \downarrow);$$
$$X_7(c_{21}) \to D(z_{11}, \uparrow) \wedge D(z_{15}, \uparrow);$$
$$X_6(c_{18}) \vee X_7(c_{18}) \vee X_8(c_{19}) \vee X_9(c_{20}) \vee X_{12}(c_{19}) \to D(z_{12}, \downarrow) \wedge D(z_{21}, \downarrow\uparrow).$$

A logic model of diagnosing the air engine PS-90A, based on the scheme “elementary failure” → “change of values of the system condition’s set of characteristics”, looks as follows:

$$X_1(c_1) \to D(z_1, \downarrow)$$
$$X_2(c_2) \to D(z_1, \downarrow)$$
$$X_2(c_{21}) \to D(z_1, \downarrow)$$
$$X_3(c_4) \to D(z_1, \downarrow)$$
$$X_3(c_5) \to D(z_1, \downarrow)$$
$$X_2(c_6) \to D(z_2, \downarrow)$$
$$X_2(c_7) \to D(z_3, \downarrow) \wedge D(z_{13}. \downarrow\uparrow);$$
$$X_4(c_8) \to D(z_2, \downarrow)$$
$$X_4(c_9) \to D(z_3, \downarrow) \wedge D(z_{13}, \downarrow\uparrow);$$
$$X_2(c_{10}) \to D(z_4, \downarrow) \wedge D(z_{15}, \uparrow) \wedge D(z_{14}, \downarrow) \wedge D(z_7, \downarrow\uparrow);$$
$$X_2(c_{11}) \to D(z_4, \downarrow) \wedge D(z_{15}, \uparrow) \wedge D(z_{14}, \downarrow) \wedge D(z_8, \downarrow);$$
$$X_2(c_{12}) \to D(z_5, \downarrow) \wedge D(z_{16}, \uparrow) \wedge D(z_{17}, \downarrow);$$
$$X_2(c_{13}) \to D(z_5, \downarrow) \wedge D(z_{16}, \uparrow) \wedge D(z_{17}, \downarrow) \wedge D(z_8, \downarrow\uparrow);$$
$$X_5(c_{14}) \to D(z_4, \downarrow) \wedge D(z_{15}, \uparrow) \wedge D(z_{14}, \downarrow) \wedge D(z_7, \uparrow) \wedge D(z_8, \uparrow);$$
$$X_5(c_{15}) \to D(z_4, \downarrow) \wedge D(z_{15}, \uparrow) \wedge D(z_{14}, \downarrow) \wedge D(z_5, \downarrow) \wedge D(z_{16}, \uparrow) \wedge D(z_{17}, \downarrow) \wedge D(z_7, \uparrow) \wedge D(z_8, \uparrow);$$
$$X_5(c_{17}) \to D(z_5, \downarrow) \wedge D(z_{16}, \uparrow) \wedge D(z_{17}, \downarrow) \wedge D(z_8, \uparrow);$$
$$X_6(c_{18}) \to D(z_{12}, \downarrow) \wedge D(z_{21}, \uparrow\downarrow);$$
$$X_7(c_{18}) \to D(z_{12}, \downarrow) \wedge D(z_{21}, \uparrow\downarrow);$$
$$X_8(c_{19}) \to D(z_4, \downarrow) \wedge D(z_{15}, \uparrow) \wedge D(z_{14}, \downarrow) \wedge D(z_6, \downarrow) \wedge D(z_{18}, \downarrow) \wedge D(z_7, \downarrow\uparrow) \wedge D(z_8, \downarrow) \wedge D(z_{12}, \downarrow) \wedge D(z_{21}, \downarrow\uparrow);$$
$$X_9(c_{20}) \to D(z_7, \downarrow) \wedge D(z_8, \downarrow) \wedge D(z_{12}, \downarrow) \wedge D(z_{21}, \uparrow\downarrow);$$
$$X_7(c_{21}) \to D(z_{11}, \uparrow) \wedge D(z_{15}, \uparrow);$$
$$X_{10}(c_{22}) \to D(z_9, \uparrow) \wedge D(z_{20}, \downarrow\uparrow) \wedge D(z_{19}, \downarrow);$$

$$X_9(c_{23}) \to D(z_{10}, \downarrow) \wedge D(z_{19}, \downarrow);$$
$$X_{11}(c_{23}) \to D(z_{10}, \downarrow) \wedge D(z_{19}, \downarrow);$$
$$X_{12}(c_{19}) \to D(z_6, \downarrow) \wedge D(z_{18}, \downarrow) \wedge D(z_7, \downarrow) \wedge D(z_{12}, \downarrow) \wedge D(z_{21}, \uparrow\downarrow);$$

A logical diagnostic model reflects, by its essence, a particular diagnostic structure of the object of diagnosing but it may also include such data as: list of points of exerting work and test impacts; list of points of checking the diagnostics parameters, list of acceptable values of the diagnostics parameters; description of possibilities of the diagnostic elements' (DE) test replacements and possible manifestations of different defects of one and the same DE.

Thus, it describes sufficiently enough the knowledge of the second and third types. The logic DM participation in the diagnostic experiment is indirect: it is a means of developing an optimal algorithm for searching defects. Therefore, we should specify for it a notion of a "defect model". "Defect model" is a formalized presentation of the fact of a physical defect manifestation in the form of wrong signals' values at either entrances or exits of the logic diagnostic model DE.

4. Conclusions

The above considered diagnostics models give us three kinds of knowledge, which allow qualitative diagnosis of the air engine. The first diagnostics model (Bayes' scheme) is based the probability-statistical methods, its disadvantage is that we need quite a lot of statistical material but after that material has been accumulated, it is conductive to the correction of the other two models. The diagnostics model based on diagnostics matrixes may also in its turn bring about correction of the logical diagnostics model. Such mutual models' complementation allows full realisation of the defect search and detection and measurement of the engine technical status condition.

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DEVELOPMENT OF RIGA-MINSK TRANSPORT CORRIDOR SIMULATION MODEL

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This paper deals with the developed cargo traffic macroscopic simulation model. The goal of model development is to analyse and study Riga-Mink transport corridor. This transport corridor is an important transport arterial between Latvia and Republic of Byelorussia. The growth of goods movement between these countries also could be explained by transit characteristics of both countries. The duration of transport corridor on Latvian territory is approximately 300 km. The corridor crosses a lot of small and large cities and that is why the question of its functioning performance exists. The simulation model was developed using specialised simulation software called PTV VISION VISUM. VISUM uses the transport model that defines requirement for input data. The developed model consists of transport network model and demand model. The demand model is presented by two origin destination matrices, which have been calibrated using TFlowFuzzy algorithm. Further calibrated model has been used to estimate two development scenarios using different output data of VISUM.

Keywords: transport corridor, macroscopic model, simulation, bottlenecks, development scenarios, TFlowFuzzy

1. Introduction

For the last years relationship between Latvia and the Republic of Byelorussia has become very close. The goods turnover is increasing between these two countries [1]. The similar feature for Latvia and the Republic of Byelorussia is the fact that both are transit countries. Mainly two transport types: railroad transport and cargo auto transport are used during transportation. This paper describes the results of work on analysis of transport corridor between Riga (capital of Latvia) and Minsk (capital of the Republic of Byelorussia).This work considers only a part of this corridor from Riga to Latvia's border, it is connected with lack of data about the second part of transport corridor. The main goal of described research is to locate bottlenecks of this corridor and estimate different indexes of its functioning. Also different development scenarios should be implemented and compared using simulation models.

The simulation models are selected because of their flexibility on possibility to play different scenarios and analysis features. The traffic could be simulated on different levels [2]: microscopic, mesoscopic and macroscopic. Because of simulation object complexity and its physical distribution the microscopic models could be applied only for simulation some parts of transport corridor [3], transport nodes or control check point, but not for whole transport corridor. The mesoscopic models could simulate such distributed objects [4], but the traffic mesoscopic models are not widely used and the software for them is not available. Macroscopic transport models are specially designed for such object simulation [5] and it is possibly to use it. The disadvantage of applying macroscopic simulation is connected with aggregated state of output data.

The first section describes the simulation model in details, paying attention to the transport infrastructure, which organizes transport corridor. The second section presents the methodology of macroscopic models development and summarizes the list of data required for model construction and calibration. The third part describes the developed model and presents calibration results. The last part describes development scenarios of the transport corridor and simulation results.

2. Riga-Minsk Transport Corridor Description

Riga-Mink transport corridor connects the capital of Latvia and the capital of the Republic of Byelorussia. All the mentioned above characteristics are related to the Latvian part of corridor from Riga to the Latvia's border with the Republic of Byelorussia. The Riga-Minsk transport corridor crosses Latvia from north-west to south-east. The Figure 1 shows the transport corridor in context of Latvian transport infrastructure.

Figure 1. Transport corridor Riga-Minsk

The duration of transport corridor from Riga to Latvia's border is approximately 300 km. The main part of corridor is presented by national level road A6, which connects the biggest two cities in Latvia – Riga and Daugavpils. From Daugavpils to the border the road A6 is used. There are a lot of small and large cities, which are crossed by this transport corridor. Mostly there are no bypass roads. The bypass roads are available only for the following cities: Jekabpils, Plavinas, Daugavpils. The road from Riga to Ogre has two lanes per direction; the same is for transport corridor part from Nicgale to Daugavpils. All the rest parts of transport corridor are presented by road with one lane per direction (see Figure 2).

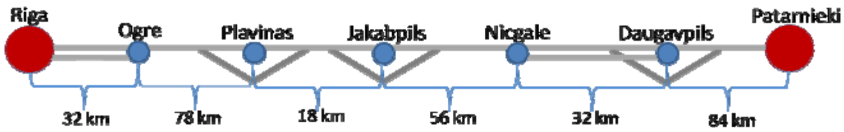

Figure 2. Transport corridor schema

The speed limits are defined by national road rules. The speed limit in city zone is 50 km/h, outside of the city zone – 90 km/h. The current traffic flow intensity is high and keeps growing. According [6] the map of intensities for different parts of transport corridor is presented in Table 1.

Table 1. Day traffic intensities for different parts of transport corridor

Road Nr.	*Road Part*	*from km*	*to km*	*2008 intensity*	*2008 CT%*
A6	Riga border - Salaspils	17.370	19.130	31416	16
A6	Salaspils - A4	19.130	22.950	20514	19
A6	A4 - Ikšķile	22.950	29.350	23204	13
A6	Ikšķile - Ogre	29.350	39.050	20154	13
A6	Ogre - Ķegums	39.050	46.980	13538	17
A6	Ķegums - Lielvārde	46.980	51.780	11734	19
A6	Lielvārde - Skrīveri	51.780	77.850	7769	22
A6	P32 - P87	77.850	87.060	9171	25
A6	P87 - Pļaviņas	87.067	117.717	7298	23
A6	Pļaviņu beltway	117.720	131.660	3198	43
A6	V996 - Jēkabpils	131.657	143.956	6871	18
A6	Jēkabpils - Līvāni	149.545	172.050	4776	18
A6	Līvāni - P64	176.170	201.736	3291	21
A6	P64 - P67	201.736	224.550	3629	21
A6	P67- P65	224.550	238.646	1893	53
A6	P65 - Krāslava	238.646	268.714	2820	17
A6	Krāslava - Boundary of Latvia	274.078	307.000	1148	31

The Table 1 defines average day traffic intensities for different part of transport corridor for 2008. The first column defines road number, the second one defines road part, the next two columns describe road kilometres, the fifth column presents average day intensity for each corridor part and the last column presents the percents from intensity of cargo (CT%).

Figure 3. The main sources of cargo traffic

The main sources of cargo traffic, which fill the transport corridor is transit traffic from Estonia and Latvian ports: Ventspils, Liepaja, and Riga. The sources are presented on Figure 3.

3. Methodology of Building Traffic Models on Macroscopic Level

For the model constructions there has been used PTV VISION VISUM software, which is one of leaders in macro modelling of transport flows. For models development system there has been used a special metamodel, which is presented on Figure 4.

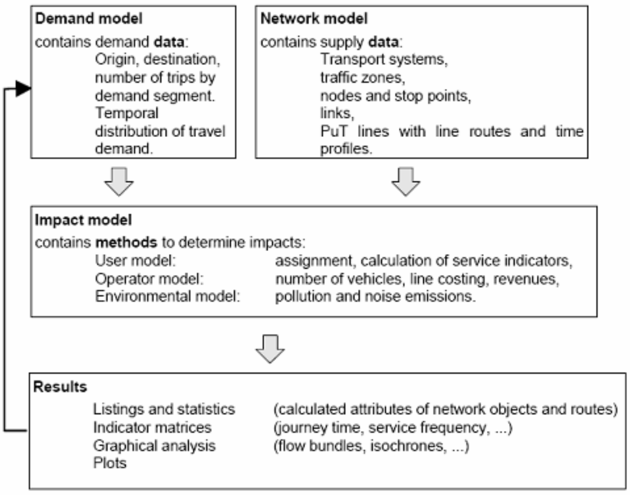

Figure 4. VISUM transport model [7]

The transport model normally consists of a demand model and a network model. The demand model contains the travel demand data. The network model describes the relevant supply data of the transport system. It consists of traffic zones, nodes, public transport stops, links and public transport lines with their timetable. The impact model takes its input data from the demand model and the network model. VISUM provides different impact models to analyse and evaluate the comprehensive transport system. VISUM displays the calculated results in graphic and tabular form and allows analysing the results graphically. In this way, for example, routes and connections per OD pair, flow bundles, isochrones and node flows can be displayed and analysed. The transport model like all models represents the abstraction of the real world. The model creation can be divided into few steps, which are described in details below.

Transport infrastructure development

This stage includes the development of the transport infrastructure using the system of special objects Nodes and Links, those objects representing roads intersections and roads accordingly. The nodes are connected with the links and in such way the transport network is implemented. Of course before constructing network the scale should be defined, allowing the program to calculate the link length automatically. Also for all links a set of the following parameters should be defined:

- Speed restriction
- Link capacity
- Allowed transport systems

Also for each node the allowed direction of moving should determined.

Zones

On this stage, the investigated object must be divided into zones. The zones of the model are represented as geometric shapes. But it should be taken into account that transport flow movement starts and ends in the zone geometric centre. It is not obligatory to define zone as the geometric shape; it could be presented as the point. Using system object called connector the zones centre must be connected with the transport network via nodes. In such way incoming and outgoing points of flow can be determined. A lot of such connections for one zone can be defined. If zone has more than one incoming/outgoing point, then the weight for each point should be defined. This weight defines the percentage of the transport flow, which uses this node for getting into the zone and getting out of the zone.

Demand model development

The demand model defines the quantity of trips between different zones, with different goals using different transport systems. But in this work there has been used only one type of transport system – private transport system and no goals are defined. So the demand model is presented only with one OD matrix (origin destination matrix), which describes the volumes of traffic flow moving from one zone to another.

4. Model Development and Calibration

According to the described above strategy the macroscopic model of transport corridor has been developed in PTV VISION VISUM 11.0 software [8]. The developed model includes not only transport infrastructure of the transport corridor, but also main national roads of the Latvia. The network infrastructure has been created using VISUM special objects called links and nodes. The network in developed models is presented by more than 60 nodes and more than 130 links of different types. The types of the links are defined by allowed moving speed. Finally only two types of links are defined:

- Links with travel speed 50 km/h – links, which represents intercity roads;
- Links with travel speed 90 km/h – links, which represents out of city roads.

Here it should be underlined that transit cargo vehicles must use bypass roads in Daugavpils and Plavinas city. The developed network model is presented on Figure 5.

Figure 5. The transport network model

The yellow links indicate the first class of link (allowed speed 90 km/h), the red one presents the second class of links (speed restriction is 50 km/h). Another important option for link, which must be defined, is the capacity of the link and transport systems. In the model only two transport systems has been used: cargo transport system and car transport system. The capacity of link should be defined taking into account that the simulation of twenty-four hours is taken. In general the capacity is also defining a number of lanes per direction. The Table 2 defines the twenty-four hours capacities for two types of link.

Table 2. The capacity of different link types

Link type	Description	One lane capacity	Two lanes capacity
R50	Speed restriction - 50 km/h	1488	2678
R90	Speed restriction - 90 km/h	26400	47520

Also the volume-delay function (VDF) should be defined for links. VISUM offer a huge set of different VDF, which differs by forms and parameters. For both types of link the following VDF called BPR [7] has been implemented:

$$t_{cur} = t_0 \cdot (1 + a \cdot sat^b)$$

$$sat = \frac{q}{q_{\max} \cdot c}$$

$$sat_{crit} = 1$$

where t_0 – free flow travel time [s],

q – traffic volume [vehicle units/time interval],

$qMax$ – capacity [car units/time interval],

t_{cur} – travel time in loaded network [s].

The values of parameters are taken by default: $a = 1$; $b = 2$; $c = 1$.

The next step of model creation is connected with transport zone definition. Transport zone is origin and destination of transport flow. The movement of traffic from and into zone happens from geometrical zone centre. But in this model the geometrical shape of the zone were not defined, because it does not influence the model. Finally 14 transport zones were defined in the model. Transport zones were connected with transport network using special VISUM objects called connectors. Necessary to underline, that movement time on connector is set to zero. The zones and connectors are presented on Figure 6.

Figure 6. Zones and connectors

As could be seen on Figure 6, totally there are 14 zones which are externally located relatively of Latvia. These zones represent main origin and destination point of transit cargo flow. As zones are defined the origin – destination (OD) matrix could be filled. The model uses two OD matrixes: one matrix for cargo transport systems, the second one for car transport system. Both of them are estimated according information from [6]. They describe traffic average twenty-four hour's traffic movement in 2008. The developed matrix could not be treated as a real one. The estimation of matrix has been done because of lack of surveys in this area. But further, estimated matrix will be replaced with calibrated one and it could be treated as a real one.

Macroscopic models in general give aggregated output data, which are mainly presented graphically or in tables. In this research we are interested in searching a bottleneck of systems and estimating different performance characteristics like average speed across transport corridor, average movement time across transport corridor. The motioned data will be presented only for cargo traffic as it is an object of research.

To assign both cargo and car flows Equilibrium assignment algorithm is used. The result of this method is assignment of traffic flows on network. The result for cargo flow could be seen on Figure 7. This Figure demonstrates twenty-four hours intensity across all links of the model. The size of diagram defines traffic volume. Of course numerical values also could be obtained. For the moment it seems strange that traffic volume from Liepaja and Ventspils to Riga is very high.

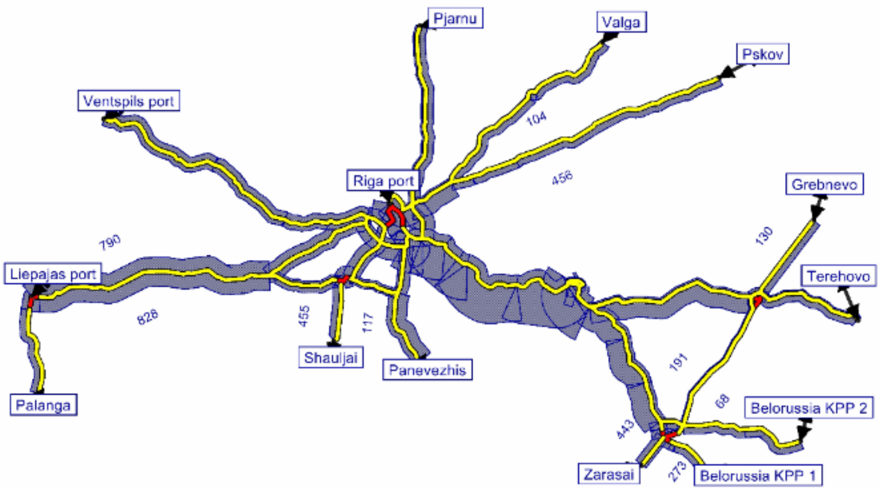

Figure 7. Cargo traffic volumes (un-calibrated matrix)

This fact assures us that estimated OD matrixes do not describe real flows from one transport zone to another. That is why the calibration of OD matrix should be used to get more realistic flow distribution. The calibration itself defines unknown or estimated parameters by comparing model output data (in our case traffic volume) with known real traffic counts in some point of transport network. These counts have been obtained by real traffic observations. Finally 20 points of counts are used to calibrate OD matrixes. TFlowFuzzy procedure has been used for calibration. The main idea of this procedure is presented on Figure 8.

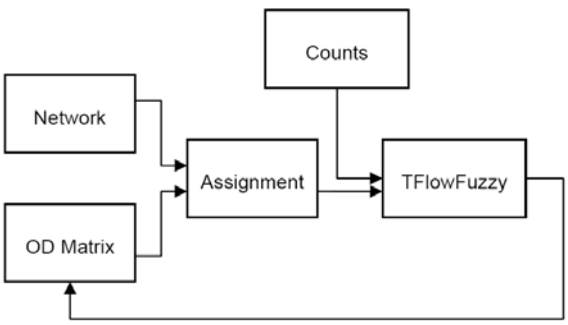

Figure 8. The main concept of TFlowFuzzy method [9]

To estimate calibration quality the R-square characteristic is used. This characteristic defines how well relationship between observed volumes and counted fit to linear relationship and to target value. The better is relationship the higher is R-square (minimum is 0 and maximum is 1)
As could be seen on Figure 9, the R-square is rather low only 0.042; after few iterations of applying TFlowFuzzy could be seen that R-square is growing and reach the level of 0.85.

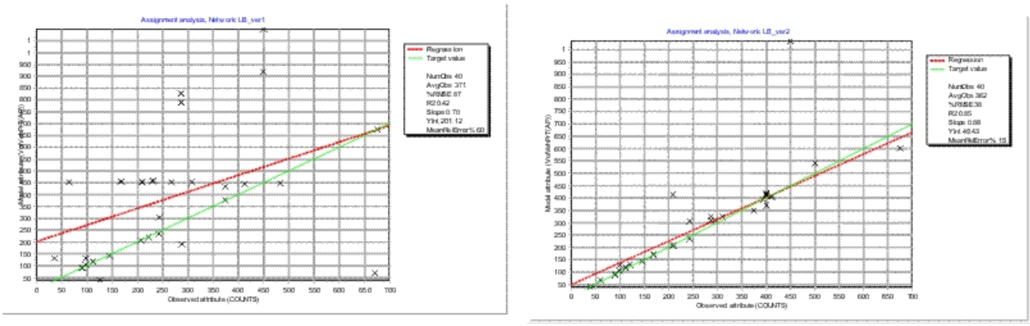

Figure 9. Dependence between simulated and real flow distribution before and after calibration

Finally after calibration procedure the flow redistribution is obtained and can be presented using Figure 10.

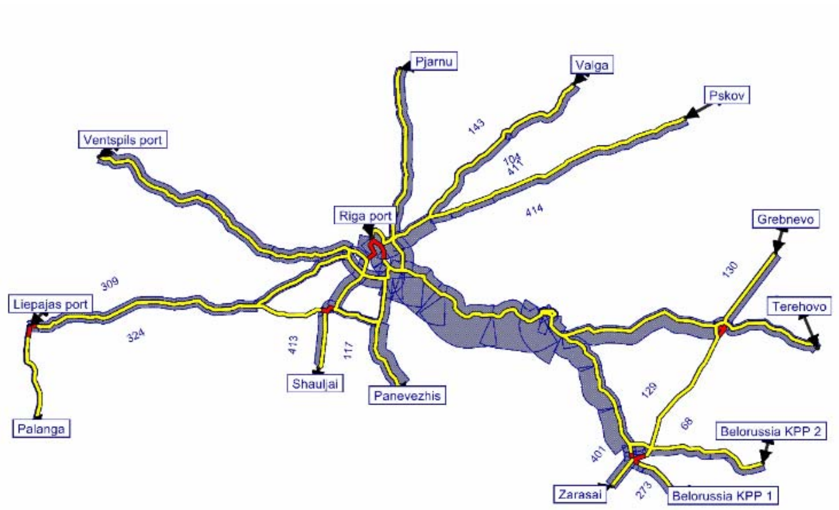

Figure 10. Cargo traffic volumes (calibrated matrix)

5. Scenario Development and Result Analysis

According to project tasks different scenarios development is considered of this corridor. In general scenarios could include the following changing factors:

- Quality of transport infrastructure – this could be simulated by increasing or decreasing capacity of some parts of transport corridors. Also new roads could be added to the model with defined options (like capacity, free flow speed and so on).
- Traffic volumes – this point is mostly oriented on changing existing origin-destination matrix.
- Quality of transport infrastructure and traffic volumes – both changes are allowed in scenarios.

We describe the scenarios, which include only changes of traffic volumes in this paper. The first scenario implies growing of traffic volumes by 50% relating to cargo OD matrix of 2008. The second scenario includes the traffic volumes by 100% relating to cargo OD matrix of 2008. But changes affect only direction to Byelorussia control check point.
To estimate the performance of transport corridor functioning the following indexes are used:

- Volume capacity ration – in general this characteristic describes the loading level of roads. This characteristic is calculated like ratio between capacity of the link and traffic volume on this link.

- Average travel speed – the average speed for transport corridor from Riga to control check point Patarnieki, measured as kilometres per hour.
- Average travel time – the journey time in minutes from Riga to border control check point Patarnieki

1st scenario **2nd scenario**

Figure 11. Loading level of different parts of transport corridor

Figure 11 demonstrates the loading level by cargo transport of transport corridor parts. The red colour presents the loading level higher than 20%, the yellow one loading level between 5% and 20% and the green colour is less than 5%. Analysing this diagram it can be concluded that the part of transport corridor from Riga to Jekabpils in direction from Riga is loaded much by cargo vehicles. The loading level of the opposite direction of this area is smaller and it seems that it does not bring any problems. The remaining part of the corridor is loaded on average or small level. Also the fact of loading level decreasing near the Daugavpils is connected with transport infrastructure two lanes per direction. The average loading level of transport corridor is approximately 13 % in both directions. It seems that there are no considerable changes in loading level of transport corridor. The high level loading of the Riga-Jekabpils part is in direction from Riga. Numerically there are some changes, which lead to average transport corridor loading level decreasing to 10%. This result confirms us that the analysed transport corridor plays a notable role in transit not only in direction from Riga to Minsk, but including another routes as well.. So it should be taken into account that the road renewal and updating is to be done according to modern conditions. Comparing such characteristics as average travel time and average speed for transport corridor across all scenarios and base model it can be concluded that there are no considerable changes in different scenarios. Average speed difference between directions is for base model 6 km\h, for first scenario 11 km/h and for the second one approximately 6 km/h. It is connected with rather small loading level of Patarnieki-Riga direction. The changes across scenarios are small and do not reach 5 km/h. The reason is a very high level of loading of transport corridor part near Riga. Average travel time can reach 5 hours to get from Riga to border control check point. In general travel time for the first scenario is the highest and gives already mentioned maximum 5 hours. In the second scenario an average travel time is decreased approximately up to 20 minutes.

The analysed model output data assure us that transit growth across Latvia will lead to increasing of loading level of transport corridor and can lead to increasing a travel time. The bottleneck of the system could be treated at the part of transport corridor from Riga to Jekabpils, also road A5, which connects left and right land near the Salaspils city. But some recommendations on roads renewal activity should be given, for instance:

- to organize additional bypass roads;
- to reconstruct existing roads to increase average travel speed;
- widening of roads to give possibility for cargo transport increase their speed.

6. Development Analysis on the Basis of Merging Macro and Micro Simulation

The results of macro-simulation presented above have aggregated characteristics and could be used only in the strategic level of decision support. To get more detailed results the use of micro-simulation - it is required. The micro-simulation could be used only for simulation some transport nodes. That is why according macroscopic simulation results two nodes have been selected for detailed analysis. The loading level of these nodes is high and could be treated as bottleneck of the systems according the macroscopic analysis. The first node – it is a border control check point and the second one is a road A5, which connects left and right land near the Salaspils city. The main idea of micro and macro simulation could be presented on the Figure 12.

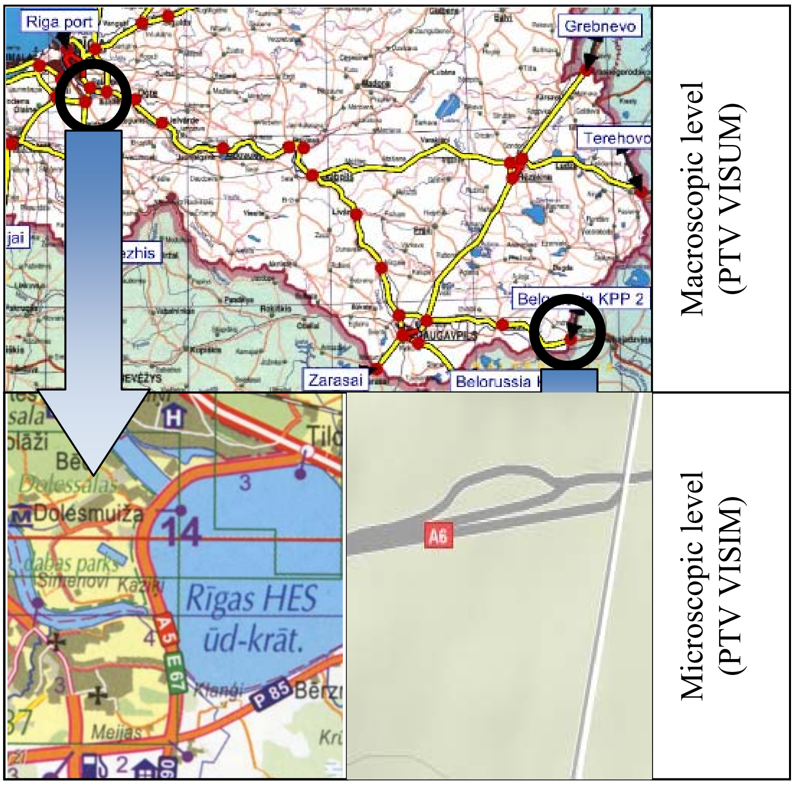

Figure 12. Relationship between macro and micro-simulation

The data required for the transport node simulation on microscopic level could be described as follows:

- Number of lanes
- Lanes width
- Road location high level
- Allowed speed
- Transport flow structure
- Flow intensity or OD (origin-destination) matrix
- Priority rules
- Traffic lights parameters
- Acceleration function
- Deceleration function

The macro simulation results give only flow intensity and transport flow structure. All another input data should be defined using direct observation of transport node infrastructure.

7. Conclusions

This paper demonstrates the approach of transport corridor functioning analysis using macroscopic simulation. The macroscopic model has been developed and calibrated using PTV VSION VISUM software on the basis of the TFlowFuzzy method. According project tasks two scenarios have been implemented and tested using developed simulation model. The loading level diagrams concern as that there are some bottleneck in the transport corridor Riga-Minsk. As the bottleneck of the system could be treated the part of transport corridor from Riga to Jekabpils in direction from Riga. The loading level in

this area is more than 20% for cargo traffic flow. Also as the bottleneck the road A5, which connects right and left land near the Salaspils, is considerable.
The capacity border control check point requires additional detailed analysis. This analysis could be performed using microscopic simulation. The next step of this work is a development of microscopic models of transport corridor parts and the border control check point to get more exact results. These models will allow estimating its capacity and will help to define different characteristics like passing time, average queue length, maximal queue length and so on. The microscopic models will be implemented using PTV VISION VISSIM software and as the input data will use output data from developed macroscopic model.

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- **Publications :** for 2002-2010 years - 4 books, 91 scientific papers, 21 international conferences
- **Orgazitional activities :** Member of editorial board in international scientific journals: Informatica (Slovenia, www.informatica.si), International Journal of Advanced Statistics and IT&C for Economics and Life Sciences (Romania), Montenegrian Journal of Economics (Crna Gora, www.mnje.com)

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- **Publications : 7** books, 49 scientific papers, 11 international conferences

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- **Publications:** 16 scientific papers.
- **Fields of research:** applied statistical analysis, modelling and simulation.

CUMULATIVE INDEX

TRANSPORT and TELECOMMUNICATION, Volume 11, No 1, 2010 (Abstracts)

Grakovski, A., Ovchinnikov, V., Kamenchenko, S. Acoustic Signals Processing and Appliance for the Problem of Traffic Flow Monitoring, *Transport and Telecommunication*, Vol. 11, No 1, 2010, pp. 4–10.

The increase of road traffic in the European Union focuses for creating intelligent transportation systems of traffic control in local, urban and regional level. The possibility of using acoustic sensors for traffic intensity measurements are discussed in this article. Acoustic signal detector, such as an ordinary household microphone, is used as the most inexpensive sensor version for stationary and mobile traffic surveillance systems. The examples of the acoustic signals records from different types of road vehicles in various weather conditions are described here.

The simplified modification of acoustic microphone's signals spectral processing algorithm and noise filtering are solved. Detection of moving road vehicles results, using records for their acoustic signals, is also discussed. The restrictions of using acoustic sensors to estimate traffic parameters are established.

Keywords: intelligent transport system, transport flow surveillance, vehicle detecting, acoustic signal, digital signal processing

Grishin, S., Schiptsov, O. Urban Transport Ecology Factors, Ecological Projects, and Their Impacts on the Ecological Situation in Latvia, *Transport and Telecommunication*, Vol. 11, No 1, 2010, pp. 11–18.

Transport and industry are among the most important factors influencing the contemporary ecological situation. The analysis of this influence is impossible without monitoring the conditions of change in the environment. In different countries, measures of ecological regulation have been undertaken. These require significant expenditure. One of the most interesting projects concerning ecological regulation and the comparative analysis of ecological risk is 'The Californian project'. In this project, proposals on the economic criteria for evaluating the measures of risk reduction have been developed.

Attention is drawn to different programs used to monitor the ecological situation in Latvia. In the research the analysis of 10-12 years of statistical data is carried out. Data analysis suggests a tendency towards an improvement in the ecological situation. In Latvia, the mechanisms for financing ecological programs, which are aimed at decreasing the levels of harmful pollution in the atmosphere, are based on the experience of the USA and European countries. This research evaluates the relationship between the financing of ecological programs and the ecological situation in Latvia.

Keywords: ecology, environment pollution, ecological laws, ecological statistics for Latvia, analysis of statistics

Dorokhov, O., Dorokhova, L., Zorina, E. A Fuzzy Approach and Modelling of Service Estimations for Drugs Freight Transportation, *Transport and Telecommunication*, Vol. 11, No 1, 2010, pp. 19–25.

Expedience of quality estimation of transport service in the conditions of narrow-mindedness, unclear, incompleteness of information and competition environment at the market of transport services on the basis of fuzzy sets is grounded. The parameters of quality of implementation of freight transportations are certain. The two-tier model of determination of integral quality of freight transportations on the basis of unclear design is built. The computer's realization of the fuzzy approach and correspondent model with the use of expert's fuzzy estimations is performed by facilities of the software environment MATLAB fuzzy logic toolbox.

Keywords: drugs freight transportation, fuzzy modelling, transport service quality, MATLAB fuzzy logic toolbox

TRANSPORT and TELECOMMUNICATION, 11.sējums, Nr.1, 2010 *(Anotācijas)*

Grakovskis, A., Ovčiņņikovs, V., Kamenčenko, S. Akustisko signālu tehnoloģija un pielietošana kustības plūsmu monitoringa problēmām. *TRANSPORT and TELECOMMUNICATION,* 11.sēj., Nr.1, 2010, 4.–10. lpp.

Ceļu satiksmes kustības pieaugums Eiropas Savienībā fokusējas uz satiksmes kustības inteliģento transportēšanas sistēmu piepilsētas, pilsētas un reģionālajā līmenī. Šajā rakstā tiek diskutēta akustisko sensoru lietošanas iespēja, lai izmērītu satiksmes kustības intensitāti. Akustiskā signāla detektors, tāds kā parastais mājsaimniecības mikrofons, tiek lietots kā vislētākā sensora versija stacionārajai un mobilajai satiksmes kustības uzraudzības sistēmai. Autors apskata akustisko signālu ierakstus no dažādu satiksmes līdzekļu tipiem dažādos laika apstākļos.

Akustisko mikrofona signālu spektrālās apstrādes algoritma vienkāršotā modifikācija un trokšņa filtrēšana tiek risināta dotajā rakstā. Bez tam tiek arī apskatīta kustībā esošo ceļu transporta līdzekļu rezultātu atklāšana, lietojot to akustisko signālu ierakstus. Lai novērtētu trafika parametrus, rakstā tiek parādīti akustisko sensoru lietošanas ierobežojumi.

Atslēgvārdi: inteliģentās transporta sistēmas, transporta plūsmu uzraudzība, satiksmes līdzekļu uztveršana, akustiskais signāls, digitālā signāla tehnoloģija

Grišins, S., Ščipcovs, O.V. Pilsētas transporta ekoloģijas faktori, ekoloģiskie projekti un to iespaids uz ekoloģisko situāciju Latvijā. *TRANSPORT and TELECOMMUNICATION,* 11.sēj., Nr.1, 2010, 11.–18. lpp.

Transports un rūpniecība ir vieni no vissvarīgākajiem faktoriem, kas ietekmē mūsdienu ekoloģisko situāciju. Šīs ietekmes analīze ir neiespējama bez vides izmaiņu apstākļu monitoringa. Dažādās valstīs tiek piemēroti ekoloģiskās regulēšanas pasākumi. Savukārt tas prasa nozīmīgas izmaksas. Viens no visinteresantākajiem projektiem par ekoloģisko regulēšanu un ekoloģiskā riska salīdzinošā analīze ir "Kalifornijas projekts". Riska samazināšanas izvērtēšanas pasākumu ekonomisko kritēriju ierosinājumi tiek doti šajā rakstā.

Uzmanība tiek vērsta uz ekoloģiskās situācijas Latvijā monitoringa dažādām programmām. Tiek izstrādāta analīze par 10-12 gadu perioda statistiskajiem datiem. Datu analīze norāda uz ekoloģiskās situācijas uzlabošanās tendenci. Latvijā ekoloģisko programmu, kuras ir vērstas uz bīstamo piesārņojumu samazināšanu atmosfērā, finansēšanas mehānisms tiek izstrādāts, pamatojoties uz ASV un Eiropas valstu pieredzi. Autori savā pētījumā izvērtē sakarību starp ekoloģisko programmu finansēšanu un ekoloģisko situāciju Latvijā.

Atslēgvārdi: ekoloģija, vides piesārņojums, ekoloģiskie likumi, Latvijas ekoloģiskā statistika, statistikas analīze

Dorohovs, A., Dorohova, L., Zorina, J. Fazipieeja un pakalpojumu novērtēšanas modelēšana medikamentu kravu transportēšanai. *TRANSPORT and TELECOMMUNICATION,* 11.sēj., Nr.1, 2010, 19.–25. lpp.

Transporta pakalpojumu kvalitātes novērtējuma lietderība, apstākļos, kad pastāv šaura pieeja, neskaidra, informācijas un konkurences nepabeigtības vide transporta pakalpojumu tirgū, tā tiek bāzēta, pamatojoties uz fazi rindām. Kravu pārvadājumu izpildes kvalitātes parametri ir zināmi. Tiek izveidots kravu pārvadājumu būtiskas kvalitātes noteikšanas divrindu modelis, pamatojoties uz neskaidru projektu. Fazi pieejas datora īstenojums un atbilstoša modeļa ar ekspertu fazi novērtējumu pielietošana tiek veikta ar MATLAB vides programmatūras fazi loģikas aprīkojuma līdzekļiem.

Atslēgvārdi: medikamentu kravu transportēšana, fazi modelēšana, transporta servisa pakalpojums, MATLAB programmatūras fazi loģikas aprīkojums

Jarasuniene, A. Dzelzceļa drošības **uzlabojums, pielietojot modernizētas tehnoloģijas.** *TRANSPORT and TELECOMMUNICATION,* 11.sēj., Nr.1, 2010, 26.–30. lpp.

Vienīgi modernais transports var uzticami veikt kravas darbus un nodrošināt efektivitāti un pilnīgu ekonomiskā procesa drošību. Informācijas tehnoloģijas apgādā mūs ar jaunām iespējām transporta darbu organizēšanā.

Informācijas sistēmas var tikt pielietotas kravas elektronisko datu reģistrēšanā. Mobilo transporta sistēmu analīzes nepieciešamība ir globalizācijas un integrācijas procesa pamats: dažādu transporta līdzekļu mijiedarbība un to pārvaldība, lai sasniegtu lielāku efektivitāti, drošību un mobilitāti kravas monitoringā, un tā ir inteliģentā transporta sektora radīšana.

Atslēgvārdi: informācijas tehnoloģijas, mobila transporta sistēma, dzelzceļa trafika pārvaldība, kontroles un drošības sistēmas

Kopitovs, J., Labendiks, V., Junusovs, S. Ekspertu sistēmas aviācijas elektrostaciju tehniskā stāvokļa novērtēšanai. *TRANSPORT and TELECOMMUNICATION,* 11.sēj., Nr.1, 2010, 31.–37. lpp.

Dotajā rakstā tiek izskatīti daži diagnosticēšanas tipi: matemātiskais, stohastiskais un loģiskais, kuri var tikt lietoti ekspertsistēmu attīstībā, lai novērtētu aviācijas elektrostaciju tehnisko stāvokli, kā tas ir parādīts dzinējiem TB-3-117 un PS-90A.

Atslēgvārdi: gaisa gāzes-turbo dzinējs, tehniskā palīdzība, parametru kontrole, automatizētā diagnostikas sistēma, ekspertsistēma, lēmumu pieņemšanas sistēma, diagnostikas matrica

Jackiva, I., Savrasovs, M. Transporta koridora Rīga-Minska attīstības simulācijas modelis. *TRANSPORT and TELECOMMUNICATION,* 11.sēj., Nr.1, 2010, 38.–47. lpp.

Autori šajā rakstā izskata attīstīta kravas trafika makroskopisko simulācijas modeli. Modeļa attīstības mērķis ir analizēt un pētīt transporta koridoru Rīga-Minska. Šis transporta koridors ir svarīga transporta maģistrāle starp Latviju un Baltkrievijas Republiku. Preču pārvadājumu pieaugums starp šīm valstīm arī varētu tikt izskaidrots ar abu valstu tranzīta īpašībām. Transporta koridora garums Latvijā ir apmēram 300 km. Koridors šķērso mazas un lielas pilsētas, un tas ir iemesls, kādēļ pastāv jautājums par tā funkcionēšanu. Simulācijas modelis bija izveidots, lietojot specializētu simulācijas programmatūru, tā saukto PTV VISION VISUM. VISUM lieto transporta modeli, kas nosaka ieejas datu pieprasījumu. Izveidotais modelis sastāv no transporta tīkla modeļa un pieprasījuma modeļa. Pieprasījuma modelis ir parādīts ar divām sākuma adresāta matricām, kurš tika kalibrēts, lietojot TFlowFuzzy algoritmu. Turpmāk kalibrētais modelis tika izmantots, lai novērtētu divus attīstības scenārijus, pielietojot dažādus VISUM izejas datus.

Atslēgvārdi: transporta koridors, makroskopiskais modelis, simulācija, sastrēgumi, attīstības scenāriji, TFlowFuzzy

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19. ***Authors Index***
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