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TRAFFIC MANAGEMENT FACILITIES USED
AT INTERSECTION OF UKMERGĖS AND GELEŽINIO VILKO
STREETS IN VILNIUS

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Vilnius, the capital and the largest city of Lithuania, is faced with serious traffic problems. The main streets of the city are overcrowded with traffic. Therefore, the effective ways to ease the congestion should be sought. The paper considers the problem of high traffic intensity and congestion at the intersection of two busy Vilnius streets. Research is based on the analysis of the data stored at the Vilnius Traffic Management Centre and the information obtained in the experimental investigation of traffic flows. All the collected data have been used in the traffic simulation program, to make some effective measures helping to increase traffic capacity of the considered intersection.

Keywords: traffic intensity, free flow, intersection, velocity

1. Introduction

For the past ten years, the traffic on Lithuanian roads has increased 2.4 times. The number of road vehicles in Lithuania in the period from 1998 to 2010 has increased from 1,145,879 to 1,954,592 units, while the number of passenger cars during the same period has grown from 920,373 to 1,554,270 units and the number of private cars per 1000 residents has increased by nearly two times (from 260 to 479 units). Therefore, the number of accidents, vehicle time losses at junctions and the environmental pollution by exhaust gases and noise has also increased. At rush hours traffic jams are formed at junctions.

Transport system in Vilnius is a legacy of the Soviet planning system. At that time, it seemed reasonable to create a large living area in the northern and western parts of the city, and the industrial districts in its southern part. As a result, most of the inhabitants were going to the work areas and then back to the dormitory districts simultaneously. Over time, the quality of life has improved and the number of vehicles has grown. This led to the formation of large traffic flows. In the morning, most of the inhabitants travel from north to south, while, in the evening, they go back. Therefore, even high capacity roads are overloaded. Zi-You Gao et al. (2007) studied the influence of the traffic dynamics on the structural properties of the evolution network, and measure the probability distributions and scaling properties of the network. Authors found that the topological structure of the evolution network is strongly related to the traffic dynamics. Various traffic control models are presented in the article written by Evangelos Mitsakis et al. (2011). Authors focused mainly in identifying the differences between the use of STA and DTA models. B. S. Kern (2002) in his article presented two phases in congested traffic: wide moving jam and synchronized flow. Author compared the free flow capacity with a wide moving jam and synchronized flow in congested traffic. G. Kotsevski and K.A. Hawick (2009) in their article presented traffic simulation packages used to help engineers simulate traffic networks. Traffic speed – one of the basic variables that indicate the level of service of a road entity presented in the article written by Xin Pei et al. (2011). Prediction models for average speed and speed dispersion established using the simulation approach full Bayesian method. Jaesup Lee et al. (2012) presented a series of regression models to predict lane use distributions of individual lanes that could provide information monitoring traffic conditions and predicting when and how traffic breakdown occur from a given condition.

The aim of the work is to analyse the factors negatively affecting traffic and causing congestion at the intersection of Geležinio Vilko and Ukmergės Streets and, based on the results obtained, to offer some effective traffic management facilities to increase traffic capacity and safety of these streets. For this purpose, it is necessary to strengthen the selected weakest points. The weakest point is the intersection of Ukmergės and Geležinio Vilko Streets.
2. Measuring Traffic Intensity in Vilnius

Traffic in Vilnius is rather heavy. All traffic information is accumulated by Vilnius Traffic Management Centre. This centre has both traffic control and surveillance systems.

The main control program is SITRAFFIC Server. This program monitors the system’s work 24 hours a day and sends alerts to operators if the program records the damage.

The data comes to the program from traffic sensors installed at intersections. There are two types of sensors (see Figure 1): video detectors and inductive sensors. The video sensor (made by ‘Traficon’) is a camera detecting vehicles. A special program controlling video sensors defines their operation area and the direction of traffic intensity is determined. Inductive sensors operate on the principle of electromagnetic induction. An induction detector is installed in the pavement, and the car passing it generates an electromagnetic pulse. This pulse is transmitted to the program, which reads it as a vehicle. All the data obtained from the sensors are sent to the main server where they are processed and stored.

The data entered into the program of the selected sensors during daytime from November 5, 2011 until November 11, 2011 were entered into the program database and used in this work.

3. The Analysis of Traffic Intensity in Ukmergės and Geležinio Vilko Streets in Vilnius

According to the statistical data, the intersection of Ukmergės and Geležinio Vilko Streets (see Figure 2) is most congested in all directions in the morning peak hours (from 7:00 to 10:00) because the dormitory suburbs’ inhabitants are travelling towards the places of their work (in the centre). In the evening peak hours, the junction load is higher only on Geležinio Vilko roadway (in both directions) because a large traffic flow is going from Geležinio Vilko to Ukmergės Street through the intersection overpass where traffic is moving without stopping.

Figure 1. Induction and video sensors and the surveillance area of a video sensor

Figure 2. The intersection of Geležinio Vilko and Ukmergės Streets
According to the statistical data (see Figure 3), the highest load on Geležinio Vilko roadway from the north-east direction was recorded on Thursday, 2011-11-08, and made 2445 vehicles per hour. In Fig. 3, we can see that this intersection is overcrowded with traffic all day long. Therefore, we can say that the measuring data are wrong, and the real load at this intersection is higher. It should be the same as the backward direction flow in the evening.

![Figure 3. The intensity of traffic at the intersection of Ukmergės and Geležinio Vilko Streets in the direction from north to east](image)

More heavy traffic is registered at the intersection in the southern direction in Geležinio Vilko Street. In this direction, according to the statistical data, the maximum traffic intensity during the morning and evening peak hours is more than 5000 vehicles per hour (see Figure 4). The maximum intensity, reaching 5,510 vehicles per hour, was recorded on Friday (2011-11-09). In the graph, traffic intensity in the morning and evening rush hours is demonstrated. The first and the second graphs show that there is a large automotive traffic exchange between the southern and north-eastern sides of Geležinio Vilko Street.

![Figure 4. The intensity of traffic at the intersection of Ukmergės and Geležinio Vilko Streets in the north-east direction](image)

The differences in traffic between Ukmergės and Geležinio Vilko Streets are shown on Figure 5. We see only the morning rush hour traffic, when vehicles travel from Ukmergės Street towards Geležinio Vilko Street in the southern direction because the vehicles going in the backwards direction use the overpass and can move without stopping. Therefore, they do increase traffic at the intersection.
The maximum intensity in Ukmergės Street in the southern direction is close to 3500 vehicles per hour (more exactly, 3371 vehicles per hour). The highest traffic intensity was recorded on Friday (2011-11-09). After the morning peak, the intensity decreased, and after 4 p.m. it did not exceed 2000 vehicles per hour.

4. Intersection and Free Flow Capacity

In SimTraffic 7 program, an intersection can be assessed according to the so-called ICU (intersection, capacity, usage) rate. The application, operating principle and method of ICU in SimTraffic 7 program are described by David Husch and John Albeck in their book “Intersection Capacity Utilization Evaluation Procedures for Intersections and Interchanges” (David Husch, John Albeck 2003). ICU is an indicator of the reserve capacity and congestion of the intersection. This method cannot determine the delay time, but it can be used for determining how often the intersection will be congested. Thus,

\[ ICU = \frac{v/s \cdot CL + t_L}{CL}, \]
\[ t_L = \min(4s, 2s + \frac{D}{sp}, Y + AR), \]

where \( CL \) is standard cycle time (120 seconds); \( t_L \) is the lost time; \( v/s \) is the volume to saturated flow ratio; \( D \) is intersection length; \( sp \) is speed; \( Y \) is yellow time (3,5s); \( AR \) is red time (0,5s).

The lost time \( t_L \) minimum value of urban intersections is up to 4 seconds. Two seconds should be added to the crossing time at the junction to get the lost time value:

The total saturated flow rate \( s \) is the adjusted saturated flow rate:

\[ s = i \cdot n \cdot fLU \cdot fT, \]
\[ fTL = 0.95; fTR = 0.85; \]
\[ fTT = (1 - 0.15 \cdot (vR - vCR)(vCT)) \cdot (1 - 0.05 \cdot \frac{vL - vCL}{vCT}), \]
\[ vCT = vT + vR* + vL** \]
\[ vCL = vL, vCR = vR, \]

where \( fLU \) is the lane utilization factor; \( fT \) is the criterion of turning evaluation; \( i \) is the ideal flow; \( n \) is the lane volume; \( T \) is a through pass; \( R \) is a right turn; \( L \) is a left turn; \( vC \) is the total intensity; *add \( vR \)
to $v_{CT}$, when $n_R = 0$, else add $v_R$ to $v_{CR}$. **add $v_L$ to $v_{CT}$,** when there is a free left-through lane, else add $v_L$ to $v_{CL}$.

The criterion of turning evaluation ($fT$) is used in regulating the volume of the right- and left-turn movements on the lanes in the lane group.

Lane utilization factor ($fLU$) is used for regulating the saturated flow, when there are two or more lanes. This amendment will help evaluate the use of different lanes (see Table 1).

**Table 1. Lane utilization factor**

<table>
<thead>
<tr>
<th>Number of lanes</th>
<th>Left</th>
<th>Through</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>0.971</td>
<td>0.952</td>
<td>0.885</td>
</tr>
<tr>
<td>3 and more</td>
<td>0.971</td>
<td>0.908</td>
<td>0.885</td>
</tr>
</tbody>
</table>

If the intersection is fully loaded (ICU is 100%), the intersection capacity dependence on the number of traffic lanes (see Figure 6) can be obtained as follows:

$$v = s \cdot (ICU \cdot CL - t_L)/CL.$$  \hspace{1cm} (6)

To describe the free flow, we can use one of the models, for example, the Greenberg’s model for one-lane road, where the flow velocity depends on the maximum density $p_{\text{max}}$ (the number of vehicles per kilometre of road), the free movement velocity $V_f$ and nominal density $p$ (Pushkin Kachroo 2007).

$$V = V_f \cdot \ln \left( \frac{p_{\text{max}}}{p} \right).$$  \hspace{1cm} (7)

The maximum density of one kilometre road is 200 vehicles/km, while free movement velocity was selected according to the ‘slowest’ road section (with the speed of 70 km/h). Using these data, the dependence of the velocity on density can be obtained.

The capacity $Q$ depends on the density $p$ and the velocity $V$:

$$Q = V \cdot p.$$  \hspace{1cm} (8)

We can use this formula to obtain the capacity dependence on the velocity (see Figure 7) and density (see Figure 8).

Thus, the maximum capacity of one lane (where the speed is 50-60 km/h) reaches 5000 vehicles per hour, when traffic density is about 75 cars per hour. Meanwhile, two-lane intersection capacity is only 3,000 cars per hour.

![Figure 6. The dependence of intersection capacity on the number of lanes](image-url)
5. Traffic Modifications in Ukmergės and Geležinio Vilko Streets in Vilnius

To increase traffic capacity at this point we suggest:

- To reduce the number of intersections controlled by traffic lights.
- To install pedestrian underpasses.
- To install an engineering tool “guardrail”, not allowing the drivers of the Geležinio Vilko Street (north-east) to turn right and mix with the flow, coming from Ukmergės Street from the north.
- To reduce the number of lanes from 4 to 2 at the entrance from Ukmergės to Geležinio Vilko Street.
- To provide all possible additional tools for ensuring the continuous traffic (to make the lanes wider on the turns).

Flows are separated, therefore, the vehicles coming to the intersection can move unobstructed. The pedestrians are also separated from the flow of vehicles. For each flow, there is a two-lane way (see Figure 10), where an ideal traffic flow can consist of up to 4000 vehicles/h, and the maximum capacity is twice as high as the ideal capacity. To make the flow continuous, the turn from Žalgirio to Geležinio Vilko Street in the south-west direction and the turn from Geležinio Vilko to Žalgirio Street in the eastern direction are prohibited. Drivers will use the nearby streets (Ukmergės and Kalvarijų), the entrance to which is continuous. To facilitate the access from Žalgirio to Geležinio Vilko Street in the northern direction an acceleration lane should be added (see Figure 10).
The intersection safety can be described by the number of moving paths’ intersection or the number of the conflict points. The smaller a number of the conflict points is – the safer the intersection. The conflict points for the selected nodes were determined before and after modification. Before the modifications have been made at the intersection of Geležinio Vilko and Ukmergės Streets, the number of conflict points reached 42 (see Figure 9), with 30 of them referring to vehicles, and 12 concerning the vehicles and pedestrians. After the modifications have been made, the number of conflict points decreased to only one point (see Figure 10) due to the reduction of the number of lanes, flow separation and installation of the pedestrian underpasses.

Before the modification of the Geležinio Vilko and Žalgirio Streets’ intersection, the number of the conflict points reached 21 (see Figure 9), with 16 referring to vehicles, and 5 concerning the vehicles and pedestrians. After modification, the number of the conflict points decreased to 2 points (see Figure 10). The total number of the conflict points decreased from 63 to 3 points, which means the reduction by 21 times.

When the velocity on the road decreases, it means that the traffic situation becomes complicated and the congestion is inevitable.

The average velocity on the considered road was rather low in the rush hours (see Figure 11). After modification, the average velocity has grown considerably (see Figure 12).

**Figure 9.** The intersection of Ukmergės and Geležinio Vilko Streets with real traffic congestion before modification

**Figure 10.** The intersection of Ukmergės and Geležinio Vilko Streets with real rush hour traffic intensity after modification
6. Conclusions

1. In order that the traffic would be organized properly, modifications should be proposed in the context to the streets category. Effective organization of traffic can be achieved only through a traffic simulation programs.

2. Making some engineering modifications will help to ease congestion on the road. The trajectories of the flows will intersect more rarely because the pedestrians will cross traffic lanes at different levels. This will increase the road safety. The traffic will be uninterrupted that will make a positive effect on the ecology of the street. The offered solutions will help to solve the problems on the particular road section, and also will provide the increasing of traffic in the future. The traffic will be continuous even if the traffic intensity at this intersection increases more than twice.

3. The main limitations to these solutions are associated with the prohibition of movement in some directions because the left turns will be prohibited. Therefore, to reach the selected point, the drivers will search for another way, which in some cases could be longer.

References


ANALYSIS OF SIGNAL FORMATION AND CONVERSION IN HYBRID RADIO OVER FIBRE NETWORK

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Calculation methods of the signal formation parameters at the central station and of selective conversion in mobile terminal receiver of the vehicle moving at speed of 200-300 km per h are described. Architecture features of radio over fibre networks to operate without handover between base stations lead to additional requirements for transmitting and receiving signal methods in the network. The solution of this problem will provide high-rate services (up to 12 Mbit per second) for subscribers moving on the highway or high-speed railway using hybrid radio over fibre network. It allows providing services of any content at any time.

Objective: calculation methods development of the signal formation and conversion parameters. Signal is a set of services in the form of OFDM-symbols, the total bandwidth of which is much higher than 1 GHz.

Keywords: radio over fibre network, signal formation of services set, selective conversion in mobile terminal receiver

Introduction

Modern development of telecommunications caused to the need to ensure services availability to users anywhere and anytime. Acceptable speed of mobile users has increased to 200-300 km per h. This scenario is relevant for high-speed roads and railways. However, mobile terminal (MT) problems associated with the MT transition from one base station (BS) to another (handover) limit the speed values to 100-150 km per h [1]. In this case, the data transfer rate is not exceeding 100 Mbit per second.

Hybrid radio over fibre (RoF) technology allows achieving the required speed of mobile subscribers’ access to multimedia resources. RoF technology combines high capacity of wired networks and portability of wireless networks [2]. Hybrid RoF architecture includes service providers, central station (CS), optical links, BS and MT [3]. Topology options and signal transmission methods define the architecture of the whole network. In [4] BS is connected to CS using star topology. It is proposed to unite several cells in virtual zones to artificially increase cell. Handover management is carried out in CA. Subscriber movement is limited at 100 km per h. In [5] research the star topology is also used and moving cells method is proposed. The necessary services are moving with MT. The need of signal and MT moving synchronization complicates CS functions and limits the speed to 130 km per h. To achieve high network capability of network it is mandatory to use millimetre waves that can accommodate a wide band signal.

RoF network architecture with high capacity and ability to serve customers moving at speed of 300 km per h is shown in [3].

This architecture has the following features, which reduce the deploying cost in comparison with similar products:
- Tree topology of connection between CS and base stations. Tree topology reduces the required total length of the fibre optic cable in the network compared to star topology;
- Simplified function of BS. It significantly reduces the whole network cost. It is required a lot of BS because of signal attenuation in the millimetre wave range. It leads to cell size decreasing.

This functional architecture allows providing services to customers at high bit rate. The principal feature is that all BS work in the same band and all BS receive all network services and transmit it in their cell.

Features of this network architecture perform demands to signal transmission in CS and receiving of signal in user’s MT.

New ways of signal formation in CS and its selective conversion in user’s MT receiver methods as well as multi-criteria mathematical model for calculating the parameters of these methods are proposed in [6, 7]. Solution is shown using the integral preference criterion. However, this solution is partial and allows finding the best option among all randomly generated, but not all valid options.
The purpose of the article is to propose calculation methods for signal formation and selective conversion parameters in hybrid RoF network. Solution differs from other known existing by using of absolute Pareto criterion and the possibility of best option finding from all valid.

1. Network Description

Traditionally telecommunication network has two directions of communication: downlink and uplink channels. Downlink channel is responsible for information transmission from network to user, and the uplink channel is responsible for from user to network information transmission. An example of using such hybrid RoF network architecture in the downlink channel is shown as a challenge to provide mobile communications along railway line from Moscow to St. Petersburg. The real task raw data are shown on Figure 1.

![Figure 1. Raw data for task to ensure mobile communications along railway route from Moscow to St. Petersburg](image)

Internet access for customers is organized via two Wi-Fi access points, installed in each coach. Downlink channel scheme using hybrid RoF is shown on Figure 2.

![Figure 2. Hybrid mobile network architecture that serves users on high-speed](image)

CS receives required services from service providers. It multiplexes all subscribers’ services (at current time) to one stream. Aggregate signal after optical modulator is sent to all BS in tree topology.
Two optical fibres fit to BS, the first with information signal and the second with a reference beam of light. The wavelength difference determines the carrier frequency in the millimetre range. The BS photodiode converts the difference between two lights into electromagnetic emission. BS receives all network services and transmits them in cell.

Network capacity for downlink equals to $10^{10}$ (Mbit per second) $\cdot$ 600 (subscribers) = 6-60 (Gb per second) that will take 1-10 GHz band using 64-QAM signal.

Uplink channel works on mobile WiMax technology:
- WiMax transmitter with capacity of 100 Mbit per second (100 subscribers multiply on 1Mbit per second) is set in the middle of train;
- Receivers (the BS) with capacity of 200 Mbit per second are set along railway on 25 km distance (for the simultaneous two trains moving in one cell).

To ensure the handover it is necessary to implement diameter of cells overlapping so that train transit time in the overlap is greater (with margin) then time required for WiMax system handover performing.

Spread spectrum multi-carrier technology based on OFDM technology is used for signal formation scheme in CS to provide high system capacity and frequency spectrum effective usage.

2. Mathematical Models of Service Set Signal Formation and Conversion

2.1. Mathematical model of signal formation in the central station

It is assumed that the multi service RoF network provides two types of services: low-rate services with rate $V_1$ [bit per second], and high-rate services with rate $V_2$ [bit per second]. Total amount of services provided is $v_1$ first type number of services and $v_2$ second type number of services, bringing the total number of services in the $K = v_1 + v_2$. $K$ equals the maximum possible number of subscribers in the system.

All $K$ services should be divided into groups of 64, 128, 256 or 512 services, depending on the modulators set used at the transmitting end. Parameters $a_1,a_2,a_3,a_4$ corresponds to the group number of 64, 128, 254, 512 services with $V_1$ rate; $b_1,b_2,b_3,b_4$ corresponds to the group number of 64, 128, 254, 512 services respectively with $V_2$ rate. It is considered for simplicity that QAM-64 is used in OFDM-symbol with 64 subcarriers, QAM-128 in OFDM-symbol with 128 subcarriers, etc. Each OFDM-symbol is a group containing up to 64, 128, 256 or 512 services using QAM-64, QAM-128, QAM-256, QAM-512 modulation, respectively. OFDM-symbol amount determines the number of groups in the system ($N_g$).

Monthly fee for the $V_1$ service equals to $A$ [units], and for the $V_2$ service it equals to $B$ [units].

Parameter $K_d$ is used as the demand for high-rate service ratio. It is defined as

$$K_d = \frac{v_2^d}{v_2}$$

where $v_2^d$ is the second type services amount, which is used by subscribers, $v_2$ is the total amount of second type services in the network.

If we denote the parameter $k$ as ratio between the second type services amount to the total number of services in the system $k = \frac{v_2}{v_1 + v_2}$, then the dependence of $K_d$ from $k$ (or it percentage,

$$k[\%] = \frac{v_2}{v_1 + v_2} \cdot 100\%$$

is determined statistically and refers to the input data.

Each type of modulator has its nominal cost characterizing the technological development level, and $c_1,c_2,c_3,c_4$ [units] corresponds to QAM-64, QAM-128, QAM-256, QAM-512 modulators cost for the service at $V_1$ rate [bit per second]; $d_1,d_2,d_3,d_4$ [units] corresponds to QAM-64, QAM-128, QAM-256, QAM-512 modulators cost for the service at $V_2$ rate [bit per second]. Obviously, more complex is modulator, more expensive it is.
Input data for task solution are the following:

- \(V_1, V_2\) – bit rate of low-speed and high-speed services, respectively, [bit per second];
- \(A, B\) – monthly services fee of the first and second type, respectively, [units];
- \(K\) – total number of services in the system;
- \(c_1, c_2, c_3, c_4\) – modulators cost for services at \(V_1\) rate, [units];
- \(d_1, d_2, d_3, d_4\) – modulators cost for services at \(V_2\) rate, [units];
- \(m\) – proportionality coefficient;
- \(K_d(k)\) – dependence of demand parameter from ratio between the second type services amount to the total number of services in the system.

Parameters to be found:

- \(a_1, a_2, a_3, a_4\) – number of groups of 64, 128, 254, 512 services with \(V_1\) rate [bit per second];
- \(b_1, b_2, b_3, b_4\) – number of groups of 64, 128, 254, 512 services with \(V_2\) rate [bit per second].

Following quality indicators have to be used for unknown parameters:

- \(D = A \cdot V_1 + K_d \cdot B \cdot V_2\) [units per month] \(\rightarrow\) max – the monthly income from services provision to subscribers;
- \(K_d \rightarrow\) max – demand parameter;
- \(N_y = \sum_i (a_i + b_i)\) \(\rightarrow\) min – number of service groups (OFDM-symbols);
- \(C = \sum_i m \cdot (a_i \cdot c_i + b_i \cdot d_i)\) [units] \(\rightarrow\) min – total cost of the system that is proportional to the modulators cost in the system;
- \(E = \frac{N_y}{R}\) [Hz/bits per second] \(\rightarrow\) min – spectral usage efficiency, where \(\Delta f\) [Hz] – bandwidth required to transmit all services, \(R\) [bit per second] – the total bit rate of all services.

### 2.2. Mathematical model of selective signal conversion for services set in mobile terminal

The solution of the signal formation task is the input data for finding the parameters of the selective signal conversion of service set in the MT receiver.

The state-of-the-art level that expresses the possibility of band-pass filters to allocate bandwidth on particular carrier also is included to input data. The ratio of bands width allocation to the carrier frequency is supposed to be no less that \(t_1\), but no more that \(t_2\). In this case, we assume that the ideal value \(t_{id}\) stays between \(t_1\) and \(t_2\) (\(t_1 \leq t_{id} \leq t_2\)).

Input data for task solution are the following:

- \(a_1, a_2, a_3, a_4\) – number of groups of 64, 128, 254, 512 services with \(V_1\) rate [bit per second];
- \(b_1, b_2, b_3, b_4\) – number of groups of 64, 128, 254, 512 services with \(V_2\) rate [bit per second];
- \(t_1, t_{id}, t_2\) – parameters showing state-of-the-art level that expresses the possibility of band-pass filters to allocate bandwidth on particular carrier.

Definition: frequency area is the frequency domain with \(\Delta f\) band on intermediate frequency, which is transmitted to digital signal processing area, and which includes one or more service groups.

Figure 3 shows the diagram of signal bandwidth conversion when signal is received.
Parameters to be found:

1) \( f_L, f_H \) – the lowest and highest operating frequency of \( \Delta f \) band which is transmitted to intermediate frequency not depending on input signal structure. This allows using same type equipment in the conversion first stage for all options. It is equal to the maximum possible bandwidth of signal frequency \( \max \{ \Delta f \} \).

2) \( \Delta f_o, N, f_{IF} \) – frequency area band, the number of areas required for overlapping all service groups, and the lowest intermediate frequency.

3) \( f_{DP} \) is the lowest spectrum frequency in area of digital processing (DP). It is determined on the basis of following inequality \( f_{DB} + \Delta f_o < f_{DP_{max}} \).

The optimal values searching of these parameters include the objective function that consists of following quality indicators:

- \( N \rightarrow \min \) - area number minimizing, and therefore the filter number to separate all groups;
- \( E_f = (\Delta f_o \cdot N - \Delta f) \) (Hz) \( \rightarrow \min \) – inefficient spectrum usage minimizing. Inefficient spectrum usage arises by partitioning groups into areas because of the OFDM-symbol feature that if it is broken it before digital processing, then original service signals restoration fails. Consequently, one group cannot be divided and placed in two areas at the same time;

\[
\Psi = \frac{\sum \Psi_i}{N} \rightarrow \min, \quad \Psi_i = \frac{\Delta f_o}{f_{IF} + (i-1) \cdot \Delta f_o - t_{id}}, \quad i = 1...N - \text{shows how the ratio of the band area to the intermediate frequency rate at which it is allocated differs from} \ t_{id}. \text{ As different versions will contain a variable number of parameters} \ \Psi_i, \text{ then to estimate them together it is necessary to minimize their average value. With the known value of the frequency band} \ \Delta f_o \text{ occupied by area, this option allows to select the intermediate frequency} \ f_{IF} \text{ on which the band allocation} \ \Delta f_o \text{ will be the most technically simplified;}
\]

\[d \rightarrow \max \rightarrow \text{to maximize the BS cell size} \ (d \text{ is inversely to} \ \Delta f_o : \ d = \frac{1}{\Delta f_o}).\]

### 3. Mathematical Models Solution Methods

#### 3.1. The solution method of signal formation mathematical model

For the signal formation problem it is necessary to solve two subtasks sequentially:

1. To find the ratio between number of two types of services to maximize profits and at the same time with the maximum use of all services by subscribers (maximization of demand parameter for high-rate services).

2. To find division of services into groups (what modulators have to be used) for which the total number of groups is minimized, the price of the system is minimized, spectral efficiency is maximized.

To solve the first subtask it is necessary to find quality index \( D \) and demand parameter \( K_d \). To solve the second subtask it is necessary to find number of groups \( N_{gr} \), total cost of the system \( C \), spectral usage efficiency \( E \). Each task is solved separately below.

##### 3.1.1. Determining ratio between numbers of two types of services

Let us suppose that the price of the first type service \( A = 1 \), price of second type service \( B = 4 \), and there are \( K = 2000 \) services in the system. For clarification and simplicity of presentation we will use the following dependence of the demand parameter: \( K_d(k) = 1 - k \). In this manner the demand parameter decreases in direct proportion to the increase of second type services. If the second type services part is 30\% (\( k = 0,3 \)), only 70\% (\( K_d(k = 0,3) = 0,7 \)) of the total amount of services will be in demand.

Dependence of the normalized quality parameters \( D^n \) and \( K_d \) for given input data on the number of the second type services \( v_2 \) is shown on Figure 4.
It is impossible to reach maximum of these both functions at the same time. It is assumed that the solution is value of $v_2$, where $D^*(k)$ reaches its maximum. This value is $v_2 = 750$.

3.1.2. Determining the types of modulators used to split signal into groups

Division of the first type service does not affect the division of the second type services and vice versa. These are two separate tasks, each of which needs to be solved.

Values [units] for various types of modulators equal to $c_1 = 1, c_2 = 2, c_3 = 5, c_4 = 15, d_1 = 4, d_2 = 8, d_3 = 20, d_4 = 60$. The proportionality coefficient $m = 3$.

Focus on quality indicators $E$ and $N_{gr}$ does not require compromise between them, as they are achieved by the use of modulation with the highest positioning. Therefore, it can be argued that it is sufficient to consider only one of these parameters, for example $N_{gr}$. It requires finding a compromise with the total cost quality parameter $C = \sum m \cdot (a_i \cdot c_i + b_i \cdot d_i)$ [units].

Let us find the structure of the modulators for the second type services (high-rate services). The task is discrete–there is a certain (finite) number of used modulators sets, each of which corresponds to a certain parameter values of $N_{gr}$ and $C$ [units]. The number of groups cannot be set less than $N_{gr_{min}} = 2$. One group (modulator) is not enough to place 750 services, because the maximum value of services in one group is 512 (using QAM-512). The maximum number of groups using modulators with the lowest point of positioning (QAM-64) equals to $N_{gr_{max}} = \frac{750}{64} \approx 12$.

For each valid value of $N_{gr}$ it is necessary to find such modulators structure for which $C$ is minimum. Figure 5 shows the calculated values.

![Figure 4. Dependence of normalized functions $K_n(v_2)$ and $D^*(v_2)$](image)

![Figure 5. System price depending on the number of groups](image)
For options \( N_{gr} > 6 \) the number of groups increases meanwhile system price remains fixed. These options are worse than \( N_{gr} = 6 \). Points \((N_{gr}, C)\) for which \( N_{gr} < 7 \) form a set of Pareto-optimal solutions. This is the set of optimal points obtained by unconditional optimisation. Further decision has to be made based on the standard criteria introduction, for example the minimax criterion of preference. Let us normalize the values of \( C \) and \( N_{gr} \) (relative to their maximum values \( C_{\text{max}} = 240, N_{gr, \text{max}} = 6 \) from Figure 5). For each option we find the maximum value \( \max \{N_{gr}^n, C^n\} \) of normalized quality parameters. The minimum value among the values of \( \max \{N_{gr}^n, C^n\} \) will match to the option that is optimal by minimax criterion. For this case it equals to \( N_{gr} = 4: \) 2 modulators QAM-256, 2 modulators QAM-128; \( C = 3 \cdot (20 \cdot 2 + 8 \cdot 2) = 168 \) [units]. The result is shown in Table 1.

**Table 1.** Decision based on the minimax criterion

<table>
<thead>
<tr>
<th>( N_{gr} )</th>
<th>( C ) [units]</th>
<th>( N_{gr}^n )</th>
<th>( C^n )</th>
<th>( \max {N_{gr}^n, C^n} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>240</td>
<td>0,33</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>180</td>
<td>0,5</td>
<td>0,75</td>
<td>0,75</td>
</tr>
<tr>
<td>4</td>
<td>168</td>
<td>0,67</td>
<td>0,7</td>
<td>0,7</td>
</tr>
<tr>
<td>5</td>
<td>156</td>
<td>0,83</td>
<td>0,65</td>
<td>0,83</td>
</tr>
<tr>
<td>6</td>
<td>144</td>
<td>1</td>
<td>0,6</td>
<td>1</td>
</tr>
</tbody>
</table>

Likewise, the composition of modulators for the first type services can be found.

**3.2. The solution method of selective signal conversion mathematical model**

For the problem of selective signal conversion it is necessary to solve two sub-tasks sequentially:

1. To find frequency band of areas and the number of areas so that the number of frequency bands is minimized, the frequency efficiency and the coverage area of one BS is maximized.
2. To find the intermediate frequency used in the selective conversion, so that the technical implementation coefficient of band pass filters is minimal.

**3.2.1. Determining number and frequency band of areas**

For this subtask the following input data is taken:
\( a_1 = 2; a_2 = 1; a_3 = 3; a_4 = 1; b_1 = 0; b_2 = 0; b_3 = 2; b_4 = 0; t_1 = 0,05; t_{id} = 0,1; t_2 = 0,15 \).

Quality parameters \( N, 1/d \) and following limitations are used to find the Pareto-optimal set of parameter options:
\( (\Delta f_a \cdot N - \Delta f) \geq 0 \) – the total bandwidth of the signal after split into zones is not less than the band of all services groups;
\( \Delta f_a \leq 1GHz \) – the frequency band of area is less than 1GHz– limit of normal digital signal processing on the second intermediate frequency;
\( \Delta f_a \geq \max \{\Delta f_{gr} \} \) – the frequency band of area is bigger than the maximum bandwidth of services group for chosen option of services distribution – any of the existing services groups should be fully located in one area, so then not to violate the integrity of one OFDM-symbol (service group);
\( N \) – positive integer;
\( \Delta f_a \) – frequency band multiple to32 MHz(discrete values of group area with increment equal to the lowest allowed band of services group are used, namely the group with 64 services at 3Mbitper s and QAM-64 modulation).

Dependence of \( \Delta f_a (N) \) according to restrictions on \( \Delta f_a \) (\( \Delta f_a \leq 1 GHz \) and \( \Delta f_a \geq \max \{\Delta f_{gr} \} = 384 MHz \)) is shown on Figure 6.
According to Figure 6, to achieve the simultaneous minimization of both \( N \) and \( \Delta f_a \) values is not possible. Reducing of one parameter results in increasing of another.

Additionally it is necessary to take into account the limitation on the positive integrity of quality parameter \( N \). Let us define its permissible value. \( N = 1 \) is invalid value since then \( \Delta f_a > 1 \text{ GHz} \). All other values are valid (but it does not mean that they are included to Pareto-optimal set – it is shown below).

The minimum values \( \Delta f_a \) for each of the possible \( N \) values with the positive integrity limitation were found ( \( \Delta f_a \) must be multiple to 32 MHz). The obtained values of \( N, \Delta f_a \) taking into account all the limitations are shown in Figure 7.

For \( N > 4 \) options the number of frequency bands increases meanwhile band is fixed. These options are far worse than the option with \( N = 4 \). Points \( (N, \Delta f_a) \) where \( N < 5 \) form a set of Pareto-optimal solutions. This is the set of optimal points obtained by unconditional optimisation.

Let us find solution among the Pareto-optimal set by the minimax criterion. The values of quality parameters are normalized by the maximum values and for each of the solutions the maximum normalized value of the parameter is found. Solution by the minimax criterion is the option where the selected value is minimal (Table 2).

**Table 2.** Finding the optimal option from Pareto-optimal set by the minimax criterion

<table>
<thead>
<tr>
<th>( N )</th>
<th>( \Delta f_a ) [MHz]</th>
<th>( N^* )</th>
<th>( \Delta f_a^* )</th>
<th>( \max {N^<em>, \Delta f_a^</em>} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>704</td>
<td>0,5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>480</td>
<td>0,75</td>
<td>0,68</td>
<td>0,94</td>
</tr>
<tr>
<td>4</td>
<td>384</td>
<td>1</td>
<td>0,55</td>
<td>1</td>
</tr>
</tbody>
</table>
The optimum point is \((N = 3, \Delta f_u = 480 \text{ MHz})\) according to the minimax criterion. This solution is an optimal solution of this subtask.

### 3.2.2. Determining the intermediate frequency

The quality parameter \(\Psi\) for the previously found values equals to:

\[
\Psi = \frac{1}{3} \left( \frac{480}{f_{IF}} - 0.01 \right) + \left( \frac{480}{f_{IF} + 480} - 0.01 \right) + \left( \frac{480}{f_{IF} + 2 \cdot 480} - 0.01 \right) \rightarrow \min.
\]

A graph of the function \(\Psi(f_{IF})\) is shown on Figure 8.

![Figure 8: Dependence \(\Psi(f_{IF})\)](image)

Minimum value of \(\Psi(f_{IF})\) function is achieved at \(f_{IF} = 4320 \text{ MHz}\) point. Thus, all parameters of selective conversion were found:

\(N = 3, \Delta f_u = 480 \text{ MHz}, f_{IF} = 4320 \text{ MHz}\).

### Conclusions

1. Method for finding the parameters of services signal formation at the central station of radio over fibre hybrid network is proposed. Rules how to determine the optimal ratio between the two types of services and optimal set of modulators for usage in the system are described.

2. Method for finding the parameters of selective conversion of all services signal in the receiver of mobile terminal is proposed. Procedure how to determine the number of frequency areas, their bandwidth and intermediate frequency is described.

Methods differ from the existing by ability to find the solution from all valid options. It is achieved by using both unconditional Pareto optimality criterion and conditional minimax criterion.

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INTERMODAL LOGISTICS PROCESSES SUPPORTED BY ELECTRONIC FREIGHT AND WAREHOUSE EXCHANGES

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Nowadays, modern companies operate in a common logistics network. In a modern approach, these networks of companies are called virtual enterprises, whose main purpose is the maximal fulfillment of customer needs and process optimization. The electronic freight and warehouse exchange is a good basis for building virtual enterprises, and that may be a new way to support the reorganization of the supply chains, and to rethink the connections within the intermodal network.

Firstly, the paper presents the need of intermodality. On the other hand, it details the benefits and the critical evaluation of intermodality. It presents the general transshipment processes and techniques then evaluates the containers based on their main features. On this basis, the paper describes the electronic freight and warehouse exchange as a member of cloud supply chain. Moreover, the paper contains the new challenges and opportunities of electronic freight and warehouse exchanges as complex logistics providers.

Keywords: Supply Chain, Intermodality, Container, Online Logistics Exchanges, Optimization

1. Introduction

The role of the intermodal logistic processes and related services are continuously changing and developing due to the spreading of transportation processes. One of the most frequent attribute of the service functions is the implementation parameters (for example, place and material requirement), which are being changed, so the logistics system must be able to follow them flexibly. Because of the complexity, at any given time and location the implemented service requires cooperation between multiple logistics subsystems which are connected together only with the common management system and the endpoint of materials flow. One of the possible surfaces to satisfy the ever growing and changing claims if these services are supported by electronic freight and warehouse exchanges to perform the logistics processes.

2. Critical Evaluation of the Intermodality

The intermodal shipments evolve their effects typically on two areas. The first one is the preparatory phase and the other is the phase of activities, which are tightly connected to the freight. The preparatory phase includes processes, which bring the transportable goods into suitable condition for transport according to the prescribed rules. Such rules belong to packaging and unit load forming, then setting up goods and transportation units with labels with appropriate information on it, and equipping it with barcodes as an adequate identification. Recent years considerable technological advances can be seen in the first phase due to the usage of advanced technologies [1].

The development of the present advanced packaging and unit load forming technologies has positive effects to reduce cost, and it helps to achieve the safer, flexible, environmentally-friendly and regularly supervised transportation. The second phase has significantly more preferred properties in term of intermodal transportation. The optimal choice of the transportation modes is an advantageous and desired solution of environmental and economic aspects. The modern information system has also a big role in the precise alignment of combined transportation. It provides vehicle and load tracking, moreover
it ensures the being of permanent monitoring functions. The electronic freight and warehouse exchanges are separate and special parts of the information systems. The reasonable solutions of the material activities are closely related to the freight (or just transhipment tasks), and the optimal choice of the transshipment equipment are the two major roles of the terminals. Because the major part of the container transhipment (as a mount point) there takes place, to improve these terminals is a further task of the intermodality optimization [2].

These transport modes have significant advantages. The most important benefits are for tending to environment-friendly (green logistics) format and for creating balance of transport ways (modal split), besides it ensures the reasonable and coordinated connection between them. Moreover, with reasonable combination of these mentioned transportation modes the overall transportation cost (which is the most important factor in logistic systems) might be significantly reduced. The optimal operating conditions of the established logistics network are the integrated subsystems, and the fact that these subsystems should be adequately connected. The organization of combined transport, as well as the development involves a significant financial investment. The reason is that the parts of the transport chain, namely: the transportation facilities, the transhipment equipment, and the storage- and transhipment areas, which are used in the supply chains need to have special properties. The intermodal freight is a transport mode has substantial resources due to its positive effects on the environment. Because of this reason the European Union provides significant financial support for development and implementation [1], [3].

Figure 1 shows a domestic intermodal network with main terminals and major railway lines which are having significant role in the international relations. The most important container and combined terminals, which link the most transport subsectors and operate as logistic service centre in the country, are located in Győr, Záhony, Csepel and Szeged. In addition, the logistic services, which belong to the cities like Miskolc, Debrecen, Nyiregyháza, Szombathely, Székesfehérvár, Sopron, Nagykanizsa and Pécs also, have high transportation volume [4].

3. General and Special Transhipment Processes

The transhipment of containers may take place at the container and combined terminals, or in the premises of carriers and freight forwarders. Because of the fact that supply chain's both participant
functions a sender place as well as recipient place, so these transfer points need to be changed into
container transhipment suitable places. Possible indirect modes of transhipment are as follows: containers
are picked with spreader (upper corner unit), with crane (lower corner unit), with crane (fork pockets),
with forklift (fork pockets), with ACTS/ARC (All-round container, Abroll-container), with Mobiler and
with support foots. The objects of investigation are common containers in terms of transportable goods,
supplemented with swap bodies and scrollable all-round containers [5].

In addition to the above described general transhipment technologies, must be mentioned special
systems too, like RTS, HCTS, NETHS processes. The RTS is a positioning system which equipped with
laser scanner at the container transhipment of trains. It enables the long haul trains to quickly unload their
cargo in their short stop time at intermediate stations [6].

The HCTS system (Horizontal Container Transhipment) enables horizontal container transhipment.
With the help of this system, the container can be raised without exceeding the height of loading gauge in
the load- and unload procedure [6].

The NETHS (Neuweiler Tuchschmid Horizontal System) is used at small and medium sized
terminals for transhipment of containers. This system was developed in Switzerland. While handling of
the system all of the elements are electrically driven. The apparatus is divided into two opposing
independent parts, which can be shifted by a common alignment. The two sub-functions are working as a
jaw, allowing receiving different types of containers [6].

4. Complex Analysis of the Containers in Terms of Transportable Goods

It is necessary to separate containers according to transportable goods, like bulk and liquid and
separate bulk goods. We can supplement these well documented distributions with own analytical results
with occupancy indicators of the volume and finally with the possibilities of the adaptability. The
summary is shown in Table 1. The occupancy indicators can be separated to six intervals, the first is the
worst, and the sixth is the optimal solution. The intervals upper and lower limits are the follows [7], [8]:

- 0-65%: 1
- 66-70%: 2
- 71-75%: 3
- 76-80%: 4
- 81-85%: 5
- 86%+: 6.

The categories of the transportable goods and transhipment techniques have similar categories.
The container is:

- suitable to use the transhipment technology and suitable for transport the good: 2
- rarely suitable to use transhipment technology and rarely suitable for transport the good: 1
- not suitable to use the transhipment technology and not suitable for transport the good: 0.

Besides the mentioned aspects, the possibility of the adaptability has a significant role in the
analysis too. We can define five classes to the evaluation of the possibilities of adaptability:

- not convertible containers: 0
- limited, rarely convertible containers: 1
- limited, often convertible containers: 2
- convertible containers: 3
- optimally, always convertible containers: 4.

Based on data from the Table 1, the containers can be ranked as follows:

1. According to the most relevant aspects, the optimum types of the containers are the box
containers, which have beneficial functional and technical parameters, besides provide the
goods protection.
2. The following group of containers are the open top containers, which only differs from the box
containers in the goods protection. This type not always provides protection, or not in the
appropriate extent.
3. The advantages of the flexi tanks have a big role in the normal and special transport too. The
third group of the containers is the flexi tank, which has advantageous properties, like
convertibility and occupancy indicators of the volume [7].

Generally we can state, that the box containers can be suggested in the transaction of intermodal
logistics processes supported by electronic freight and warehouse exchanges.
Table 1. Comparison table for the container types and swap bodies

<table>
<thead>
<tr>
<th>Container types</th>
<th>Occupancy indicators of the volume</th>
<th>Packet goods</th>
<th>Bulk</th>
<th>Liquid</th>
<th>Transferability, manageability</th>
<th>Adapability</th>
<th>Final score</th>
<th>Containers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>spreader + upper corner unit</td>
<td>crane + lower corner</td>
<td>forklift + fork pockets</td>
<td>ACTS</td>
<td>Mobiler</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Containers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Box containers</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2 2 2 2 2 2 3</td>
<td>3</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Open top containers</td>
<td>6</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2 2 2 2 2 2 2</td>
<td>2</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Flat rack containers</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2 2 2 0 2 1</td>
<td>1</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Reefer containers</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2 2 2 2 2 2 2 2</td>
<td>2</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Isolated containers</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2 2 2 2 2 2 2 2</td>
<td>2</td>
<td>17</td>
<td></td>
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<tr>
<td>Ventilated containers</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2 2 2 2 2 2 2 2</td>
<td>2</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Collapsible containers</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2 2 2 2 2 2 1</td>
<td>1</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Tank containers</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2 2 2 2 2 2 2 0</td>
<td>0</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Bulk containers</td>
<td>6</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2 2 2 2 2 2 2 0</td>
<td>0</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Flexi tanks</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2 2 2 2 2 2 4</td>
<td>4</td>
<td>21</td>
<td></td>
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<tr>
<td>Swap bodies</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0 2 0 0 2 2 2</td>
<td>2</td>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>

5. Electronic Freight and Warehouse Exchanges as Cloud Service Providers

The electronic freight and warehouse exchange facilitates a forum for logistics service providers to advertise their service supply, such as transport and storage capacities on the worldwide web; whereas consigners can choose the offer, which suits the best their needs (transport and storage tasks). The cloud (cloud computing: [9]) structure of the electronic freight and warehouse exchange is shown by Figure 2.

The freight and warehouse exchange (as cloud computing service provider) offers the following main services [10]:

- e-commerce toolbar (agile information and communication techniques):
  - advertising and searching freight/storage tasks/capacities in a simple catalogue,
  - automatic offer sending based on individual settings,
  - tenders/auctions,
multi-criteria decision supporting algorithms (to choose the best offer), [11], [12], [13],
optimization algorithms (optimize the logistics processes),
other functions (e.g. statistics, blacklists, data maintenance, etc.).

Figure 2. The cloud model of electronic freight and warehouse exchange

The electronic freight and warehouse exchange has three participants: consigners, logistics providers, and the cloud computing service provider. The aims of the electronic freight and warehouse exchange: to advertise freight/storage capacities/tasks, to choose suitable offers based on e-commerce methods and complex optimum criteria [14], to support complex logistics processes (e.g. combined transportation, city logistics, etc.), [15].

Over the current known applications, the electronic freight and warehouse exchanges are able to provide such logistic processes, in which the information and communication deficiencies between the participants cause the more significant problem. The role of freight and warehouse exchanges in complex logistics problems (city logistics, combined transportation) may be viewed as the route planning systems: the processes (e.g. tours, utilization) can be optimized by handling demands and capacities in one system. With the help of these exchanges the logistics providers can improve their own logistics processes; moreover, the capacities are harmonized by the sharing of transport and storage [16], [17] capacities (virtual enterprises are formed). In addition, through the coordination they are able to establish collecting-distributing routes, to organize back haul, and through this to reduce the number of vehicles. In this way, support of complex logistics problems (e.g. city logistics: [18], combined transportation) will be possible. These exchanges are suitable for organizing the transport and storage processes of the multimodal logistic centres (combined transport and city logistics). Therefore, these exchanges can provide the green logistics principles, mostly through the decreasing number of the trucks and the decreasing measure of the exhausted fumes. In other words, freight and warehouse exchanges are one of the “simplest”, but still the most efficient way of optimizing complex logistics processes (see example Figure 3). Moreover, the freight and warehouse exchanges can be an excellent example of cloud supply chains [19].

To prove this thesis, an ant colony algorithm was developed (BA_ACO), [15]. In case of freight and warehouse exchanges, we have to define a complex objective function. On one part of the total transport route, the freight tasks are transmitted together and then with the help of an intermodal centre the freight tasks are transferred (multimodal transportation with rail/river). The objective functions: minimal transportation performance increase; maximal total mileage reduction; maximum use of the rail/river vehicle [10], Fig. 3. The modelling logic was completed with a factor which helps to take into consideration the demand of the surplus logistic services. These problems can be solved by ACO (ant colony optimization), which is an optimizing algorithm [20] developed by Marco Dorigo [21], [22] based
on the modelling of the ants’ social behaviour. In the electronic freight and warehouse exchange similar problem emerges as the ants’ search for food: the target is the agile performance of freight/storage tasks offering the higher profit.

6. Intermodal Supply Chain Supported by Electronic Freight and Warehouse Exchanges

The simplified system model of the conventional supply chain can be shown on Figure 4. The main features of the current supply chain system (+: positive features, -: negative features):

+ The wholesalers have extensive relationships with retailers and manufacturers, so they manage the demands.
- The wholesalers perform the freight and storage tasks, but they do not have:
  - suitable stock capacities,
  - suitable freight capacities,
  - logistics know-how.
- In the case of wholesalers the logistics processes are non-core.
- Due to the above-mentioned problem the current logistics system (e.g. combined transportation system) is not optimal.

To solve the above-mentioned problems, the electronic freight and warehouse exchange is expressly useful. The conventional supply chain can be modified, as shown on Figure 5.

The main features of the modified supply chain system:
+ The logistics providers (storage providers, transportation providers, logistics centres) perform the physical freight and storage tasks, whereas they have:
  - suitable stock capacities,
  - suitable freight capacities,
  - logistics know-how.
Electronic freight and warehouse exchanges perform the supply-demand (capacities-tasks) harmonization; the decision supporting and the optimization (shown functions in Figure 2).

In the case of logistics providers and electronic freight and warehouse exchanges the logistics processes are core.

Due to the above the modified logistics system (e.g. combined transportation system) may be optimal.

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**Figure 4.** The simplified system model of the conventional supply chain

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**Figure 5.** The simplified system model of the supply chain supported by electronic freight and warehouse exchanges

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7. Conclusions

Consequently, green logistics systems, e.g. **green combined transportation supply chains** can be realized. In addition, this system is beneficial not only for the individual actors (e.g. retailers, wholesalers, logistics providers, manufacturers, intermodal centres) but also for the national economy. The future plans include further development of algorithms and tests in real supply chains, e.g. supply chains of drink industry or other possible combined or complex city transportation system.

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References

RISK ANALYSIS IN MANAGERIAL PROCESS AND FUZZY APPROACH

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One of the most important steps in managerial process is the risk analysis. While various methods for conducting the risk analysis exist, in certain conditions only subjective qualitative approach can be used. The typical reason is the lack of input quantitative data. Methods of fuzzy logic can provide a convenient way to conduct risk analyses. The article describes an application of fuzzy logic and fuzzy approach into risk analyses and into risk management process. All needed requirements for using this approach are described. The main advantage of using fuzzy approach is limitation of subjectivity in risk assessment. That can provide basis for regular repeating of risk analyses thus, efficient control system can be created instead of formal occasional risk analyses. Article also describes recommended modification of threat identification process to maximize mutual effect when applied together with this kind of risk analyses.

Keywords: risk analysis, fuzzy approach, risk management

Introduction

The risk analysis is considered to be a very important task of managerial process of every complex system, such as transportation, communication or information system. However, it is also considered to be one of the most difficult tasks. Bad implementation of risk analysis can lead to a subjective behaviour of a whole analysis with consecutive unclear results. We believe that the main reasons for criticism are based on qualitative essence of modern methods widely used in risk analysis. Naturally, every possible tool that can be effectively used to reduce subjectivity has to be investigated deeply.

There are a lot of approaches for conducting risk analysis. Since there are a lot of different kinds of systems, many techniques have been developed to struggle with the most common issues of risk analysis:

- Subjectivity;
- Lack of information about threats and weaknesses;
- Formality and insubstantiality of analysis;
- Untrustworthiness of information about environment;
- Indeterminate results when analysing alive and rapidly changing systems.

The special problem in conducting the whole analysis is the way that it is not considering the actual countermeasures, so repeating the analysis before and after implementation of additional countermeasures has completely the same results. That is the case if only information about environment is taken into account, or when meaning and significance of these data are significantly overestimated.

There is not any universal and best method for conducting risk analysis and it is unlikely that such method will be created. However, it is important to understand the strengths and weaknesses of various approaches for conducting risk analysis.

Qualitative analysis relies on the subjective judgment of the competent personnel to determine the overall risk. We believe that further development of fully qualitative approach to risk analysis is not going to reduce the common disadvantages of current methods. Perhaps, additional development of this approach can create robust methods, with extensive and useful indices of threats, weaknesses and countermeasures, but essential problems caused by subjective matter of assessment is not going to be solved using fully qualitative methods.
Certainly there are also some advantages of conducting fully qualitative risk analysis, such as:

- Relative simplicity of risk evaluation;
- Lack of data can be substituted with experts estimations;
- Sometimes qualitative approach is ordered by law or other regulations.

Quantitative analysis is an approach that relies on specific formulae and calculations to determine the value of the risk decision variables. Certainly, there are significant advantages of quantitative approach:

- More objective;
- Based on mathematical methods;
- Meaningful statistics;
- Generally more credible than qualitative approach.

Also, quantitative approach is provided for cost-benefit analysis. Many corporate decisions requiring the expenditure of limited resources are made only after a careful cost-benefit analysis. This means that the perceived benefit of the project must outweigh the cost involved in such a project. Quantitative analysis can provide the information necessary to analyse the costs and benefits of proposed controls [1].

However, quantitative analysis is very complex, sometimes even not understood correctly by management and important concerns about risks can be overridden with information, that can be easily measured and they are proven by statistics. That is the main reason why implementing fuzzy logic is meaningful – because fuzzy logic can calculate also with non-accurate inputs [2] so the whole analysis does not rely only on data that can be exactly measured.

**Implementing the Fuzzy Logic**

Fuzzy logic is a convenient way to map an input space to an output space [3]. Method with implementing fuzzy logic that we describe in this article is suitable for risk analyses of highly dynamic systems where other approaches are often impractical. Comprehensive understanding of some processes in the system is required and is critical for conducting risk analysis based on fuzzy logic:

- Correct and consistent identification of sources of risk;
- Understanding the process of risk activation;
- Correct identification of input data that determines significance of risk.

The most important feature of risk analysis based on fuzzy logic is that the whole process leads to creating the control system that can effectively reduce risk. Because of exact output of analysis and consideration of countermeasures we can repeat risk analysis on a regular basis with valuable output.

Moreover, using fuzzy logic and methods based on fuzzy logic we can reduce subjectivity to acceptable level, because we are using quantitative input data so subjectivity is moved to process of creating relations and dependencies between input data and risk assessment, so it can be better controlled. Certainly, subjectivity is not eliminated completely. However, it is unlikely that method with no subjectivity will ever exist for risk analysis.

Basic element of risk analysis is a risk assessment. It is the activity that measures the strength of the overall system and provides the information necessary to make planned improvements based on information risks. There are also other stages of the risk analysis that make up risk management process (such as testing and gathering information, risk mitigation or risk reporting) that can be even more time-consuming, but we will focus our attention on the process of risk assessment, because it is a part that can use a fuzzy approach effectively.

The basic equation for risk calculation is risk = assets * probability [4]. Fuzzy approach uses methods of fuzzy logic to quantify both needed parts using quantitative input data. The main idea is to determine a few fuzzy variables for every part (assets, probability) of every risk that can be defined with fuzzy sets so in the following phase we use fuzzy rules and base of rules to build a fuzzy system. The fuzzy system is based on some “common sense” statements. [3]

Using fuzzy approach append some additional steps compared with common qualitative methods of risk analysis. On Figure 1 we can see these additional steps. The first step is to define non-numeric linguistic fuzzy variables.

*Figure 1. Additional steps in fuzzy approach, source: authors*
The second step is to define the base of fuzzy rules. The basic form of fuzzy rule is: IF variable IS property THEN action.

The common logic operators can be used, such as AND, OR and NOT. A fuzzy set is a clearly defined boundary. It can contain elements with only a partial degree of membership. [3] In fuzzy logic, the truth of any statement becomes a matter of degree. Fuzzy variables are described with membership functions. A membership function is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. The simplest membership functions are formed using straight lines. The simplest is the triangular membership function that is shown on Figure 2.

![Figure 2. Triangular membership function, source: authors](image)

The triangle membership function is usually appropriate in risk analysis. However, theoretically also other shapes can be used, such as Gaussian, trapezoidal, generalized bell and others. On Figure 3 we can see these shapes combined in a single figure.

![Figure 3. Gaussian, trapezoidal and bell membership function combined in single figure, source: authors](image)

The last step is fuzzy inference. Fuzzy inference is the actual process of mapping from a given input to an output using fuzzy logic. [3] In the end, output fuzzy sets for each rule are aggregated into a single output fuzzy set and the last step is process called defuzzification. The input for the defuzzification process is a fuzzy set (the aggregate output fuzzy set) and the output is a single number.

Usually, various techniques can be used in every step. For example, fuzzy aggregation can be used with three methods: max (maximum), probor (probabilistic or), and sum (simply the sum of each rule’s output set). On Figure 4 there is example of maximum and sum aggregation.

![Figure 4. Max and Sum aggregation operators, source: authors](image)

One of the biggest advantages of fuzzy logic is that the whole system is very flexible [5]. This is especially important in dynamic systems. We can say that every situation that we can solve with fuzzy logic we can also solve with other methods. However, the fuzzy logic can be the most efficient one. Modifying the fuzzy system is simple because the changes require only adding some other variables or rules [6]. There is no need to change majority of what was done before.

Some authors distinguish the fact that fuzzy logic is based on natural language as one of the most important. But since fuzzy logic is built atop the structures of everyday language, it not only makes it easy for us to use it (since fuzzy logic more closely “speaks our language”) but it also takes advantage of the long history of natural language [3].
Determining Value of Assets with Fuzzy Logic

The value of asset can be determined in two ways:

- Financial value of asset;
- Severity of the impact to company when asset is stolen, destroyed or temporary unavailable.

We believe that these two parts are completely equal. Sometimes even financial value of asset can be considered as less important especially when they are insured and easily accessible on the market. However, impact of destroyed assembly line can be fatal no matter of insurance of line itself or goods made by line, but because of layoff time that can produce significant loss.

Because of this, we prefer to use both factors in calculating value of each asset. Overall value will be determined by fuzzy system that will treat both factors equally, so layoff time that can cause significant financial loss is equal to stealing or destroying of asset with the same value.

There are some methods for financial value estimations that are widely used:

- Cost valuation – this approach to determining the value of an asset uses the economic principle of substitution.
- Market valuation – this approach is based on the economic principles of competition and equilibrium, better known as the law of supply and demand.
- Income valuation – this approach is based on the economic principle of expectation. This principle states that the value of an asset is equal to the expected incomes from that asset [1].

Using these methods, financial value of assets can be determined. With the next step we estimate the layoff time of crucial activities if various assets are stolen, destroyed or unavailable for normal operation. Then we can build a fuzzy system that will determine the value of each asset as logical conjunction of these two values – financial value and severity of impact of assets loss. Fuzzy logic is a convenient way to solve this task because there is no need to convert a lay-off time of various business processes directly to financial value and vice versa.

In Table 1 there is an example of simple base of fuzzy rules. Two antecedent variables are used: financial value and severity of system drop-out.

<table>
<thead>
<tr>
<th>Financial Value</th>
<th>Severity of the Drop-out</th>
<th>Consequent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Short Drop-out</td>
<td>0</td>
</tr>
<tr>
<td>Low</td>
<td>Long Drop-out</td>
<td>1</td>
</tr>
<tr>
<td>High</td>
<td>Short Drop-out</td>
<td>1</td>
</tr>
<tr>
<td>High</td>
<td>Long Drop-out</td>
<td>1</td>
</tr>
</tbody>
</table>

In Table 1 we used logical operator AND, however this base can be easily written with using operator OR:

- IF Financial value = Low AND Severity of the Drop-out = Short THEN f(u) = 0
- IF Financial value = High OR Severity of the Drop-out = Short THEN f(u) = 1

On Figure 5 we can see the calculation of output value in this example based on financial value of asset and severity of drop-out.

On Figure 6 there is graphical representation of output values in relation with input values and defined base of fuzzy rules.
Determining the Probability that a Vulnerability will be Exploited

Determining the probability is the next step. Using of term probability isn’t technically correct in the context of this approach. We will use it, because it is widely used in general specifications and standards that describe risk management process.

Determining the probability is not more complicated than estimating a value of assets. Simple and universal technique is to choose and specify for each risk fuzzy variables that can be objectively (but not necessary precisely) enumerated and that are in definite relation with a particular risk.

A reliable method for this is to analyse the past events and determine the critical variables from the past events. Variables can be described as enumeration of threat and enumeration of countermeasures. We need to specify dependencies using fuzzy logic and use fuzzy sets to define particular values.

There are some occasions when there is more efficient another more specific technique for estimating a probability of risk. All the variables can describe only efficiency of various countermeasures with defined mutual relations. To specify a relation we use attributes. There are three kinds of possible attributes:

- Sufficient condition – means that this countermeasure is theoretically sufficient for complete elimination of risk (for example regular backup of information system can eliminate risk of data loss).
- Necessary condition – means that elimination of risks is not possible to achieve without this countermeasure (for example security awareness is necessary for elimination of risk connected to social engineering).
- Sufficient and necessary condition – means that both attributes are present and other countermeasures have limited impact.

On Figure 7 we illustrate this concept graphically. In the upper left image there are two countermeasures marked as CM1 and CM2 and both have no attributes assigned. In this case the output that represents the probability that vulnerability will be exploited is symmetrical. In the upper right image countermeasure CM1 is marked with a sufficient condition attribute, while CM2 is marked with no attribute. Analogically, in the bottom images: CM1 is marked as a necessary condition (left) and a sufficient and necessary condition (right).
There is a simple example. We are considering risk that intangible assets in the information system will be corrupted because of accidental fault from personnel. We define countermeasures for elimination of this risk:

- Data Backup;
- Training;
- System monitoring and extra pay for no violation of internal rules.

From these countermeasures there is one countermeasure that has attribute – it is data backup, because complete online data backup can theoretically completely eliminate this risk. In real scenario keeping data on different location also would be required for complete elimination [7]. Other countermeasures can only partially eliminate this risk therefore no attribute is assigned to them.

On Figure 2 there is a graphical representation of relations between various countermeasures and probability of risk.

![Graphical representation of relations between various countermeasures and probability of risk.](image)

**Figure 8.** Concrete application of attributes in real scenario, source: authors

In Table 2 there is a fuzzy rule base for the given example. Sixteen rules were chosen with various combinations of input values.

**Table 2. Fuzzy rules base, source: authors**

<table>
<thead>
<tr>
<th>No.</th>
<th>Data Backup</th>
<th>Training</th>
<th>Extra pay</th>
<th>System monitoring</th>
<th>Consequent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>0.25</td>
</tr>
<tr>
<td>4</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>0.25</td>
</tr>
<tr>
<td>5</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>0.25</td>
</tr>
<tr>
<td>6</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>0.5</td>
</tr>
<tr>
<td>8</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>0.5</td>
</tr>
<tr>
<td>9</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>0.5</td>
</tr>
<tr>
<td>11</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>0.75</td>
</tr>
<tr>
<td>13</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>1</td>
</tr>
<tr>
<td>16</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>1</td>
</tr>
</tbody>
</table>

On Figure 9 we can see an activation of various rules with concrete input values. Because we chose just two fuzzy sets in this example, shape of fuzzy sets are adjusted in the way, that every non-zero input values activate part of rule.
On Figure 10 we can see a fuzzy inference, aggregation and numeric output. Sugeno-type fuzzy inference was chosen. The result is 0.448. The output value that represents probability is 0.552, because we have calculated the likelihood, that vulnerability won’t be exploited.

Using this approach we have to modify other techniques during risk management process, especially risk identification that has to take into account all other possible information, such as:
- Existence of risk itself, especially existence of source of risk.
- Sufficient motivation for harmful actions (if applicable).
- Similar past events.
- Other indicators of existence of risk.
Benefits of Fuzzy Approach for Risk Management

There are some important benefits of fuzzy approach for risk management process that are not possible to achieve with fully qualitative methods. The fuzzy risk assessment, no matter of used methods and input data, leads to a specific numerical output. Any further changes of input data also change this output, so regular repeating of analysis is meaningful.

Certainly, suitable and comprehensive input data for constructing the fuzzy system is required. There are a lot of risks that normally do not seem to be important and it looks that there is no need to take some countermeasures against them. Using only fully qualitative approach can lead to underestimation of these risks, because occasional analysis conducted under normal circumstances will not uncover their negative potential. However, under some specific and rare circumstances the same risk can be significant and dangerous. If we can define and track indicators that are associated with these rare circumstances then we can struggle effectively also with these kinds of risk.

Regular repeating of fuzzy risk analysis is important for achieving the optimal results. That is a reason why there are good results of using fuzzy approach for assessing the highly dynamic systems where there are regular changes in values of input data. Some risks can be evaluated only after long and time-consuming tracking and analysis of statistical data. This is not going to change no matter of method we are going to use, however some fully qualitative methods do not really require this tracking and they can use subjectivity instead. This seems to be a dangerous practice in the management of complex systems.

Relation with other Techniques in Risk Management Process

Since the comprehensive risk analyses conducted with fuzzy approach can be very time-consuming it is important to focus on meaningful and dangerous risks. It is important to combine risk analysis with correct threat identification.

Threat identification is a substantial part of risk management process. It is important to define relation between threat identification and risk assessments.

As we have mentioned before, we prefer fuzzy approach for analysing systems that are dynamic and are difficult to analyse with other methods. In this kind of systems, there are sometimes situations that we have very limited available information about dangerous risks:

- We know how to deal with risk so we know which countermeasures theoretically to take to prevent risk to occur.
- We have information about current countermeasures, especially how efficient they are compared to ideal countermeasures that could theoretically eliminate the risk completely.

With this information we can build fuzzy system for risk assessment. If we do not have this information we cannot conduct a comprehensive risk analysis, so these data can be understood as minimal requirements for conducting a risk analysis.

However, a lot of other information has to be analysed prior to process of risk assessment that will use only this kind of information. Some information cannot be objectively obtained and verified. In this case, information should be isolated from risk assessment (because we expect a quantitative output from risk assessment) and it should be moved completely to phase of threat identification. During risk assessment phase, the technical aspects of each risk are assessed and defined [8].

In the phase of threat identification we can use approved methods to analyse threats using a pre-defined factors, such as generalized method derived from the method specified in FM 3–19.30 [9] that define several factors:

- Factor 1: Proven or theoretical existence of source of risk.
- Factor 2: Capability. It is apparent that current countermeasures do not eliminate risk.
- Factor 3: Intentions. For human caused risks only.
- Factor 4: History. Demonstrated activity over time or past events (like disasters).
- Factor 5: Targeting. Current credible information on activity indicative of preparations for specific type of attack or event.

After that a threat can be classified on scale and then deep risk analysis can be conducted for significant risks:

1. Critical: factors 1, 2, and 5 are present. Factors 3 or 4 maybe present.
2. High: factors 1, 2, 3, and 4 are present.
3. Medium: factors 1, 2, and 4 are present.
4. Low: factors 1 and 2 are present. Factor 4 may be present.
5. Negligible: factors 1 and/or 2 may be present [9].
Risk assessment should be based on information that is essential for estimation of risk exposure and on the effectiveness of defense mechanism that should protect us from actual threats. These data are based on effectiveness of countermeasures so they are available for us. Critical task is then to define fuzzy system correctly so it will match real relations and dependencies in real system.

Conclusions

We can conclude that there are several reasons why to use fuzzy logic in the process of risk analysis:

- Fuzzy approach creates flexible framework that can built on top of the experience of experts [3];
- Fuzzy logic is tolerant to imprecise data [10];
- Regular risk analysis based on fuzzy logic can create an effective control system.

The most important conclusion is that fuzzy approach limits subjectivity in situations where fully quantitative approach cannot be used. Fuzzy approach can be also good motivation for management to go deeper in risk analysis because of numerical (not qualitative) output. Numerical output for overall risk representation is big advantage in efficient risk monitoring process. In Table 3 we can see sample table of risk levels and relative risk changes (in percentages of previous value) throughout time. Such practice can enhance risk monitoring process.

<table>
<thead>
<tr>
<th>Risk No.1</th>
<th>Risk No.2</th>
<th>Risk No.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level</td>
<td>Change (%)</td>
<td>Level</td>
</tr>
<tr>
<td>Analysis</td>
<td>Feb.2012</td>
<td>0.17</td>
</tr>
<tr>
<td>Analysis</td>
<td>Sep.2012</td>
<td>0.17</td>
</tr>
<tr>
<td>Analysis</td>
<td>Feb.2013</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Various risks that endanger complex systems have very difficult mechanisms of activation so precise mathematical modelling the system is usually too complex for practical application. Fuzzy logic with built-in toleration to imprecise data is an ideal tool for enhancing the effectiveness of risk analysis. Certainly, fuzzy approach requires real experiences of experts and competent personnel to identify and collect needed data and to build a fuzzy system. However, subjective evaluation is limited especially compared to other methods.

References

DEVELOPMENT OF METHODOLOGY AND TOOLS FOR COMPARATIVE ASSESSMENT OF OPERATIONAL EFFICIENCY OF KPI-BASED LOGISTICAL INFRASTRUCTURE FACILITIES

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The article features an approach to comparative assessments of logistics centres operational efficiency based on the system of logistics key performance indicators and describes the framework methodology and the order for the development of the methodological support of the specified task.

The study was conducted in the framework of the Rail Baltica Growth Corridor (RBGC) Russia project, which seeks to involve North-West Russia in the dialogue about Rail Baltica transport corridor and is supported by the Delegation of the European Union to Russia for the period 2012–2013. Particularly, RBGC Russia addresses the issues of operational and functional interoperability of logistics centres in Eastern Baltic Sea Region.

Keywords: assessment of efficiency, logistics activity, terminal and logistics complexes, key performance indicators of logistics activity (KPI), general logistical costs model

Introduction

New requirements for the applied logistics technologies used to manage the systems of different levels are imposed by the current economy trends, which are associated with the increase of national economies integration level, growing globalisation of various activities, formation of modern production and distribution systems, etc. Alongside with that, implementation and active use of these technologies implies that there is a high-technology and efficiently operating logistical infrastructure where, to our opinion, top priority should be given to establishing integrated systems of the infrastructure support based on the international projects on logistics infrastructure development which are expected to result as follows: growing intensity of the cross-border traffic flows, reduced logistical costs related to transit and interstate traffic flows, development of the intermodal delivery technologies, increase of the development level and operational efficiency of the warehouse component of the logistics infrastructure. We believe that the principles of integration and coordination of logistics centres operation should form the basis for successful implementation of such projects. Global experience evidence the importance of the logistics centres in providing coordination and interaction in the work of various means of transport, development of the intermodal cargo traffic and ensuring state-of-the-art logistics technologies being implemented. In this case the integration and coordination principles are implemented depending on the level of the development and operability both of the entire complex of the respective logistical infrastructure facilities and of the individual logistics centres.

In this regard a number of issues need to be resolved.

1. What are the state and development prospects of the logistical infrastructure in the region under consideration?

2. What is the methodological basis for the comparative assessment of the logistics centres operational efficiency?
3. What indicators can most reasonably be used to get such estimates?

4. Which methods ensure obtaining the results which make it possible, on the one hand, to take into account the specific features of particular logistics centres’ business processes and, on the other hand, to provide quantitative estimation of their impact upon general performance indicators, for example, the total logistical costs?

The following succession in solving the problems raised was applied within the Rail Baltica Growth Corridor project.

1. Assessment of the State and Trends of the Terminal and Warehouse Services Market Development in the North-Western Region

This problem was resolved in two stages:
- general analysis of Saint-Petersburg warehousing property market based on the published data provided for by the independent consulting and analysis agencies (ASTERA, Jones Lang Lasalle, Colliers International, Knight Frank Saint Petersburg, etc.);
- detailing features of the demand for high-quality warehouse spaces, stockpiling and handling services using polling techniques (including online questioning) and the subsequent interview.

According to the estimates given by the experts of analytical departments of independent consulting companies in respect of the warehousing property market, the warehousing property facilities of the North-Western region have managed to overcome the economic slowdown after-effect, and their indicators are gradually growing up.

The constantly growing demand for high-quality warehouse premises is taken into consideration when analysing the situation at the warehousing property market of the North-Western region. Increase in the demand for warehouse facilities may be observed both from perspective of small companies and major logistical market players. This causes severe reduction in the share of high-quality vacant warehousing areas. Increase in the demand for high-quality warehouse premises is promoted by the activities of the majority of the development companies which have chosen not to construct any facilities without prior agreements with customers. Currently the most popular type of warehousing property facilities is customer-paid warehouse complexes that are subject to “build-to-suit” conditions. Further rental rate growth has been promoted by the existing relation between the warehouse premises being placed in operation and those in demand.

At the end of the year 2012, the share of the vacant warehouse spaces in Saint-Petersburg was the lowest in recent 5 years. According to different analytical agencies, it has reduced to 2.2–4.9 % (Fig. 1). At the same time the facilities declared to be commissioned in the coming years have not yet covered the existing deficit and the level of vacant spaces may decrease to terminal values. The year 2012 saw an 11% increase in the total scope of the speculative supply (the scope of the leased and leasable areas) at the Saint-Petersburg high-quality warehouse property market, which, according to different sources, makes from 1.07 to 1.85 million m².

![Figure 1. Level of vacant warehousing areas and their acquisition, Saint-Petersburg](image)

In 2012 an aggregate net acquisition of the areas in the operating complexes made up about 150 ths.m² showing a 4% decrease, compared to 2011. Shortage of cost effective areas in the existing high-class warehouse complexes results in the leaseholders’ demand being gradually reoriented to the operating facilities of lower class, to the new complexes under construction and industrial parks. The
share of the vacant warehousing areas and rental rates have come back to 2006 level, when a great number of speculative projects started to be actively commissioned on the market.

The following changes have been recently recorded in the pattern of demand at the Saint-Petersburg high-quality warehousing property market: the most active lease market participants are still trading companies and commercial and industrial companies renting the warehouse areas to arrange their own distribution centres (63%). Logistics operators’ share in the total demand pattern was reduced to 34%, while the share of the manufacturing companies went down to 3%. Construction companies, hardware suppliers and food industry enterprises are the most active players at the Saint-Petersburg warehousing property rental market. According to the data provided by Knight Frank Saint-Petersburg, in 2012 online trading distributors have accounted for about 80% of lease transactions on the Saint-Petersburg warehousing property market.

Following the results of the examinations performed by the experts of major consulting agencies, the sales representatives of large hypermarkets, distributors and logistics operators are the key tenants in the high-quality warehouse complexes. The blocks of 3–5 th.s.m² are the most popular lease format. 56% of the total number of the recent warehousing property lease transactions is accounted for the transactions with an area of up to 5 ths.m²; in its turn 25% is accounted for transactions with an area over 10 ths.m² and 19% – for transactions with an area from 5 to 10 ths.m². At the same time the average size of the leased warehouse module tends to grow.

Table 1 represents basic indicators of the Saint-Petersburg warehousing property market.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>I quarter of 2008</th>
<th>I quarter of 2009</th>
<th>I quarter of 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area in most high demand, m²</td>
<td>2000 - 4000</td>
<td>500 – 2000</td>
<td>3000 - 5000</td>
</tr>
<tr>
<td>Rental rate, USD (net of operating expenses and VAT)</td>
<td>128 - 208</td>
<td>90 - 150</td>
<td>A: 120-130</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>B: 98-117</td>
</tr>
<tr>
<td>Lease agreement term</td>
<td>3-7 years</td>
<td>1 year</td>
<td>3 years</td>
</tr>
<tr>
<td>Lease agreement currency</td>
<td>USD</td>
<td>Roubles</td>
<td>Roubles, Euro</td>
</tr>
</tbody>
</table>

A questionnaire was used to specify the characteristics of demand for high-quality warehouse spaces and stockpiling and handling services. The questionnaire includes 6 sections (26 questions): company’s overall performance, financial indicators of a company’s activity, assessment of the state and development prospects of the logistics services market, customer management, company’s expected future development and information technologies.

Based on the estimates received, the companies involved in the questionnaire noted the general excess of supply over demand on the logistics services market. Rendering complex logistics services aimed primarily at the domestic market and at the limited number of large clients (1-3) is considered to be the business opportunities for the companies. The following is named as the areas of activity optimisation: selecting subcontractors, introducing information systems; according to the respondents, the potential threats can be: change of the legal framework in the field of logistics, shortage of financial resources and intensification of competition.

The results of the received data analysis make it possible to conclude that settling the problem how to make rational choice of the logistical infrastructure facilities (herein – terminal and logistics centres) when included into the project under development requires formation of tools for comparative assessment of operational efficiency thereof. The settlement of the task might be of interest, first of all, for supply chain prospective partners and for moderators of the projects related to the development of terminal and warehouse infrastructure, and only then for logistics centres themselves as in the circumstances where the facilities are occupied to the maximum possible extent the problems of in-depth analysis of business processes are not treated as topical by such companies. However, this situation seems temporary in our opinion; when the warehousing property market conditions change, affected, for example, by commissioning of the declared warehousing complexes or by the intensified competition at the warehousing services market, management of logistics centres will also require available tools to estimate how the decisions made affect general performance indicators of a facility and the supply chain.

2. Analysis of the Existing Approaches to Formation of the Systems of Logistics Activity Assessment Indicator Systems

Positive business results in aspects of the logistical strategy appear to be achievable when using Balanced Scorecard (BSC) as the key tool for analysing and regulating a company’s activity. A widely
used Balanced Scorecard concept is based on the requirement to consider in aggregate various business aspects – particularly, finances, clients, and processes, potential – to provide for the company’s effectiveness assessment. But application of basic BSC ideas to logistics meets certain challenges as this concept was initially formed as an instrument for adequate evaluation of manufacturing companies’ value using non-monetary indicators alongside with the traditional financial indicators. It stands to reason that composition of these indicators reflected the specific features of the enterprises under study and could not be applied without having been respectively revised and adapted to the assessment of the logistical activity. Thus, one of the primary tasks of BSC being used in logistics is related to forming a complex of the logistical activity’s key performance indicators (KPI). Settlement of this issue appears to be important as KPI system is an effective means of controlling logistical business processes.

The analysis of the contemporary logistics sources enables to admit that by now there is not any universal viewpoint established in respect of the composition and the structure of the key estimated figures (indicators) of the logistics activity effectiveness. In particular, according to M.Christopher [1], the minimum set of indicators for logistics assessment includes estimation of the service quality (in respect of providing for the designated level of an “ideal (or perfect) order”), response time (according to the time spent to fulfill the order in the supply chain), general costs (according to costs for logistical service). J.Stock and D.Lambert [4] highlight four groups of key logistical indicators, including both quantitative and qualitative ones.

Scientific and study logistics materials represent other approaches to distinguishing the indicators of the logistical decisions efficiency for various logistical fields and logistical infrastructure facilities (for instance, [5], [6], [7]).

Summing up different approaches described in the course of the scientific discussion on the issue under consideration we believe that the key (or complex) indicators generally evaluating efficiency and effectiveness of logistics should include: total logistical costs (KPI-1), quality of logistical service (KPI-2), logistical cycles duration (KPI-3), productive capacity (KPI-4), return on the investments in logistical infrastructure (KPI-5) [2].

Alongside with that, there is a group of particular indicators included into the structure of the companies’ logistics activity indicators which, in their turn, are divided into effectiveness indicators (Ple) and performance indicators (Pli). Figure 2 outlines the hierarchy of companies’ logistical activity indicators.

<table>
<thead>
<tr>
<th>Balanced ScoreCard (BSC) of an enterprise</th>
<th>1) Financial results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2) Order portfolio</td>
</tr>
<tr>
<td></td>
<td>3) Domestic business processes</td>
</tr>
<tr>
<td></td>
<td>4) Staff training and development</td>
</tr>
<tr>
<td>Logistics General Indicators</td>
<td></td>
</tr>
<tr>
<td>Logistics key performance indicators (KPI)</td>
<td>1) General costs</td>
</tr>
<tr>
<td></td>
<td>2) Logistical service quality</td>
</tr>
<tr>
<td></td>
<td>3) Cycle execution time</td>
</tr>
<tr>
<td></td>
<td>4) Productive capacity</td>
</tr>
<tr>
<td></td>
<td>5) Investment application</td>
</tr>
<tr>
<td>Logistics Specific Indicators</td>
<td></td>
</tr>
<tr>
<td>Effectiveness Indicators (Ple)</td>
<td>1) Number of orders processed per unit of time</td>
</tr>
<tr>
<td></td>
<td>2) Cargo shipments per unit of a terminal and logistics center capacity, etc.</td>
</tr>
<tr>
<td>Performance Indicators (Pli)</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2. Hierarchy of a company’s logistical activity indicators
3. Itemization of the Existing Approaches to Formation of Performance Indicator Systems as Applied to Terminals, Terminal Complexes and Warehouses

Systems of key indicators estimating the warehouse activity are formed on the basis of the development (or description of the existing) materials handling business processes covering all component processes. It is evident that the described systems of business processes of different terminal and warehouse complexes are unique and determined by the accepted technological process of handling, specifics related to integration relations with arrival and departure transport and other elements of a supply chain. This reasons the variety of the developed KPI systems related to transformation of the traffic flows at the warehousing logistical infrastructure facilities.

4. Selecting a Technique to Form Quantitative Estimates of How General Logistical Costs are Affected by the Work of Certain Logistics Centres

Modern approaches to assessment of the logistics key indicators are mainly limited to application of the methods of comparison: with the reference standard (or absolute standards, i.e. the best results that can ever be achieved), with best practices (benchmarking), with targets, with past standards (the results that were achieved in the past periods). An obvious advantage of these approaches is their simplicity; however, they also have serious faults which prevent them from being put into practice. In particular, the method of comparing with the previous standards brings into focus the problem of data compatibility, the method of comparing with the targets requires that plan figure values should be estimated, benchmarking involves prior analysis of companies’ logistical business processes. Moreover, the specified methods fail to provide the basis for KPI factorial analysis, therefore it is impossible to estimate the impact that the management decisions rendered have upon the effectiveness of the logistical system expressed in terms of the key estimates, which should be regarded as the most essential fault of comparison methods.

Elimination of the said drawbacks, reduction of the analysis terms, more complete coverage of the factors influencing business results, substitution of approximate or simplified calculation by exact computation may be achieved with the use of the integral method as one of the mathematical methods of the economic analysis. But the integral method application is connected with the search of the analytic dependence representing interrelation between arguments-factors and the resulting characteristic. In our opinion, the model of total logistical costs (TLC) can be accepted as such dependence as the formal representation of model (1) includes individual indicators of effectiveness (performance) and productive capacity of the logistics activity, which, in their turn, may be reduced to KPI total (key) indicators. Thus, the direction in which the analytic dependence should be searched is based on the statement of connection and interrelation of TLC model and the key estimates of the KPI logistics activity.

\[
C_\Sigma = A C + \frac{A}{S} C f + \frac{S}{2} C f \sigma \cdot k \cdot P(T_0<T) \cdot C_w, \tag{1}
\]

where
- \(A\) – production requirement during the period under review;
- \(C_p\) – price per unit of product;
- \(C_o\) – costs related to arrangement and execution of an order;
- \(S\) – order lot (delivery) size;
- \(f\) – storage cost share depending on the price per unit of product;
- \(\sigma\) – standard deviation of the reserve stock;
- \(k\) – coefficient (parameter) corresponding to probability of shortage absence \(P(S)\);
- \(C_s\) – losses caused by inventory shortage;
- \(\varphi(z)\) – loss function (tabulated for normal law of distribution);
- \(z\) – safety factor;
- \(C_w\) – amount of fines paid for contractual terms infringement, for instance, for breach of the delivery schedule;
- \(P(T_0<T)\) – probability of contractual terms infringement, namely, of the delivery schedule.

Detailed representation of the structure of the total logistical costs model enabled to reveal strong interrelation with logistics key performance indicators (KPI). In particular, the total value of the logistical costs under model (1) is KPI-1 value, individual factors like “Costs for internal and external transportation”, “Costs for stockpiling and materials handling”, “Order procedure related costs”, “Costs for stock management” are included into an equation of the total logistical costs (1). The similar analysis has been carried out for KPI-2 “Logistics service quality”, KPI-3 “Duration of logistical cycles”, KPI-5 “Return on logistical infrastructure investments”.

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5. Development of KPI-Based Analytical Tools to Assess the Activity of Terminal and Logistical Complexes

The next stage is aimed at the development of the analytical tools. An integral method of the economic analysis has been chosen as an applicable methodological framework. The analysis method has been adopted due to a number of reasons:
- the method makes it possible to determine the impact the indicators have on the function value at any number of arguments, any form of their connection and irrespective of the succession of factor analysis; it is also notable for high accuracy of computation;
- large-scale practical application thereof, as the use of the working formulas obtained during the analysis does not require the practitioners to know any source data required in the course of the mathematical transformation analysis.

Formation of the KPI-system for terminal and logistics complexes is based on the stage.
- by-stage decomposition of the structure of the total logistical costs model as regards the elements connected with implementation of stockpiling and handling functions. To do this it is necessary to itemize the total logistical costs model with transport and logistics operations at a terminal and logistics complex being taken into account. In this case the number of the model components and, therefore, the number of arguments-factors are obviously going to increase (Fig. 3).

To sum it up, the specifics of the proposed approach are as follows: the KPI composition may be considerably variable depending upon specifics of operational activities of the terminal and warehouse complex; at the same time, the total logistical costs model comprising different logistic functions (stock management, transportation, stockpiling and handling, etc.) being used as the basis allows to tie up interests of different companies forming the supply chain.

\[ C_{\text{cost}} = C_v + C_X + C_Y + C_{\text{stock}} + C_{\text{order}} + \sum C_{\text{um}}. \]

where \( C_v \) – costs related to an order arrangement and processing;
\( C_X \) – costs for the current stock storage;
\( C_Y \) – costs for the reserve stock storage;
\( C_{\text{stock}} \) – costs for customer order batching;
\( C_{\text{order}} \) – total costs for service of vehicles arrived at the customs and logistics center;
\( \sum C_{\text{um},i} \) – expenses related to I type of fines.

\[ C_{\text{cost}} = C_{\text{order}} + C_{\text{stock}} + C_s. \]

\[ C_{\text{order}} = \frac{A \cdot C_s}{S} \]

– costs associated with selection of inventory items from storage

\( C_s \) – costs for intra-terminal transportation

**Figure 3.** Itemization of the total logistics costs model for terminal and logistics centres (complexes)

Intra-terminal mileage under selection
- System of inventories withdrawal from storage areas
- System of placement for storage, etc.

Speed of the inventories withdrawal
- Equipment used
- Personnel qualification
- Number of stock items in an order
- System of inventories withdrawal from storage areas
- and others.

Cost of 1 hour of withdrawal
- Cost of 1 hour (shift) of the equipment operation
- Cost of 1 staff working hour (shift), etc.
References

NUMERICAL SIMULATION OF PAVEMENT RESPONSE TO DYNAMIC LOAD

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Road structures are loaded by heavy vehicles and also they have an influence of temperature changes, which cause a difficult stress and strain distribution over layers of the pavement and the subgrade. Knowing this, distribution of stress and strain can help to better understand the behaviour of the pavement during the service time. For this purpose, the mechanical characteristics like elastic modulus, Poisson ratio, or damping ratio have to be known. The special device is used for determination of these mechanical characteristics, which loads the surface of the pavement by a force impulse. The deflections are measured in the surroundings of point of load impulse. The signal can be evaluated by use of 2D or 3D calculation model of pavement construction. In this case was used the axially-symmetric 2D model. This reduced the time consumption of individual tasks solution. The article considers also the influence of boundary conditions on deflections of models with varying width. The following text describes findings acquired from numerical simulation of pavement response to dynamic load.

Keywords: calculation model, dynamic method, deflection

1. Introduction

The transport load as well as the weather conditions causes degradation of material of construction layers of pavement. Therefore it is necessary to have diagnostic procedures for obtaining information on current condition of the pavement. Using this information it is possible to determine residual service life or to suggest effective maintenance to eliminate the defects. Methods for determination of deformation characteristics can be divided into static and dynamic diagnostic methods. Presently, static methods of the pavement load are already worked out in detail. This article deals with methods of the dynamic load.

This article provides numerical simulation of load impulse of pavement, which in a simplified form takes into account the effect of deformation characteristics of pavement layers on the resulting deflection time curves [1], [2]. The shape of load impulse corresponding to the shape of load impulse of device FWD Dynatest is used for determination of the excitation force time curve [3]. This device is used commercially for measurement of the mechanical characteristics of the pavements. It is highly accurate, reliable and has a simple user interface.

2. Description of Calculation Model

The calculation model was created in the software Adina [4], using finite element method (FEM) [5], [6]. The calculation model represents the composition of the structural layers of the pavement on subgrade. Characteristics of the construction layers of pavement and individual thickness are shown in the Table 1. Parameters are changing depending on the pavement type in consideration of changes of asphalt layers modules caused by change of their temperature. Zero displacement at the edges of calculation model has been considered (Fig. 1).
The solution time depends on the amount of elements connected with the amounts of equations. Firstly, the area, which represents the pavement layers, and subgrade was discretized by using 3D solid elements. It led to the big amount of elements as well as the demanding requirement for the computer capacity. After first attempts to solve this we realized that it would not be effective. The decision to decrease the amount of elements by using axial symmetry was made. So the geometry for model in z-plane was modified and the area was discretized by using axis symmetric 2D Solid elements. Comparing the results obtained in dynamic analysis it is obvious that there is no need to create complicated and time-consuming 3D model. A lot easier axially-symmetric model, which gives the same results, is sufficient. This is also evident from the following comparison of the time curve of road surface deflections in analysed points (Fig. 2).
For this reason only easier axially-symmetric 2D model of pavement construction was used for further analysis. This reduced the time consumption of individual tasks solution as far as the number of the equation system solutions significantly decreased.

The load is characterized by a pressure applied on the load plate differing in dependence on the load impulse (Fig. 3). Position of the points (nodes) in which the results were analysed (their distance from the axis of the load) was equal to the location of points for road surface deflection measurement (Fig. 2).

![Figure 2. Display 2D and 3D model](image)

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![Figure 3. Time history of load impulse](image)

**Figure 3.** Time history of load impulse
3. Influence of Boundary Conditions of Calculation Model

The dynamic analysis of influence of 2D model width changes on the resulting deflections was performed. Calculation models were created with a width of 3 m, 5 m and 10 m (Fig. 4).

*Figure 4. Time curve of pavement surface deflections in analysed points for dynamic analysis*

The comparison shows that in case of width 3 meters and 5 meters time curves are different and mainly in the points further from the axis of the load. In comparison to the model of width 5 meters and
10 meters, it is not such a visible and significant change. The same results are obtained by comparing amplitudes. It is visible that in case of deviations of time curves at further points, the time span is not long enough to display the part of curve where deflection expires. Therefore, it is difficult to estimate the amplitudes, particularly for models with smaller width. In these models amplitudes are also affected by reflection of propagated wave from the edge of the calculation model.

4. Comparison of Results of Numerical Simulation of Pavement Response to Load Impulse

The 2D calculation model was used for three types of pavements A1, A2, A3 in the dynamic analysis. Zero-displacements at edges of calculation model were considered. The modulus of elasticity of pavement construction layers were modified depending on temperature for each type of pavement. Thus nine numerical models of pavement have been created. Their material characteristics and thickness of structural layers are shown in Table 1.

The figure (Fig. 5) shows amplitude values for individual models of pavement labelled A1, A2 and A3 (Tab.1). Temperatures for which modules have been determined are defined for each model. Maximum deflections of pavement are developed in load axis and gradually diminish with increasing distance from the axis of the load. The graph shows that the maximum deflections measured in the axis of the load are in the range from 0.37 mm to 0.42 mm. The largest values have been obtained for the model A1 characterizing semi-rigid pavement at 0°C. The smallest values have been obtained for the A3 model characterizing flexible pavements at 0°C.

![Figure 5. Changes of maximum z-displacements in dependence on the type of pavement and material characteristics of layers](image)

The comparison shows that for models A1 and A2 characterizing the semi-rigid pavement the maximum deflection is at the load axis at 0°C and 27°C almost the same and changes significantly at 11°C. In the case of flexible pavement, maximum deflection increases with increasing temperature and thus with the influence of the reduction in the elastic modulus of asphalt pavement layers.

The following analysis of the results has been focused on the influence of the pavement construction type on the calculated maximum deflections in the observed points. The selected reference temperature is 11°C. For better comparison, the results of deflections in the observed points are shown as ratio to the maximum deflection in the load axis (Fig. 6). The comparison shows that the changes occur in observed points in the distance of more than 1.2 m. At this distance it is possible to monitor the influence of thickness changes of road base. This road base has the greatest stiffness and therefore change of its thickness affects the size of deflection. The relative value of maximum deflection at a distance of 1.2 m decreases with increasing thickness of asphalt layers of pavement in comparison to the maximum deflection of the load axis.
To the same conclusion results also the comparison of the influence of temperature changes and thus of the change of the stiffness of pavement construction layers (Fig. 7). For comparison, the semi-rigid pavement model A2 has been selected. It is visible that the difference of deflection ratio in observed point versus deflection in the axis of load is significant with distance of 0.9 m and more. Deflection is the smallest at 0°C, where the road base has the largest elastic modulus, and gradually decreases with reducing stiffness. It is interesting that in the distance of 1.2 m the difference is not so significant.

5. Conclusions

The signal can be evaluated by use of 2D or 3D calculation model of pavement construction. From comparison of results acquired from dynamic analysis is obvious that it is not necessary to create complicated and time-consuming 3D calculation model. The axially symmetric 2D calculation model was created for this purpose in modelling program ADINA 8.9. Dynamic analysis solved the influence of change of model width on deflections. Mathematical simulation showed that the time span for models with higher width was not sufficiently long to see the part of curve, where deflection expired. In this case, it is difficult to create an adequate calculation model and estimate the size of the modelled area so that the results are not affected by reflected propagation wave from the edge of the modelled area.
This article deals with comparison of results of numerical simulation of pavement response to load impulse. The results of numerical simulation of 2D model shows that change of the pavement type leads to change of maximum deflection in the axis of load. Using the calculated values of maximum deflection at all points and by their comparison it is possible to determine the influence of temperature and thus also of stiffness of asphalt pavement layers on relative value of maximum deflection to maximum deflection in load axis.

Acknowledgment

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FROM BUBBLE TO SUSTAINABLE ECONOMY IN THE BALTIC STATES

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The Baltic States became independent in the early 90’s, when the iron wall collapsed in the whole Eastern Europe. Thereafter, development in economic terms was rapid and particularly manufacturing and transportation sectors were responsible for prosperity formation. However, after late 90’s situation changed, and boom was apparent in credit led real estate, finance, retail and construction sectors. As these sectors are all domestically oriented, and while the Baltic States in this credit boom period did not experience any trade surpluses, it was evident that credit crunch in 2008–2009 affected economies severely. This research work shows that the Baltic States need to change again weight in Foreign Direct Investment (FDI) for manufacturing and transportation, sectors which have been supported previously only by European Investment Bank and EU Cohesion fund. FDI is vital for the Baltic States, since they have been for long time net receivers of capital, and GDP has greatly been dependent on these inflows. However, future prosperity is only built with export oriented FDI.

Keywords: the Baltic States, FDI, loans, EU cohesion, manufacturing, transportation

1. Introduction

Credit crunch of USA during years 2008–2009, which led to global economic slowdown, hit hard all the Baltic States [1]. Experienced change in downsized was very sudden, and even private sector actors were entirely unaware of its magnitude [1]. Therefore, unemployment increased within very short time [1–2] and construction sector was severely hit [2–3]. However, not only domestic economy led sectors were suffering, but this has been present also in export industries, like metal industry, which was experiencing 40% slump in orders in Latvia (the largest export industry; [4]).

However, root problem in the Baltic States for these sudden negative changes was the economic structure formation and renewal, which took place during previous boom time. Relatively loose monetary policy of banks (international phenomenon then) resulted in fixed capital investments, and it has been analysed that in Lithuania during years 1995–2009 these fixed capital investments alone explained 91.54% from GDP change [3]. Even if investments soared, and construction industry experienced boom period [2], other sectors, like export based manufacturing was continuously declining [5–6]. Similar situation happened with e.g. agriculture [3]; EU support has been argued here to be effective, that this branch even exists in the Baltic States today (volumes were continuously declining before EU membership; [7]). So, the problem of the Baltic States in general was that there did not exist any seriously taken industrial export arm, which could have aided their recovery out of the crisis with agreed and implemented lower salary levels. The Baltic States economies remind in miniature scale that of USA; in large extent their economic growth model was based on demand alone, not on supply. Therefore, it is not surprising to find out that Latvia has stated that export based manufacturing is their main development objective [6]. Challenge in export industries is that they are low technology companies (mostly food and beverages; [8; 6]), and main customers are in Europe [9]. This low-technology status mostly concerns Lithuania and Latvia. Based on research of Bernatonyte [9], Estonia is the most competitive in export industries, and two other Baltic States follow it with considerable distance. However, it should be noted that even in Estonia the industrial renewal is needed, e.g. the readiness for CO₂ emission prevention and year 2020 and 2030 reduction targets could be higher as industries will most probably face increasing electricity prices due to CO₂ emitting production processes of heat and electricity production [10].

Situation is not entirely hopeless, as EU cohesion funding is plenty during program period of 2007–2013 for all the Baltic States and continues to be so in the future cohesion funding rounds. Most of this granted funding was unused before the crisis, e.g. Lithuania only had used one third of them before the credit crunch [11]. Similarly Estonia reports in program webpages, that half of the entire funding is used in their country now, but rest of the projects for the end of 2013 are agreed, and costs will accumulate in late year 2012 and mostly in 2013 [12]. These funds are, of course, hope for a better future, since their use now in the challenging times is replicating Keynesian stimulus of economic downturns.
This research is structured as follows: Section 2 portrays economic development in the Baltic States within recent decade. Strengths and weaknesses are reviewed briefly in this section, too. Thereafter, in Section 3 FDI inflows are examined in long-term perspective from all the Baltic States by industrial branches and countries involved in this activity. Role of international lending organizations (like EIB and ERBD) is analysed in Section 4, where it is shown that loans and especially the role of EIB has increased in recent years. EU cohesion funding is reviewed in longitudinal perspective in Section 5. Research work is concluded in Section 6, where also avenues for further research are being provided.

2. Economic Development in the Baltic States

All the Baltic States were growth tigers in the previous decade, and economic prosperity in national currency terms grew at least 10% p.a. before credit crunch. However, if we measure GDP change in euro terms, Latvia was experiencing some IT bubble burst problems in 2002–2003, but recovered strongly out of this (in national currency GDP growth was still 10%, but this mostly caused due to depreciation of currency). Signs of overheated economy were very much present in year 2007, when GDPs grew 20–30% p.a. (Figure 1). As will be shown later on this research work, overheating was caused by the massive capital inflows to the countries, particularly improvement of FDI inflows. However, as uncertainties in the world economies started to be present, investment activity disappeared suddenly as confidence on future growth was hurt. This eroded economic growth rather suddenly. Of course long-term loans taken from EIB and structural funds used out of EU cohesion helped a bit, but we may note that in year 2009 decline was massive. GDPs declined by 15–19% then. Thereafter all three countries have experienced recovery process, but still in absolute terms GDPs of year 2011 were below the level of year 2008. During year 2012 Estonia (+6.6%) and Lithuania (+6.7% in EUR terms) passed GDP level of year 2008, and also Latvia is showing strong growth (+10.1% in EUR terms), but in absolute terms is still slightly below year 2008 top.

Among investment attraction, all three Baltic States hold naturally important role as transit cargo locations for eastern (Russia, Ukraine, Byelorussia, Kazakhstan etc.) export of raw materials and/or import of consumer goods. This also affects greatly on employment and consumption, in turn having connection on GDP growth. In period of 2000–2009 these three countries had continuously changing position in transit cargo handling (e.g. [13]). For example, Estonia lost significantly coal transports during the decade perspective (development was in part fostered by small political crisis with Russia in 2007), but in turn Latvia was able to grow significantly in coal transit with sea port of Riga (capital city). However, in oil handling and fertilizers Latvia and Estonia have experienced decline in decade perspective, while Lithuania has grown considerably. In containers (general cargo) only Riga sea port in Latvia has been able to show in decade perspective clear growth – Lithuania and Estonia are looking also promising in this respect [14]. So, we could argue that transit transport is messy topic to be connected directly in GDP growth (as it changes between three Baltic States so rapidly), however, we may conclude that crisis in year 2009 took significant part from handling volumes away, and in turn caused GDP slump in crisis year. Declines before this crisis year were in parts caused due to rapidly deteriorating business climate, but also due to political tensions.

![Figure 1. Gross Domestic Product (GDP) change in the Baltic States during previous decade (GDP converted to Euros with BOF [15]). Source: Statistics Estonia [16], Central Statistical Bureau of Latvia [17], Statistics Lithuania [18]](image)
As an anomaly to the Baltic States acts the United States. Similarly to USA, all the Baltic States significant trade deficits (these considerably widened after early 2000; recent years, see Figure 2) have recorded for years. After credit crisis situation has still remained, mostly due to high priced oil (was, of course, problematic also during growth period; see e.g. for Switzerland, Atukeren [41]), which all the Baltic States need to import from abroad. However, boom period of early 2000 was mostly caused by domestic sectors, and investments did not see manufacturing as an opportunity. Actually it is so that the Baltic States enjoyed healthy manufacturing development in 90’s, but in ten recent years Asia has took over its share from this activity. Typically this meant that manufacturing units (e.g. subcontracting) were relocated to Asia. This concerns very many such branches as electronics and light weighted product production. So, in simplistic terms trade deficits mean that all three countries are in need of more capital (loans), either to be taken by private or public sector. Of course, capital could appear in form of FDI, too, or as EU structural support. It is open question, how long time capital in-flight could substitute uncompetitive export structures.

![Figure 2. Trade deficit of the Baltic States within period of 2006–2011 (in mill. euros). Source: UN Comtrade [19]](image)

As observing the development of trade account after crisis, only Estonia has started to show development, where exports could potentially in forthcoming years to be in parity with imports (Figure 2). However, situation in Latvia and Lithuania is repeating life before crisis – trade deficits in year 2011 were already more than two billion euros, and trend in both countries is strikingly downwards. This is not minor issue as in year 2011 Lithuanian trade deficit was one fourth from GDP, and Latvian in turn roughly one sixth. Year 2012 has not changed situation that much, Estonian trade deficit has increased slightly above 1 billion EUR, followed by 2 billion EUR deficit of Latvia and 2.56 billion EUR deficit of Lithuania. So, from trade account perspective recovery is not that sustainable, especially in case of Latvia and Lithuania.

Rapid expansion of manufacturing based export activity is very doubtful in all three economies (Figure 3) as all have followed the same pattern in the job loss during period of 2008–2012. Basically from the first quarter of year 2008 to the end of 2010 approx. 30% of manufacturing working places were lost. Of course, during years 2011–2012 small recovery has been taking place, but still from early 2008 all countries are missing one fourth of working places. Job loss in this scale means that factories have streamlined further their operations, and expansion of production volumes is difficult or even impossible in large extent within future. Therefore, trade deficit showed on Figure 2 could be changed only with making import amounts lower. One potential is energy, which all of these countries are largely dependent on foreign sources.
3. Foreign Direct Investments in the Baltic States

As the Baltic States could be classified as emerging economies (actually typical term was “Baltic Tigers”, used e.g. banks such as Credit Suisse [20] and magazine The Economist [21]) in European landscape during the previous decade time, their Foreign Direct Investment (FDI) have followed same emerging pattern. This experienced development was also the main reason, why GDP contracted in such significant manner during credit crunch, and in turn resulted in high unemployment rates. Three Baltic States’ economies experienced severe boom in real estate, finance, wholesale and construction sectors and in their interaction (growth was domestic oriented and endogenous interactions with increasing amount of foreign investments that created bubble). As world economy was in general going through very loose monetary policy after IT bubble burst, these sectors attracted impressive amount of funding from foreign investors. This is apparent in longitudinal development of FDI in Estonia (Figure 4), Latvia (Figure 6) and Lithuania (Figure 8). It is interesting to note that in Estonia these four mentioned domestic market focused sectors accounted more than 70% of total FDI position in year 2007, as in Latvia more than 65% in year 2008 and in Lithuania more than 45% in year 2008.

During the last decade time period all the Baltic States were experiencing high GDP growth (until credit crunch slump), which was accompanied with continued deficits in trade accounts (also concluded in Ojala et al. [22]). Mostly much higher amount of FDI as compared what the Baltic States themselves invested abroad was the success formula. FDI dominance is the case still today, in Estonia country has more than 3.5 times investments from abroad than what it has invested to other countries, Latvia in turn has more than 13 times, and Lithuania nearly 7 times.

Economy overheating in year 2007 could be detected from Figures 4, 6 and 8. FDI inflows just spiked in this year rather significantly, and, of course, resulted on GDP growth of 20–30%. This growth stopped entirely on credit crunch crisis during years 2008–2009, but mostly caused FDI to halt (not new inflows, but investments remained). Only Lithuania experienced declining FDI development, so namely FDI outflows. It also could be argued that most recent recovery is caused by the strength of FDI inflows, particularly growth experienced in years 2011–2012 (this last year 2012 not shown in Figures 4–9, but FDI growth has accelerated in Estonia from year 2011, in other two Baltic States it has been growing, but not like in 2011).
As domestic oriented sectors were taking in attention during the previous decade, manufacturing and transportation have been rather slow growing in terms of FDI. However, in positive respect these two sectors have still shown some growth in three Baltic States within chosen observation periods. What is not apparent from FDI statistics is that manufacturing has transformed increasingly as low tech and local. Export industries which are left are most competitive in Estonia. In Lithuania large proportion of manufacturing in FDI could be explained with oil refinery ownership changes.

Figure 4. Foreign Direct Investments to Estonia (in million Euros) by branch within period of 1998–2011 (position in the end of the period). Source (data): Bank of Estonia [23]

Figure 5. Ten most important FDI countries (in million Euros) for Estonia (ascending order with most recent year, 2011). Source (data): Bank of Estonia [23]
Figure 6. Foreign Direct Investments to Latvia (in million Lats as 1 Lat was 1.423 Euros at the end of 2011) by branch within period of 2004–2011 (position at the end of the period). Source (data): Bank of Latvia [24]

Figure 7. Ten most important FDI countries (in million Lats) for Latvia (ascending order with most recent year, 2011). Source (data): Bank of Latvia [24]
Figure 8. Foreign Direct Investments to Lithuania (in million LTL as 1 Lita was 0.29 Euros at the end of 2011) by branch within period of 2004–2011 (position at the end of the period). Source (data): Lithuanian Central Bank [25]

Figure 9. Ten most important FDI countries (in million LTL) for Lithuania (ascending order with most recent year, 2011). Source (data): Lithuanian Central Bank [25]

In country and Baltic Sea perspective, Sweden and Finland have been active in seeing and acting upon FDI front in all the Baltic States (Figures 5, 7, and 9). However, it should be emphasized that Sweden has been extremely active in Latvia and Lithuania, while Finland has been mostly interested from Estonia. Investments differ in a manner that Swedish activity is centred in banking sector. Along these
two countries, Germany and Netherlands are present in ten most active countries of FDI in all the Baltic States. Also Estonia has been active in other two Baltic States, but mostly so in Latvia. Country peculiarities exist too, like high importance of France and Luxemburg in Estonia and Poland in Lithuania.

As it is today with employment and export manufacturing competence [26], it is also so with overall FDI attraction during observation period: Estonia leads in absolute amounts two other Baltic States, and its FDI activity was not that greatly interrupted by credit crunch. It should be noted that Estonia is having clearly the lowest population from all of the evaluated countries.

Analysed time period in three Baltic States is over-emphasizing importance of finance and real estate sectors – as these were the boom sectors during the late IT bubble burst era. However, it should be reminded that in the Baltic States main FDI target sectors were during 90’s telecommunications and transports, but also in parts manufacturing. It could be explained that these sectors prospered as advances of mobile telecommunications were rapidly developing and neighbourhood countries, like Sweden and Finland, had leading positions in them (e.g. during 1999 from Estonian FDI Sweden and Finland together accounted 70%; see Lesser [27]). So, on the other hand these two countries were active (with Danish) in FDI not only in telecommunication sector (operators), but also in related manufacturing of devices and infrastructure. Transportation sector received vast interest, too, but it did not turn out to be a high success within eastern transit business. For example, Latvian stock market listed from governmental program, Ventspils Nafta (transit business of oil and petroleum, mentioned as case already in Ojala & Queiroz [28]), did not turn out as a major success (it has profitability, but not growth story), and could be eyed as an example that huge growth in this sector was and still is not in sight in the Baltic States. Similar constrained growth story could be set up from Estonian transit oil business and railway freight company privatisation, and later on its followed re-nationalization [29–30]. However, these could be rapidly changed to growth mode as in year 2015 very tight sulphur regulation takes off in the entire Baltic Sea region. This means that short sea shipping becomes expensive (30–40%; [14; 31]) and actors will most probably minimize shipping route lengths (particularly important for east originating raw material export).

4. Role of International Lending Organizations

Among cohesion funds of European Union, international lending organizations such as European Bank for Reconstruction and Development (EBRD), European Investment Bank (EIB), Nordic Investment Bank (NIB) and World Bank have played important role in the support of the development of economies in the Baltic States (comprehensive analysis from the past transportation logistics projects is given in [22; 28]). However, as all the Baltic States developed in economics terms so rapidly in recent decade time period, role of direct aid type of finance changed as loans. This also increased the presence of some banks, like EIB: Growth of lending in most recent observation period (years 2008–2012) increased by factor of 3–5 times. Figure 10 illustrates this drastic change further. However, it should be emphasized that EIB loans have mostly been taken during years 2008–2009 in the most recent spike period (detailed analysis on [32]).

![Figure 10. Amount of European Investment Bank (EIB) loans (in Euros) for the Baltic States during period of 1998–2012 (March). Source: EIB [33]](image-url)
Although funding amounts have increased significantly from EIB, they have concerned transport, energy or industrial sectors in recent analysed period (2008–2012) with not that impressive share. At least this is the case of Latvia and Lithuania (25% from overall funding; Tables 2 and 3). In Latvia only company investing in large-scale into energy sector is state-owned Latvenergo, which is replacing old gas turbines and improving distribution network. EIB finance is 200 million EUR, but it should be reminded that EBRD provides additional 150 million EUR for this large project [38]. Apart from EU project co-financing loans, in Lithuania minor activity exist with further improvement of freight trains (have already started in period of 2003–2007) and small-scale industrial development loans.

Table 1. EIB financed projects in Estonia (in Euros) within transportation and energy sectors (period of 2008–2012). Source: EIB [33]

<table>
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<th>Project</th>
<th>Sector</th>
<th>Signature</th>
<th>Amount</th>
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</thead>
<tbody>
<tr>
<td>TALLINK RO-PAX II</td>
<td>Transport</td>
<td>18/12/09</td>
<td>90,000,000.00</td>
</tr>
<tr>
<td>MUUGA HARBOUR INTERMODAL FACILITIES</td>
<td>Transport</td>
<td>14/12/09</td>
<td>11,500,000.00</td>
</tr>
<tr>
<td>EU FUNDS CO-FINANCING 2007-2013 (EST)</td>
<td>Transport</td>
<td>25/05/09</td>
<td>115,500,000.00</td>
</tr>
<tr>
<td>PORT OF TALLINN EXPANSION</td>
<td>Transport</td>
<td>12/02/09</td>
<td>40,000,000.00</td>
</tr>
<tr>
<td>TALLINN MUNICIPAL INFRASTRUCTURE</td>
<td>Transport</td>
<td>19/11/08</td>
<td>31,955,000.00</td>
</tr>
<tr>
<td>TALLINK ROPAX</td>
<td>Transport</td>
<td>27/06/08</td>
<td>25,000,000.00</td>
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<tr>
<td><strong>Total:</strong></td>
<td></td>
<td></td>
<td><strong>313,955,000.00</strong></td>
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Table 2. EIB financed projects in Latvia (in Euros) within energy sector (period of 2008–2012). Source: EIB [33]

<table>
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</thead>
<tbody>
<tr>
<td>LA TVENERGO CHP</td>
<td>Energy</td>
<td>02/10/09</td>
<td>100,000,000.00</td>
</tr>
<tr>
<td>LA TVENERGO POWER DISTRIBUTION</td>
<td>Energy</td>
<td>24/10/08</td>
<td>100,000,000.00</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td></td>
<td></td>
<td><strong>200,000,000.00</strong></td>
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Table 3. EIB financed projects in Lithuania (in Euros) within transport and industry sectors (period of 2008–2012). Source: EIB [33]

<table>
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<tr>
<td>CIE AUTOMOTIVE MULTITECHNOLOGY PARTS</td>
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<td>23/12/09</td>
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<td>WIENERBERGER PRODUCTION DEVELOPMENT</td>
<td>Industry</td>
<td>03/12/09</td>
<td>19,000,000.00</td>
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<td>LITHUANIAN RAILWAYS II - LOCOMOTIVES</td>
<td>Transport</td>
<td>29/03/10</td>
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<td>EU FUNDS CO-FINANCING 2007-2013 (LT)</td>
<td>Transport</td>
<td>13/03/09</td>
<td>226,400,000.00</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td></td>
<td></td>
<td><strong>268,400,000.00</strong></td>
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Estonian industrial and energy sector project portfolio looks more diverse and double to that of two other Baltic States (Table 1). In Transport sector improvements are targeted to the maritime sub-branch, which is natural, since Tallink Silja is one of the leading short sea shipping companies in the Baltic Sea. Table 1 shows, how this operator modernized its fleet couple of years ago. Also improvement projects have been completed in Tallinn sea port (the largest passenger sea port in the Baltic States), and sea port’s industrial terminal located in Muuga. Similar to Latvia, electric network and power generation
is under renewal in Estonia. It is important to note that electricity distribution is not only improved within Estonia domestically, but investment project of linking Estonian electricity network to Finland (submarine cable, ESTLINK 2 TEN-E) also consists. Notable is the role of wind energy, which has also been supported by EBRD [34]. In overall solution for future energy needs, Estonia relies upon oil shale based energy production in the future, too. It recently selected Alstom to supply power plant close to Narva (plant called as Auvere; [35]). It is unclear how finance of this power plant has been case specifically organized (operational in 2015), however, it should be noted that Eesti Energia gathered 300 mill. Euros with bond sale from European investors in March 2011 [36].

In most recent information from EBRD [37], it is reported that they are committed in the funding of the new energy production capacity of Lithuania. This was due to the closure of Ignalina Nuclear Power Plant (large-scale facility, which was closed in the end of 2009, major producer of electricity, even contributing to export). Based on EBRD [37] brochures, help in energy production is being implemented with the renewal of old gas turbines at Lietuvos Elektrine – sharing similarities with Latvia’s gas investments.

5. EU Cohesion Funding

All three Baltic States became full members of European Union (EU) during May.2004. Until today only Estonia is also member of monetary union, Euro, while Latvia and Lithuania have still in use national currencies (Latvia has ambitious plan to enter monetary union in the early 2014). EU membership has enabled all three countries to access important cohesion funds (in here incl. European Regional Development Fund, European Social Fund and Cohesion Fund), which are given for the development of economically less developed regions in Europe. For program period of 2007–2013 total sums were as follows [39]: 3.4 bill. Euros for Estonia, 4.6 bill. Euros for Latvia and 6.8 bill. Euros for Lithuania. In comparison, more or less similarly sized with the Baltic States, Finland and Sweden received 1.7 bill. Euros and 1.9 bill. Euros, respectively. So, due to economical situation, the Baltic States attracted nearly eight times development funds as compared to neighbours in west or north. These large sums of development funds are not only intended for transportation infrastructure or manufacturing industry development, but are used to improve and protect environment, foster R&D and innovation as well as healthcare (EU Structural Assistance to Estonia, 2013). It could be assumed that one third or one fourth from total funds will be devoted to transportation infrastructure.

The Baltic States were able to enter EU cohesion funds partly during program period of 2000–2006, as EU accession was completed in May.2004. However, funding in this period was rather limited. For transportation infrastructure the following sums were granted [4]: 233 mill. Euros for Estonia, 409 mill. Euros for Latvia and 208 mill. Euros for Lithuania. For the author other granted sums are unknown. Anyway, even if funding sums seem to be rather small, it should be remembered that for the Baltic States these sums were still significant in years 2004–2006. Also it should be noted that program period was only three years long.

![Figure 11. Share of EU Cohesion funds in the Baltic States from GDP during years 2004–2011](image-url)
Importance of EU cohesion funds is illustrated on Figure 11 by estimating what is their share from respective year’s GDP. In here we have distributed cohesion funds equally to program period, and for the years 2004–2006 is only devoted these known transportation infrastructure funds. At first glance it is inevitable that especially most recent program period has played key role in the economy development. It could be even argued that for Lithuania these funds pay too large role, and dependence as well as economy overheating could be caused by these. It could also be argued that without this funding, all the Baltic States would have suffered even more from credit crunch, and their recovery would have been much more fragile. Without a doubt these funds have played key role as an instrument to stimulate the economies. However, as all the Baltic States have continued to recover and show GDP growth, share of EU Cohesion funds has continued to decline in year 2012.

6. Conclusions

As emerging economies, the Baltic States have attracted significant amount of FDI after late 90’s. However, this rapid growth of FDI stock showed levelling off development during year 2009 in Estonia and Latvia – in Lithuania year 2008 was showing decline. Based on our analysis, important and large-scale loans were available in this moment, but were mostly used in years 2008–2009. Thereafter, three Baltic economies have showed rather cautious approach for making investments. However, in positive respect effect of credit crunch was short-term lived, and FDI has started again to increase in all countries (has continued also in the most recent year 2012). This growth has its limits, since very robust growth has been caused earlier by domestic oriented sectors (finance, real estate, construction and retail), and growth from now onwards need to be attracted out of export oriented sectors (like manufacturing and transport). Until today all the Baltic States have only shown trade account deficits – these have slightly improved as compared to time before crisis, but still are notably on negative side. Opportunities lie ahead as great environmental legislation changes take off in the Baltic Sea region (starting from sulphur ban in year 2015). These will mean that shorter routes at sea and longer journeys in hinterlands will become reality.

As all the Baltic States could be seen as hinterland for its northern and southern neighbours, and therefore strengthening this axis together with old strengths of raw material transit export are lucrative investment places for future.

As all three Baltic State economies are rather small ones in absolute terms, it is rather fortunate for them that they joined EU already during year 2004. From current EU cohesion funds the Baltic countries (among other east and south European counterparts) receive relatively high sums. This enables them to renew e.g. transportation infrastructure in large-scale. Even if instrument could be seen as stimulating element, it should be connected more on attracting FDI inflows, too. So, these infrastructure investments should enable higher amount of transit transports through the Baltic States, and as well support inauguration of export based manufacturing industries. Of course, it is problematic in EU cohesion funding perspective to support these, but taking into account this perspective, together with population well-being, should not be impossible. However, measures should be integrated into the most important area of economic development: Improving trade deficit in all three countries, and in particular Latvia and Lithuania. Current situation in these two mentioned countries resembles too much life before crisis, which does not lead to sustained growth (actually will lead to great bubbles ahead). Slow, but clear manufacturing job growth should be secured in the forthcoming years. Still today one fifth of manufacturing jobs are missing as compared to early 2008.

For the further research, we would be interested to build a model (analytical or simulation), which would take into account different forms of capital inflows in economically less-developed countries in Europe, and also estimate role of capital inflows into development of GDP. Most probably private and public sector attraction of funds plays a key role. For the future development we would like to seek countries or regions, where these attracted funds have resulted on investments and renaissance of export based industries. Without this important link, fund inflows are just a cause of yet another recession as business confidence erodes for one reason or the other. This again leads to massive unemployment, which is entirely undesired outcome in the current state of European economy.

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- Publications: one publication in Hungarian language
- Fields of research: applications of Euro containers in the logistics industry, grouping of container types according to different standards, future of intermodal shipments and transhipment processes

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- Fields of research: electronic freight and warehouse exchanges, e-commerce methods, decision supporting algorithms and ant colony optimization algorithms

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- **Publications**: Dr. Hilmola has published more than 110 refereed journal manuscripts

Vilnius, the capital and the largest city of Lithuania, is faced with serious traffic problems. The main streets of the city are overcrowded with traffic. Therefore, the effective ways to ease the congestion should be sought. The paper considers the problem of high traffic intensity and congestion at the intersection of two busy Vilnius streets. Research is based on the analysis of the data stored at the Vilnius Traffic Management Centre and the information obtained in the experimental investigation of traffic flows. All the collected data have been used in the traffic simulation program, to make some effective measures helping to increase traffic capacity of the considered intersection.

Keywords: traffic intensity, free flow, intersection, velocity


Calculation methods of the signal formation parameters at the central station and of selective conversion in mobile terminal receiver of the vehicle moving at speed of 200-300 km per h are described. Architecture features of radio over fibre networks to operate without handover between base stations lead to additional requirements for transmitting and receiving signal methods in the network. The solution of this problem will provide high-rate services (up to 12 Mbit per second) for subscribers moving on the highway or high-speed railway using hybrid radio over fibre network. It allows providing services of any content at any time. Objective: calculation methods development of the signal formation and conversion parameters. Signal is a set of services in the form of OFDM-symbols, the total bandwidth of which is much higher than 1 GHz.

Keywords: radio over fibre network, signal formation of services set, selective conversion in mobile terminal receiver.


Nowadays, modern companies operate in a common logistics network. In a modern approach, these networks of companies are called virtual enterprises, whose main purpose is the maximal fulfillment of customer needs and process optimization. The electronic freight and warehouse exchange is a good basis for building virtual enterprises, and that may be a new way to support the reorganization of the supply chains, and to rethink the connections within the intermodal network.

Firstly, the paper presents the need of intermodality. On the other hand, it details the benefits and the critical evaluation of intermodality. It presents the general transshipment processes and techniques then evaluates the containers based on their main features. On this basis, the paper describes the electronic freight and warehouse exchange as a member of cloud supply chain. Moreover, the paper contains the new challenges and opportunities of electronic freight and warehouse exchanges as complex logistics providers.

Keywords: Supply Chain, Intermodality, Container, Online Logistics Exchanges, Optimization


One of the most important steps in managerial process is the risk analysis. While various methods for conducting the risk analysis exist, in certain conditions only subjective qualitative approach can be used. The typical reason is the lack of input quantitative data. Methods of fuzzy logic can provide a convenient way to conduct risk analyses. The article describes an application of
fuzzy logic and fuzzy approach into risk analyses and into risk management process. All needed requirements for using this approach are described. The main advantage of using fuzzy approach is limitation of subjectivity in risk assessment. That can provide basis for regular repeating of risk analyses thus, efficient control system can be created instead of formal occasional risk analyses. Article also describes recommended modification of threat identification process to maximize mutual effect when applied together with this kind of risk analyses.

Keywords: risk analysis, fuzzy approach, risk management


The article features an approach to comparative assessments of logistics centres operational efficiency based on the system of logistics key performance indicators and describes the framework methodology and the order for the development of the methodological support of the specified task.

The study was conducted in the framework of the Rail Baltica Growth Corridor (RBGC) Russia project, which seeks to involve North-West Russia in the dialogue about Rail Baltica transport corridor and is supported by the Delegation of the European Union to Russia for the period 2012–2013. Particularly, RBGC Russia addresses the issues of operational and functional interoperability of logistics centres in Eastern Baltic Sea Region.

Keywords: assessment of efficiency, logistics activity, terminal and logistics complexes, key performance indicators of logistics activity (KPI), general logistical costs model.


Road structures are loaded by heavy vehicles and also they have an influence of temperature changes, which cause a difficult stress and strain distribution over layers of the pavement and the subgrade. Knowing this, distribution of stress and strain can help to better understand the behaviour of the pavement during the service time. For this purpose, the mechanical characteristics like elastic modulus, Poisson ratio, or damping ratio have to be known. The special device is used for determination of these mechanical characteristics, which loads the surface of the pavement by a force impulse. The deflections are measured in the surroundings of point of load impulse. The signal can be evaluated by use of 2D or 3D calculation model of pavement construction. In this case was used the axially-symmetric 2D model. This reduced the time consumption of individual tasks solution. The article considers also the influence of boundary conditions on deflections of models with varying width. The following text describes findings acquired from numerical simulation of pavement response to dynamic load.

Keywords: calculation model, dynamic method, deflection


The Baltic States became independent in the early 90’s, when the iron wall collapsed in the whole Eastern Europe. Thereafter, development in economic terms was rapid and particularly manufacturing and transportation sectors were responsible for prosperity formation. However, after late 90’s situation changed, and boom was apparent in credit led real estate, finance, retail and construction sectors. As these sectors are all domestically oriented, and while the Baltic States in this credit boom period did not experience any trade surpluses, it was evident that credit crunch in 2008-2009 affected economies severely. This research work shows that the Baltic States need to change again weight in Foreign Direct Investment (FDI) for manufacturing and transportation, sectors which have been supported previously only by European Investment Bank and EU Cohesion fund. FDI is vital for the Baltic States, since they have been for long time net receivers of capital, and GDP has greatly been dependent on these inflows. However, future prosperity is only built with export oriented FDI.

Keywords: the Baltic States, FDI, loans, EU cohesion, manufacturing, transportation


**Atslēgvārdi:** satiksmes intensitāte, brīva plūsma, krustojums, ātrums


Rakstā tiek aprakstīts signāla veidošanas parametru centrālā stacijā un selektīvā konversijas transportlīdzekļa mobīlā termināla uzsvērējā aprēķināšanas metodes, pārvejot tos ar ātrumu 200-300 km/stundā. Radio arhitektūras iepašības caur optiskās šķiedras tīkliem, lai darbotos bez pilnvaru nodosanas starp bāzes stacijām rada papildu prasības, lai tā tās nosūtītu un saņemtu signālu metodē. Šis problēmas risinājums nodrošina augsta klasēs pakalpojumus (līdz pat 12 Mbit sekundē) abonentiem, kas pārvietojas starp bāzes transportlīdzekļiem hibrīdā caur optiskās šķiedras tīklu. Tas jāuz nodrošināt jebkuru pakalpojumu jebkurā laikā. Mērķis: signāla veidošanas un konversijas parametru aprēķināšanas metožu izstrāde.

**Atslēgvārdi:** radio caur optiskās šķiedras tīklu, signāla veidošanas, selektīvā konversijas mobīlā termināla uzsvērējā


Mūsdienās uzņēmumi darbojas kopējā logistikā tikai subjektīvi kvalitatīva pieeja, lai veidotu virtuālo tīklu. Mūsdienās uzņēmumi darbojas kopējā logistikā tikai subjektīvi kvalitatīva pieeja, lai veidotu virtuālo tīklu. Mūsdienās uzņēmumi darbojas kopējā logistikā tikai subjektīvi kvalitatīva pieeja, lai veidotu virtuālo tīklu. Mūsdienās uzņēmumi darbojas kopējā logistikā tikai subjektīvi kvalitatīva pieeja, lai veidotu virtuālo tīklu.

**Atslēgvārdi:** piegādes šķide, protokolācija, konteiners, tiešsaistes logistikas apmaiņa, optimizācija


Ir aprakstītas visas vajadzīgas prasības, lai izmantotu šo pieeju. Galvenā priekšrocība ir izmantot fazi-pieejas, lai subjektīvās ierobežojumu riska novērtēšanu. Tas var nodrošināt pamatu riska
analīžu regulārai atkārtošanai, tādējādi, formālu gadījuma riska analīžu vietā var tikt radīta efektīva kontroles sistēma. Rakstā arī ir aprakstīts ievesīgam draudu noteikšanas procesa modifikācija, lai palielinātu savstarpējo iedarbību, ja to piemēro kopā ar šādu veida analīzēm.

**Atslēgvārdi:** riska analīze, fazi-piecie, riska pārvaldība


Raksts piedāvā piecieju logistikas centrā darbības efektivitātes, pamatojojoties uz logistikas galveno darbības rādītāju sistēmu, salīdzinošajiem novērtējumiem un apraksta struktūras metodiku un kārtību norādīja uzdevuma metodiskā atbalsta attīstībai.

Pētījums tika veikts saistībā ar Rail Baltica izaugsmes koridora Krievijas projektu, kura mērķis ir iesaistīt Ziemeļrietumu Krievijas delegācija laipposmam 2012-2013. Īpaši, Krievijas Rail Baltica izaugsmes koridors risina jautājumus par logistikas centru Baltijas jūras austrumu reģionā operatīvo un funkcionālo savietojamību.

**Atslēgvārdi:** efektivitātes novērtējums, logistikas darbība, termināla un logistikas kompleksi, galvenie darbības rādītāji, vispārējais logistikas izmaksas modelis


Ceļu būves ir piekrautas ar smagajiem kravas transportlīdzekļiem, kā arī uz tām ir ietekme no regulārās vērtējuma administrācijas. Šajā gadījumā tika izmantots aksiāli kārtību, darbības efektivitātes analīzes, pamatojoties uz logistikas galveno darbības rādītāju sistēmu, salīdzinošajiem novērtējumiem un apraksta struktūras metodiku un kārtību norādīja uzdevuma metodiskā atbalsta attīstībai.

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**Atslēgvārdi:** efektivitātes novērtējums, logistikas darbība, termināla un logistikas kompleksi, galvenie darbības rādītāji, vispārējais logistikas izmaksas modelis


Baltijas valstīs jau daudzus gadus norādījumi par labklājības veidošanos. Tomēr, kā arī to nav nepieciešams izlasīt kā vienīgus rezultātus no regulārās vērtējuma administrācijas. Šajā gadījumā tika izmantots aksiāli kārtību, darbības efektivitātes analīzes, pamatojoties uz logistikas galveno darbības rādītāju sistēmu, salīdzinošajiem novērtējumiem un apraksta struktūras metodiku un kārtību norādīja uzdevuma metodiskā atbalsta attīstībai.

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**Atslēgvārdi:** aprēķina modelis, dinamiska metode, novirze.
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