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FAILURE DEVELOPMENT IN A SYSTEM OF TWO CONNECTED NETWORKS

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We consider a pair of networks A and B which are subject to failures of their components. In A, edges are subject to failure, and A fails when it disintegrates into several isolated clusters each containing a single terminal. Edges of A fail in random order and their failure moments follow Poisson process. After A has failed, terminal α of A causes a failure ("attacks") on R_α randomly chosen non terminal nodes of network B. All edges incident to an attacked node are erased. The "attacks" take negligible time. Network B failure takes place if it loses its terminal connectivity. We study the probability that B will be in failure state at moment t as a function of t and $R = \sum R_\alpha$. The main formal tools which we use are the D-spectra (signatures) of networks A and B and de Moivre's combinatorial formula.

Keywords: *Network terminal connectivity, signature, D-spectrum, Poisson process, Monte Carlo, random allocation, de Moivre formula*

1. Introduction

Networks attract overgrowing interest in modern research literature. Since network type systems presently appear in every sphere of our life (social networks, communication networks, Internet, etc.) their reliability, survivability and resilience studies are becoming a hot and important issue. Particular interest is attracted by the so-called cascading failure phenomena in networks, i.e. massive network failures triggered by failure of a small part of the network components; see e.g. [7] and many references presented there on this issue.

Majority of the works on network reliability deals with probabilistic failure description and modelling in a single network. At the same time most modern networks do not exist and function in an isolated mode. As noted in [2], "due to technological progress, modern systems are becoming more and more coupled together. While in the past many networks would provide their functionality independently, modern systems depend on one another to provide proper functionality". For example, the financial network of banks and related financial institutions is interconnected with the business network of industrial enterprises. A "failure" (e.g. bankruptcy) of a particular bank in one country may cause serious problems of financing and/or industrial activity of several enterprises operating in another part of the world.

One of the few works devoted to the failures in interdependent networks is an important paper [2], which discusses as an example a communication network and the power supply network. In this case, the nodes of the communication network, which control the operation of power supply stations, depend on the power supplied by the power station, while the power station operation depends on information and control supplied by the communication network.

In the work [2] is considered cascade-type phenomena in a pair of networks having different topology and equal number of nodes, which interact with each other on the basis of one-to-one correspondence between the nodes of both networks: if a node α of network A becomes dysfunctional, then the same happens with its image node of $\beta = \beta(\alpha)$ of B. Initially, a $(1-p)$ fraction of nodes in A become nonfunctional. This means that all edges in A incident to these nodes are erased. Simultaneously, the "images" of failed A-nodes, also become nonfunctional and the B-edges incident to them are also erased. As a result, both networks disintegrate into a number of isolated clusters. The problem investigated in [2] is the following: "what is the critical $p = p_c$ below which all the mutual clusters constitute only an infinitesimal fraction of the network, i.e. no mutual giant component exist".

In this paper we study a pair of small networks A and B with different topologies. Several nodes in A (called *terminals*) "mark" (or "attack") in a random and independent way a certain number of non terminal nodes in B. Similarly to [2], all edges incident to a marked (attacked) node $\beta \in B$ are erased.

Typically, we will consider edge failures in network A, as a result of which it disintegrates into a number of isolated clusters. (A cluster is a connected isolated sub network containing at least one terminal).

The first phase of the process of failure development in our model is disintegration of A into isolated clusters resulting from a random process of its edge failures that is governed by a Poisson process. After this phase ends, all terminal nodes of A ”mark” (”attack”) in a random way some number of non terminal nodes in B. It means the beginning of the second phase of network failure. All edges incident to marked (attacked) nodes of B are erased, as a result of which B may be in failure state, according to its operational criterion. For example, B may lose its $s-t$ connectivity. We assume that the second stage lasts negligible amount of time. The problem which we investigate is the following. Assume that at $t = 0$ network A starts to disintegrate. Then we are interested in finding the probability $P(DOWN_B;t)$ that network B will be in failure state at moment t.

The further exposition is as follows. In section 2 we consider the formal model of networks A and B and the failure development mechanism. Section 3 is devoted to the derivation of the expression for $P(DOWN_B;t)$. Section 4 presents a numerical example of two small networks. A has 25 nodes, 34 edges and 4 terminals and B has 20 nodes, including 3 terminal nodes, and 34 edges. Failure of B is the loss of terminal connectivity. After A fails each of its terminals ”attacks” 3–5 non terminal nodes of B. We investigate numerically how $P(DOWN_B;t)$ depends on t and the total number of ”attacks”.

2. Model Description

Network *A*. Network A is a triple $N_A = (V_A, E_A, T_A)$, where V_A is the set of nodes (vertices), $|V_A| = n_A$; E_A is the set of edges (links), $|E_A| = m_A$, and T_A is a subset of special nodes called *terminals*, $|T_A| = r_A$. Edges in A are subject to failures, edge failure means that the edge is erased. Edges fail in random order according to a Poisson process having rate λ. In other words, random intervals between edge failures have exponential distribution with density $f(t) = \lambda \exp(-\lambda t)$. The probability that exactly x failures take place in the interval [0, t] equals therefore

$$P(N(t) = x) = (\lambda t)^x \exp[-\lambda t] / x!, x = 0,1,2,... \qquad (1)$$

In the course of edge failures, A disintegrates into separate components, where each component is a connected sub network isolated from other sub networks. An isolated connected sub network, which contains a terminal, is called *cluster.*

Initially, A is connected and has therefore a single cluster. When edges fail, the network disintegrates into several clusters. The state when N_A falls apart into r_A clusters means, by the definition, the failure of A denoted as $DOWN_A$ -state.

Network *B*. B is a triple $N_B = (V_B, E_B, T_B)$, where V_B is the set of nodes, $|V_B| = n_B$; E_B is the set of edges (links), $|E_B| = m_B$ and $T_B \subset V_B$ a set of special nodes called terminals, $|T_B| = r_B$. The components subject to failure in this network are the *nonterminal nodes*. Node β failure means that all edges incident to it are erased, and therefore β becomes isolated. The $DOWN_B$ state is defined in terms of terminal connectivity, e.g. as loss of $s-t$ connectivity, or isolation of one of the terminals from other terminals, see e.g. [3, 4, 5]. Another option is defining the $DOWN_B$ state as network disintegration into connected isolated subnetworks the largest of which does not have more than $L_{\max}$ nodes [6].

Action of A on *B*. Each terminal $i \in T_A$ is randomly mapped onto M_i non terminal nodes in B, which means the following. M_i nodes of B are randomly and equiprobably chosen from the set of $n_B - r_B = n_0$ nodes. One can imagine this mapping as a sequential process of random throwing of M_i balls into n_0 boxes. (It is not excluded that two or more balls may fall into the same box).

One can imagine that M_1 balls are randomly thrown from terminal 1 of A into n_0 white boxes. All boxes receiving at least one ball are coloured red. Then the same procedure takes place for the second terminal, and M_2 balls again are randomly and independently thrown into the same n_0 boxes. The white boxes which receive a ball are coloured red. The red boxes receiving again a ball remain red, and so on, until the procedure is repeated $r = |T_A|$ times. Denote by $R = M_1 + ... + M_r$ the total number of balls thrown into the n_0 boxes. In another language, one can say that each A-terminal "attacks" a random number of non terminal nodes in B, see Figure 1.

Let us denote by $p_k(R; n_0)$ the probability that exactly k boxes will be red. The following de Moivre's formula (see [1], p. 242) gives this probability:

$$p_k(R; n_0) = \binom{n_0}{k} \sum_{t=0}^{k} \binom{k}{t} (-1)^t \left(\frac{k-t}{n_0} \right)^R . \tag{2}$$

Let us assume that the action of A on B is implemented in the following way. After network A gets *DOWN*, its terminals randomly "throw balls" on the non terminal nodes of B in the above described manner. This "bombardment" lasts negligible time.

The nodes of B receiving a ball (marked "red") *are declared as failed*, and all edges incident to these nodes are erased. As the result, B may get *DOWN*. Our ultimate goal is to find the probability $P(DOWN_B; t)$ that B is *DOWN* at moment *t*.

Remark: cascading failures. According to *WIKIPEDIA*, "cascading failure is a failure in a system of interconnected parts in which the failure of a part can trigger the failure of successive parts". In our system of two networks, the cascading effect will exist if complete isolation of few terminals in A causes network B to enter $DOWN_B$ state.

3. Probabilistic Analysis

The central role in our analysis is played by the so-called network D-spectra [3, 4]. Let us shortly remind this notion. Suppose that we number the network components subject to failure as 1, 2, ..., *n*. Consider a random permutation $\pi = \{i_1, i_2, ..., i_n\}$ of these numbers. Assign to each permutation probability 1/*n*!. Imagine that all components are functional *("up")* and we start turning them *down* moving along the permutation from left to right. After each step of this process we check the state of the network and note the number of the components needed to be turned *down* to reveal *for the first time* that the network has failed.

Let

$$P(\text{the network failed on step } j) = f_j,\ j = 1, 2, ..., n. \tag{3}$$

Obviously, $\{f_j\}$ is a proper discrete density: $\sum_{j=1}^{n} f_j = 1.$ In literature it is known also under the name *signature* [8]. We will use the *cumulative* signature (*cumulative* spectrum) $F(x)$ defined as

$$F(x) = f_1 + f_2 + ... + f_x,\ x = 1, 2, ..., n\,. \tag{4}$$

The probabilistic meaning of $F(x)$ is the following: $F(x)$ is the probability that the network is *DOWN* if exactly *x* of its randomly chosen components are *down*.

In practice, the exact computation of $F(x)$ is an NP-complex problem, and usually it is approximately calculated using Monte Carlo, see [3, 4].

Now suppose that we know the D-spectra $F_A(x), x = 1, ..., m_A$, and $F_B(y), y = 1, 2, ..., n_0$ of networks A and B, respectively. (We remind that there are m_A edges subject to failure in A and n_0 nodes subject to failure in B).

Let us find the probability $P(DOWN_A;t)$ that A will be $DOWN$ at the instant t. Obviously,

$$P(DOWN_A;t) = \sum_{x=1}^{m_A} (\lambda t)^x \frac{e^{-\lambda t}}{x!} F_A(x) + \sum_{x>m_A} (\lambda t)^x \frac{e^{-\lambda t}}{x!} \ . \tag{5}$$

(The second sum in (5) is the probability that there will be more than m_A failures in $[0,t]$ which leads to network failure with probability 1).

After A has failed, as a result of the second phase, some random number of nodes Y in B will be damaged. We know the distribution of Y, see (2):

$$P(Y=k) = p_k(R;n_0), k = 1,2,...,\min(n_0,R).$$

Given that k nodes in B are damaged, B is $DOWN$ with probability $F_B(k)$. This gives the following probability that B is $DOWN$ if A is $DOWN$:

$$P(DOWN_B \mid DOWN_A) = \sum_{k=1}^{n_0} P(Y=k) \cdot F_B(k) \ . \tag{6}$$

Finally, we are ready to write the expression for the probability $P(DOWN_B;t)$:

$$P(DOWN_B;t) = P(DOWN_A;t) \cdot \sum_{k=1}^{n_0} P(Y=k) \cdot F_B(k) \ . \tag{7}$$

4. Example

Network A has 25 nodes, 34 edges and $|T_A| = r = 4$ terminals, see Figure 1a.

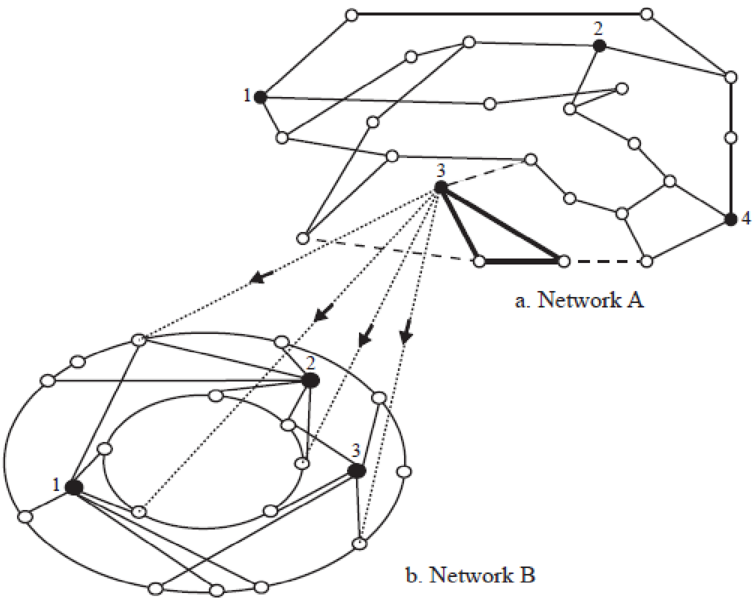

Figure 1. Two networks

This network was investigated in [4], Section 2.3. We assume that A is $DOWN$ when all 4 its terminals (shown bold) become isolated from each other because of edge failures. Below is the edge cumulative spectrum calculated in [4: 68]:

F(1) = ... = F(7) = 0, F(8) = 0.00001, F(9) = 0.00016, F(10) = 0.00124,
F(11) = 0.00612, F(12) = 0.02033, F(13) = 0.05281, F(14) = 0.11094,
F(15) = 0.19166, F(16) = 0.28924, F(17) = 0.39887, F(18) = 0.50586,
F(19) = 0.60720, F(20) = 0.69737, F(21) = 0.77295, F(22) = 0.83484,
F(23) = 0.88400, F(24) = 0.92141, F(25) = 0.94906, F(26) = 0.96829,
F(27) = 0.98165, F(28) = 0.99042, F(29) = 0.99578, F(30) = 0.99826,
F(31) = 0.99963, F(32) = F(33) = F(34) = 1.

Assume that the edges fail in a random order according to a Poisson process with parameter $\lambda = 1$, i.e. the average interval between two successive edge failures equals 1. After A has failed, its terminals 1, 2, 3, and 4 are randomly "attacking" $M_1 = 5, M_2 = 4, M_3 = 4, M_4 = 2$ non terminal nodes of B, respectively. These nodes are chosen in a random and independent way, and the maximal number of nodes which can be destroyed equals $R = M_1 + M_2 + M_3 + M_4 = 15$.

Network B is shown on Figure 1b. It has 20 nodes and 34 edges; nodes 1,2,3 are terminals. These nodes are the "hubs" of the network, and isolation of any of them from two others is considered as B *DOWN* state. This network has been studied in [5]. Below is the node cumulative D-spectrum of B, see [5]:

F(1) = ... = F(4) = 0, F(5) = 0.000686, F(6) = 0, 007581, F(7) = 0.033789,
F(8) = 0.097702, F(9) = 0.212468, F(10) = 0.375406, F(11) = 0.562010,
F(12) = 0.739308, F(13) = 0.875172, F(14) = 0.957617, F(15) = 0.992610,
F(16) = F(17) = 1.

After A fails, the number of damaged nodes Y in B lies in the interval [1, 15], and the probability that $Y = k$ nodes are damaged equals by (2)

$$p_k(15;17) = \binom{17}{k} \sum_{t=0}^{k} \binom{k}{t} (-1)^t \left(\frac{k-t}{17}\right)^{15} \tag{8}$$

98% of all probability of Y is concentrated in the interval $8 \le Y \le 13$, as one can see from the data below:

$$p_8 = 0.074, p_9 = 0.207, p_{10} = 0.312, p_{11} = 0.255, p_{12} = 0.110, p_{13} = 0.024.$$

Table 1 presents the values of $P(DOWN_B;t)$ for *various* t values. It is seen that the maximal failure probability of B does not exceed 0.417 and it is reached at time t = 50 when all edges of A have already failed.

Somewhat surprising is the fact that R = 15 "attacks" on 17 non terminal nodes of B result in a relatively low failure probability. This happens because many nodes receive more than one "ball" and some nodes, therefore, remain undamaged.

Let us investigate the dependence of $P(DOWN_B;50)$ on R for R > 15. The corresponding data are presented in Table 2.

Table 1. $P(DOWN_B;t)$ as a function of t for R = 15

t	10	15	20	25	30	40	50
$P(DOWN_B;t)$	.016	.112	.156	.358	.401	.416	.417

Table 2. $P(DOWN_B;50)$ as a function of R

R	12	15	18	21	24	27	30	35
$P(DOWN_B;50)$	.214	.417	.602	.742	.837	.900	.940	.970

It is seen from this table that $P(DOWN_B;50)$ grows relatively slow with the increase of R. To guarantee that B fails with probability at least 0.90, 27 or more "attacks" need to be carried out from A on nodes of B. When, on the contrary, $R = 12$, the failure probability drops to 0.214. We conclude that B in our example is quite reliable and its reliability is rather sensitive to the total number of random "attacks" on the non terminal nodes of B.

It is expected that the "attacks" of A terminals will be more efficient if R is divided into several portions and each portion will be "attacking" a subset S_i of nodes, chosen in such a way that these subsets are not intersecting and $\bigcup_i S_i = V_B \setminus T_B$. As calculations show, separation into two subsets will provide a rather small increase of failure probability. For example, if $R = 20$ is divided into two equal portions "attacking" subsets of 9 and 8 nodes, then $P(DOWN_S;50) = 0.73$ while in the original setting this probability is equal 0.70.

5. Concluding Remarks

Our further research will be aimed at the extension of the above described model to the situation of *interconnected* networks, i.e. to the study of failure development in the presence of mutual dependence of networks A and B states. In the case of interconnection, it is interesting to investigate how the failures of both networks evolve in time and how are distributed the time instants of their failure.

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WAREHOUSING IN FINNISH AND SWEDISH COMPANIES: STATE OF OPERATING ENVIRONMENT DURING PERIOD OF 2006–2012

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Despite all the efforts of Just in Time philosophy, companies are still required to run numerous warehouses to accomplish distribution management objectives, and match supply network to this activity. In this research is being reported state of the warehousing practices in the largest Finnish and Swedish companies relying on longitudinal data gained through five different surveys. Research findings show that together these two countries are still on the cost pressure with respect of transportation. Also companies in these two northern countries are still using mostly semi-trailers on their distribution transportation. However, some evidence is on place that containers are taking higher role. Interestingly, most of the warehouses of these two countries report to be located in the countries of the Baltic Sea Region, finding which is rather striking as we have given so much effort on economical integration of this region in the recent decades. Finnish companies seem to hold much larger interest on Central and Eastern European Countries warehousing. Size of warehouses is likely to increase a little bit, and units located in other continents are much smaller.

Keywords: warehousing, transportation, Finland, Sweden, Geographical Coverage, CEEC

1. Introduction

Importance of warehousing is difficult to illustrate through statistics, since manufacturing and retail companies are still having this activity at their own disposal, and only partly these operations have been outsourced (world-wide outsourcing is still progressing trend, like [1, 2]). Based on European wide transportation statistics, warehousing companies (have named this as their branch) employ second largest amount of people in the sector, led by road transportation (freight). However, based on numerous studies, outsourcing levels in warehousing work itself are not extremely high (opposite to transportation, where it is at level of 90%). Based on Cap Gemini [3] study outsourced level in Europe is 68%, and later Hilmola & Tan [4] illustrated that in Finland and Sweden this is close to 50%. Large-scale survey completed in Finland recently illustrated that warehousing outsourcing level could be in reality as low as 25–30% [5].

In regional comparison countries of interest in this study, Finland and Sweden are following, e.g., in relative terms Germany, Estonia and Latvia in warehousing sector employment. Interestingly, in Finland during years 2008 and 2009 warehouses employed roughly as many people in this sector as what is the situation in Latvia. In turn Swedish warehousing employment is at the level of all The Baltic States together. Germany with strong manufacturing industry representation, central position in Europe as well as large internal consumer markets lifts it to class of its own with warehousing branch. More than a half million people are working in companies having main activity in here. Also worth to mention is that one of the worst economic crises in decades taken place in year 2009 did not affect that greatly warehousing employment in our two year observation period – decline was roughly 2.5–3.6% (in EU12, 15 and 27). This might be due to the reason that inventory levels have been streamlined with Just In Time and Lean systems, and therefore warehousing follows end demand closely, and some volume is still left at warehouses (in both directions, incoming and outgoing), even if sudden collapse is experienced (and this decline is not further fostered by large inventories at hand). It should also be noted that amount of warehouses and m^2 are still on long-term growth path, even if manufacturing is in turn at the structural and long-term decline (they are soon intercepting each other e.g., in UK, [20]).

Table 1. Warehousing employment ('000) in European Union during years 2008 and 2009.
Source: European Union [6, 7]

2009

Region/country	Employees	% from total
EU27	2379.3	22.5%
EU15	2010.0	23.6%
EU12	369.3	17.8%
Germany	548.5	29.7%
Estonia	10.3	27.3%
Latvia	24.6	34.9%
Lithuania	14.1	15.4%
Finland	28.1	18.3%
Sweden	49.0	18.9%

2008

Region/country	Employees	% from total
EU27	2463.9	27.1%
EU15	2084.7	29.1%
EU12	379.2	19.7%
Germany	566.1	39.5%
Estonia	10.5	28.8%
Latvia	26.1	37.1%
Lithuania	15.4	16.8%
Finland	27.4	22.3%
Sweden	53.0	23.7%

During the last decades (mostly after the oil crisis of the 70's), main tendency in warehousing has been centralization [8–11, 21]. Many factors have enabled this, but mostly it is accountable to cheap oil (during the 80's and 90's), deregulation in different sub-sectors of transportation logistics, free trade movement around the world (World Trade Organization) and over capacity of transportation sector (caused by different factors). So, basically in numerous industries it has been beneficial to shift inventories and warehouses on wheels (or sea vessels or airplanes; e.g., [12]), and reduce drastically distribution network nodes. This has enabled short response (implemented typically with road and air) and considerably lower amount of inventory investments. Again inventory reduction and centralization on very few locations, to say like in Europe, has increased the ability for companies to introduce newer models faster, recover from product quality problems easier and enable service and customisation based on orders [13, 14]. However, with ultra low interest rates (implemented after credit crisis), extremely dear oil, product flows coming around the world for own end products, and increasing pressures to respond on environmental demands (and to be able to lower amount of transport, and particularly increase fill-rates) have changed this ongoing centralization wave. Also emerging countries in Europe, outside free trade area, have required, together with earlier mentioned factors, that companies need to have more warehouses [15, 16, 19]. So, current tendency is a bit diverting from earlier path – we need to modify structures on new business environment changes. However, this does not mean that we shall rewind ourselves back to the 60's, when all sub-regions of one country were having small warehouses. It just means that instead of one centralized location, companies do consider to have the second, third and possibly fourth warehouse to serve their needs [17].

This research work is structured as follows: In Section 2 methodological issues of five surveys conducted during years 2006–2012 is being reviewed. Thereafter, Section 3 analyses research results from transportation costs, transportation units used and geographical coverage of warehouses and size of warehouses (employment). We conclude our research work in Section 4, where also further research avenues are stated.

2. Research Methodology

The aim of this study is to use secondary data to illustrate warehousing importance, and primary data gathered through logistics survey during five occasions between years 2006–2012. Survey part of the research work was conducted by utilizing a web-based questionnaire, which was translated into English, Finnish and Swedish. The research sample was gathered from two leading economical magazines, Talouselämä from Finland and Affärsdata from Sweden. Both magazines gather TOP500 company listings, giving good base for our research (for the year 2012 survey Swedish list was a bit extended to take into account also some significant companies out of TOP500 list). We either sent survey form link to directly logistics director of these respective companies or in a case of not having direct contact, sent email to respective company's info address. Email addresses have been updated during the years with web search and own information from key decision maker changes.

As strategic information from logistics flows is difficult to obtain, we sent in each year initial contact email and in many cases three remainders (each respondent had own code in answering, further increasing reliability of our sample). Survey form in general has been kept as the same, having some minor changes due to contemporary events in logistics branch (e.g., influence of economic crisis on operations, pressure of environmental legislation on costs, small shipments, used transportation units etc.).

Table 2. Five surveys conducted, answers received and total contacts being made

Year	All answers	Valid answers	Emails sent	Response rate
2012	36	28	833	3.4%
2011	28	26	516	5.0%
2010	31	25	570	4.4%
2009	44	35	533	6.6%
2006	74	64	768	8.3%
Total	213	178	3,220	

As not all companies listed in TOP500 lists do not have significant logistics flows at their disposal (e.g., financial, software, service, and insurance), the total sample was less than 1000 companies: During years 2009–2011 survey was sent roughly to 500 respondents (both Sweden and Finland together), while in the base year 2006 and most recent year we had more than 750 respondents. Response amounts have not been that great as in each year we have achieved below 10% response rate (Table 2). Interestingly during first survey round we achieved approx. 8% response rate (maximum), and thereafter gradually declining to min. 3.4% in year 2012. However, absolute amount of answers have been above 25, giving some confidence over the analysis results. In the last observation year we were able to increase absolute of amount answers, which is small positive surprise in the declining popularity of our longitudinal survey rounds.

Our sample is a somewhat biased to Finnish companies side, since during year 2006 approximately 70% of all answers came from Finland, and during year 2009 this share was at the level of 60%. In year 2010 survey share of Finnish responses increased up to 72%, but declined to the level of 60% in year 2011. As we a bit modified and extended the audience of year 2012 for most recent survey concerning Sweden, we received first time most of the answers form this country. Share of Finnish answers in the last round was just above 35%.

Nearly all respondents were managers, white collar workers or directors that were having a long experience in the field of logistics. Typically respondents had been working in company for four years or more (approx. 80%), and had long experience from logistics in general (highest frequency, more than half, at class of 8 years or more). Due to this our sample's reliability is strong. Furthermore, the fact that nearly same questionnaire was utilized in previous studies, confirms the survey's validity. We have also visited companies and have completed case studies during years 2006 and 2010. These site visits confirmed that our research area is valid, interesting, and used survey form applicable to its purpose.

3. Survey Findings from Period of 2006–2012

Transportation Costs Estimates in Recent Year Surveys

In earlier surveys (2006, 2009 and 2010) transportation costs (excluding warehousing) were typically either in medium class (4–6%) or in the highest (8–10%). However, during year 2011 survey highest frequency in answers was recorded in lowest transportation cost class (Figure 1). This could be caused anomaly arising from industrial sub-sectors or sales terms used, but what is interesting in year 2011 survey was that many companies were evaluating that their costs remained as the same. So, two lowest classes took above half from the frequency for the year 2017 estimate too. Even if most of the companies were arguing that their cost development was low and stabile – in some limited amount of companies it was opposite. During year 2011 on Figure 1 we could identify that share of two highest cost classes is nearly double in year 2012 and 2017 as compared to year 2009. It could be only guessed, why this sort of development occurs. One reason could be crisis year of 2009, when transportation costs declined heavily due to lack of demand and excessive capacity in the transportation sector overall.

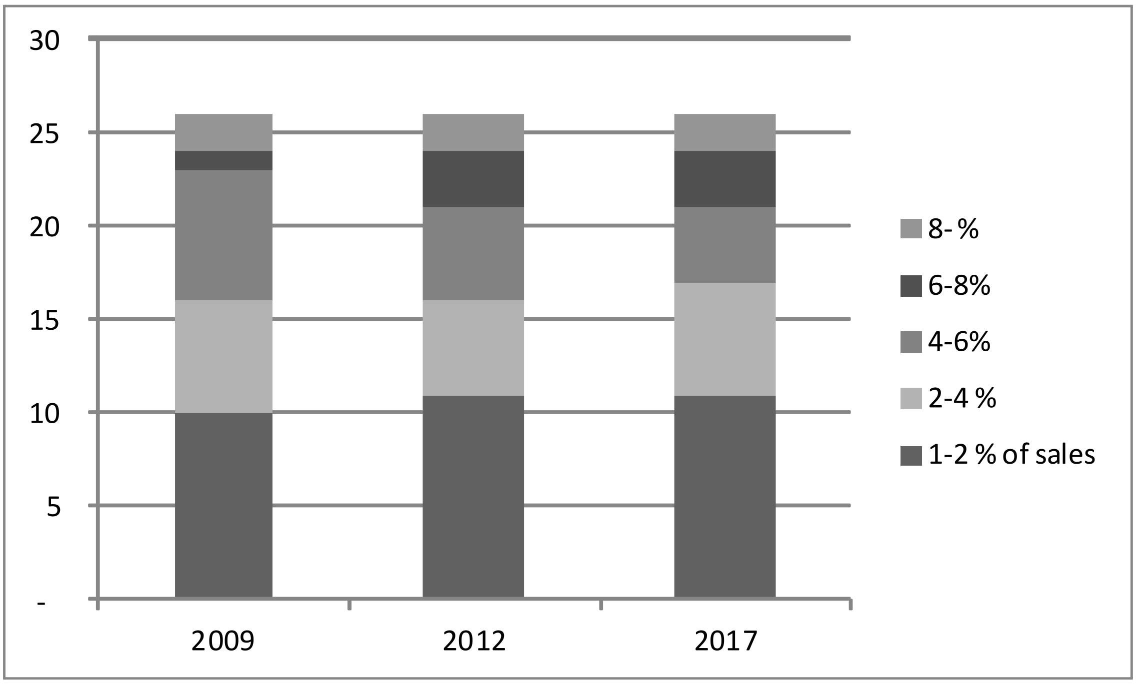

Figure 1. Companies estimate from simply transportation costs (excl. warehousing) during year 2011 survey (n = 26)

In most recent survey (year 2012) transportation cost picture has changed back what it was in the earlier surveys: Highest frequency is now in the middle class (4–6%), followed closely by highest (more than 8%) and lowest (1–2%) classes. Again we may find similar polarization in the answers – group of 10–11 companies in all three years estimate that their costs are going to be low (two lowest classes). However, some companies are in turn reporting from increasing costs within the future (two highest classes).

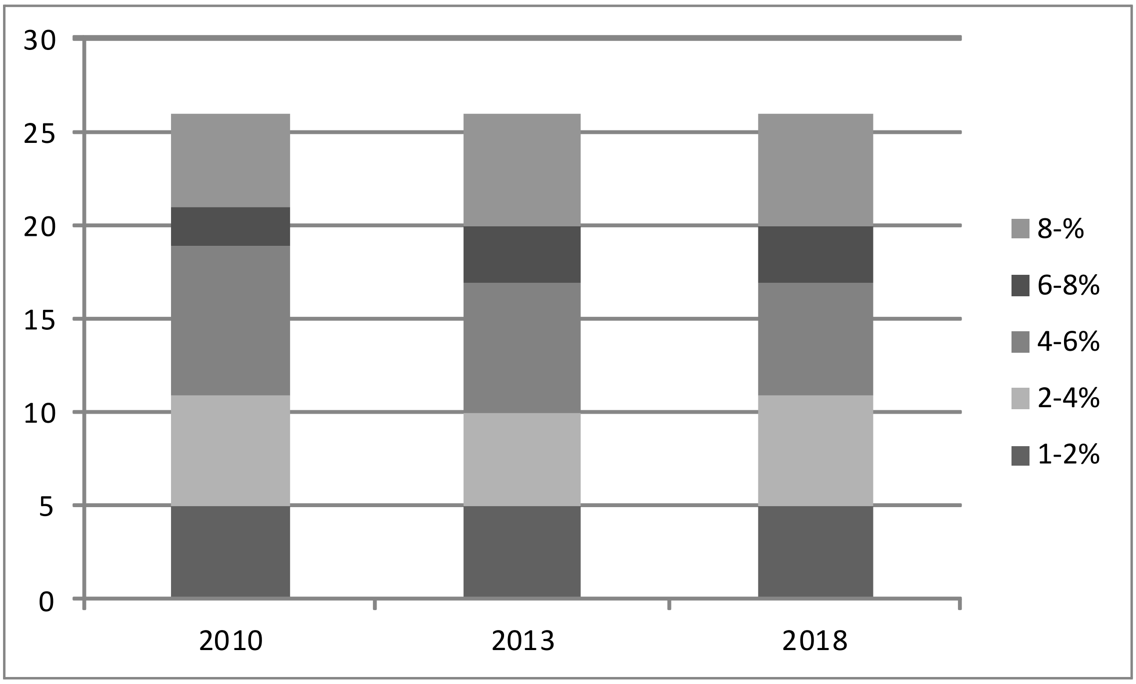

Figure 2. Companies estimate from simply transportation costs (excl. warehousing) during year 2012 survey (n = 26)

Development in costs could be explained with number of different factors. For example, in most recent survey we asked from companies that will the new IMO/EU sulphur regulations increase the transportation costs (based on independent studies this increase will be 30–40% higher tariffs at Baltic Sea from year 2015 onwards; [18]). Not that surprisingly 78% of the companies responded that they will hurt and increase their transportation cost competitiveness. Similarly in year 2011 we had additional question from the effect of year 2009 credit crunch and individual company recovery out of it. Still one third from the companies responded that they have not fully recovered from recession. During year 2011 we also asked about taking into account environmental effects, while selecting transportation mode. Most of the companies (77%) were claiming to take environment into account, which just further reveals that companies are following ongoing environmental regulation change (and possible additional user charges) on transport sector very closely.

From these two additional questions out of two most recent survey rounds we may say that for export oriented companies transportation costs from Northern Europe onwards will increase. Companies also realize this and are rather consistent in their opinions. So, they do not expect any improvements on legislation, in subsidies from government / EU or from rapid technological development (that e.g., sulphur could be taken out with low cost with scrubbers installed on ships). However, on the other hand many companies still in year 2011 felt that they have not recovered from crisis of year 2009 – this in the big picture of transportation demand will surely mean that growth of transport is not problem free issue within Northern Europe, and earlier trajectories are not necessarily kept. Therefore, this development will without a doubt be seen in transportation prices as downward pressure. Most probably this will mean better cost competitiveness for those companies, which are not import-export intensive.

Used Transportation Units

In recent decades globally we have been experiencing significant shift to unitised cargo, mostly leading to the increased use of containers. However, this movement started to catch countries of interest in this study within larger extent two decades ago. Up in north still today within short distance transport (e.g., from Sweden or Finland to Europe) most popular type of transportation unit is semi-trailer. Even if it is much more capital intensive (trailer will cost approx. 50000 euros as a new, while 40 feet container 3500 euros), and weights more, but companies have used to this container on wheels option, as it is flexible (strikes at container sea ports) and versatile. Also additional equipment is not needed in sea ports, if truck is put inside of sea vessel too. However, companies are often completing European shipments, e.g., in Finland in a manner that semi-trailer is left in sea port, from where terminal tractors take them inside of RoRo ship.

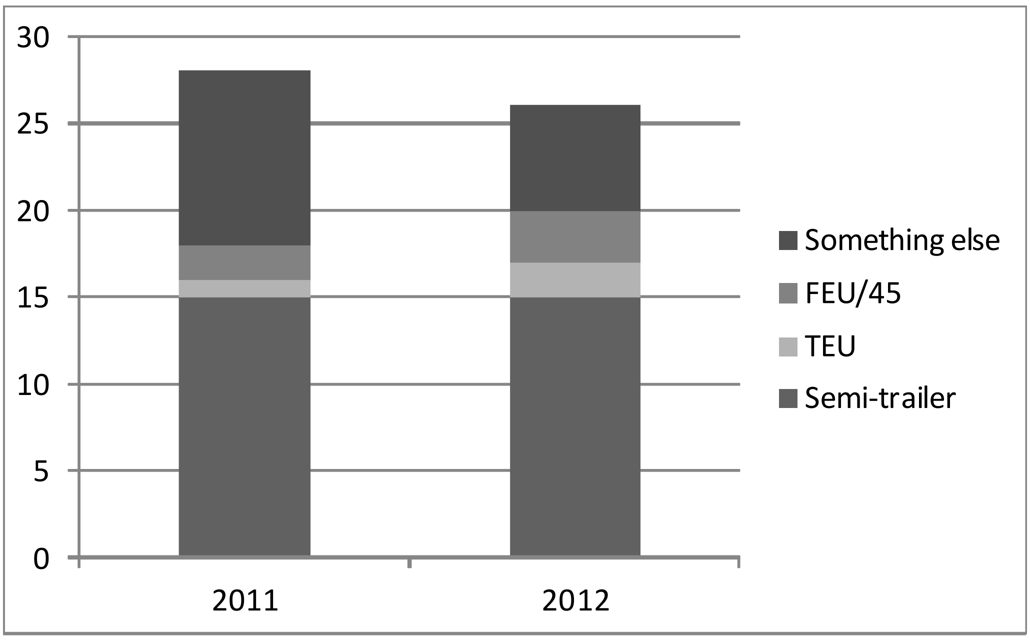

Figure 3. Use of transportation units in Northern Europe during years 2011 and 2012 (amount of absolute answers)

Although, containers (on Figure 3, FEU and TEU) have sure advantage over semi-trailer, companies are still mostly favouring latter ones (more than 50% in both years). However, as encouraging small change is that both container types are a little bit increasing their popularity (still their share from overall responses in most recent year is slightly below 20% as it is roughly 10% during year 2011). This ought to improve reaching environmental objectives, as e.g., transporting container on rail is much lower weight than putting semi-trailer wagon on railway wagon. Also otherwise e.g., RoRo ships (main sea transport mode for semi-trailers) are more environmentally unfriendly than container vessels. Containers should have platform for further growth as most of the long-distance trade (e.g., Asian and North American trade) is completed with these, and they are in large numbers available to be used in transportation within Northern Europe. Readers should note that mixture of answers in country level was totally different in years 2011 and 2012 – so in other words semi-trailers are not popular only in Finland, but in Sweden, too.

Location of Warehouses in Europe

Each year we have been asking from the companies about their European warehouses (not only European Union, but whole geographical Europe, incl. also e.g., Russia, Byelorussia, Turkey and Norway). Surprisingly companies do have number of warehouses in Europe, and they do not distribute products only from one location (which could be one most probable path due to higher economical integration in Europe). What is striking in the answers, is the role of the Baltic Sea Region countries (incl. also Norway) – as Table 3 shows Finnish and Swedish companies are having most of their warehouses in this region. Relative share variates during the years, but is between 60–70% during period of 2006–2011. In most recent survey (year 2012) this trend is broken due to Finnish answers, and total amount drops to just above 40%. Reasons for this drop could be just based on low amount of Finnish answers, but also due to the reason that economic situation has remained as challenging, e.g., in the Baltic States (GDP contracted in these three countries during year 2009 by 15–19%, and has not still increased to pre-crisis level). We have even evidence from this sort of change in our longitudinal data. During year 2006 Finnish and Swedish companies argued that they have 51 warehouses in Poland and the Baltic States, while in year 2012 this have dropped to five (in relative amount this drop has been from 20% to just above 3%). This reduction has been ongoing during the years, and particularly so among Finnish respondents.

Table 3. Warehouses of Finnish and Swedish companies in Europe – role of Baltic Sea Region

Warehouses in the Baltic Sea Region	**2006**	**2009**	**2010**	**2011**	**2012**
Finland	116	68	45	31	32
Sweden	55	20	19	26	31
Total	171	88	64	57	63
Finland	75.3%	63.6%	77.6%	79.5%	30.2%
Sweden	56.7%	47.6%	55.9%	60.5%	67.4%
Total	68.1%	59.1%	69.6%	69.5%	41.4%
Warehouses in Europe					
Finland	154	107	58	39	106
Sweden	97	42	34	43	46
Total	251	149	92	82	152

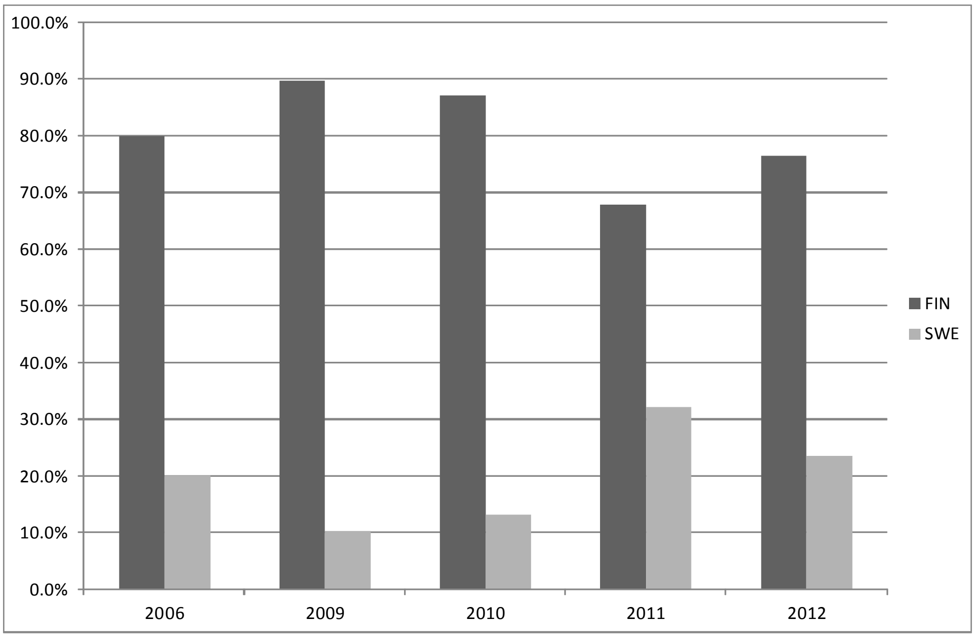

Figure 4. Share of warehouses in Central and Eastern European Countries (CEEC) during observation period in each year among Finnish and Swedish respondents

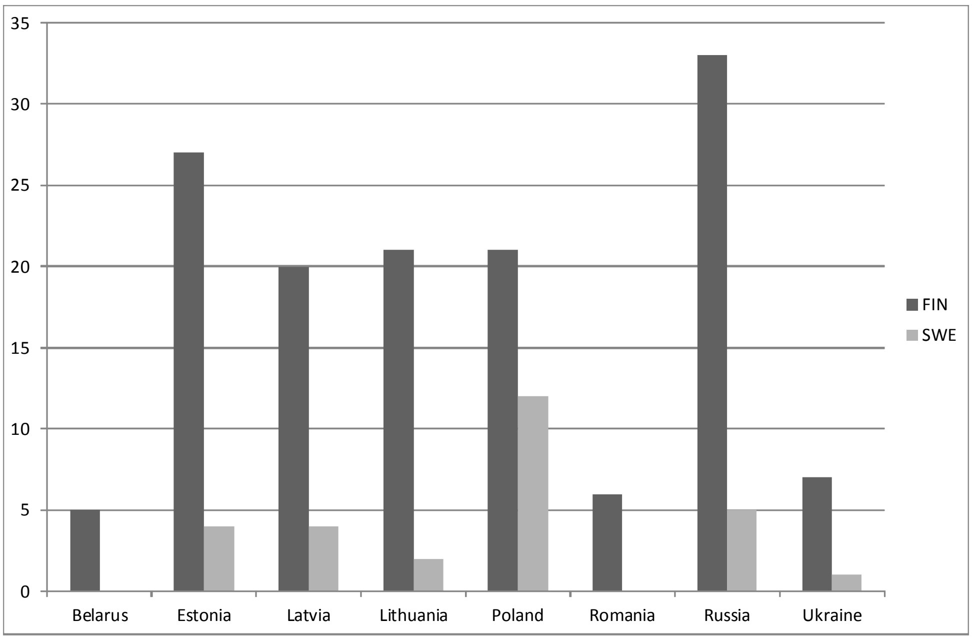

Figure 5. Total number of warehouses (absolute) in five selected Central and Eastern European Countries (CEEC) during observation period (five surveys) among Finnish and Swedish respondents

Figures 4 and 5 illustrate situation further. Typically Finnish companies are much more active in warehousing (and sales thereof) to more risky European markets, CEEC (Figure 3). Difference was of course wider, when warehouses in the Baltic States and Poland were at record levels, but still in year 2012 difference between Finland and Sweden is very much present (should be noted that Finnish answers to survey were lower than Swedish ones in the last observation year, while earlier Finnish answers have dominated the responses). Finland is much more active still in Russian markets, and in Byelorussia (Figure 5).

Employment in Warehouses

Like in earlier years of the survey completion, years 2011 and 2012 repeated the same already identified pattern: Both small and large warehouses are present in the future too, however, with the small tendency, where larger warehouses are about to be more popular in the future. Change for larger is not that much apparent on Figure 6 (year 2011 findings), but is more so on Figure 7. Interestingly in most recent survey, change is from second largest class to the largest one. Also worth to notice is the continuing existence of very small warehouses – these most probably due to the volume differences and markets being served. For example, company could concentrate only on the Baltic States or Russia with its manufacturing export, and then warehouses are at typical small ones and overall volumes remain low (in target regions).

As reported earlier, we asked from companies in year 2012 survey separately from the emerging market warehouses outside of European continent. In total 13 responses were gained from companies, and most of the argued to use small units in their warehousing activity in distant location. For the future this situation will remain very much as the same, but with distinction that small shift is possible from second lowest class to middle sized warehouse.

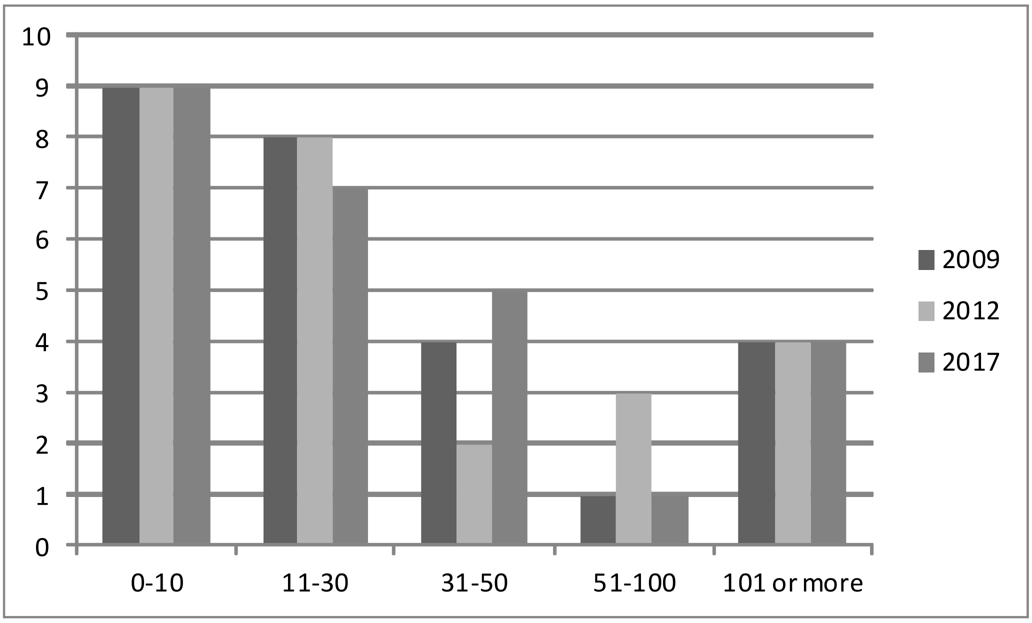

Figure 6. Frequency distribution of the employment (size) of warehouses concerning both countries using year 2011 responses (n = 26)

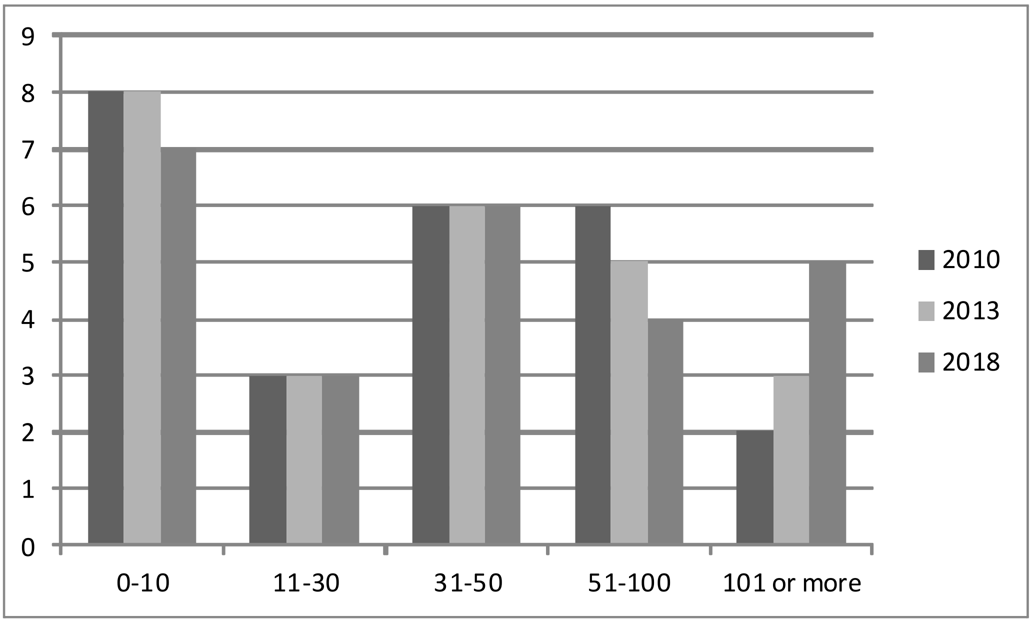

Figure 7. Frequency distribution of the employment (size) of warehouses in Europe concerning both countries using year 2012 responses (n = 25)

In light of these answers, it could be concluded that drastic improvements in productivity of warehousing work are not at sight – these typically are completed with larger units, higher volume and automation investments. It is of course known fact that entirely centralized (e.g., one European warehouse) will lead to massive amount of transportation, particularly road. However, a bit more decentralized structure (e.g., three to four European warehouses) will considerably decrease transportation activity ([17] talk about reforming regional distribution centres). It is understandable that companies are not keen to centralize and make warehouses larger units in current environment, where oil prices have sustained their high levels, and in future we have additional environmental payment burden coming in terms of CO_2 emission payments.

4. Conclusions

Warehousing holds significant importance on the employment of European Union, and most of the working places are not included in the statistics of the region wide records. Currently warehousing is following on transportation sector statistics road transports (freight), but it could be assumed that it is at same level or even higher as in-house completed activities, e.g., at retail and manufacturing are taken into account (which is not currently the situation). However, based on our research findings, environment has not that greatly changed in warehousing front in Finnish and Swedish companies (e.g., size of them in terms of employment remains as the same or slightly increases). We could state that costs remain in the same level or to slightly increase in the future. This even in the post 2009 economic crisis world, where transportation logistics sector is not having prosperous future insight in North European countries. Also transportation logistics practices are not that greatly changing: Still dominant transportation device is semi-trailer. However, in positive light could be reported that containers are taking some more share in most recent survey round. In all survey rounds we also were able to identify that short-distance, basically Baltic Sea Region countries, attract most of the warehousing placement in larger European context. This is interesting finding as, e.g., the Baltic States and Poland have been for years in the same trade area together with other EU countries. Some evidence is that the Baltic States warehousing is among Finnish company responses on decline, together with finding that weight is transferred from BSR to elsewhere in Europe. However, this argumentation arises from most recent survey round, and has only limited amount of answers. In longitudinal perspective we were able to show that Finnish companies are much better placed within CEEC distribution than Swedish counterparts.

As a further research natural step to be taken would be completion of this survey during year 2013. Together with this we would be interested from warehousing change after economic hardship started in year 2009. Effects are still ongoing in European business practices, and would be extremely interesting to examine, how uncertainty and possible declines in sales are taken into account. Environmental issues and their role in this new demanding business environment would be interesting to study, too, maybe simultaneously with operating models in post 2009 era.

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LITHUANIA TRANSPORT SERVICE PROVIDERS' POSITION IN THE BALTIC SEA REGION TRANSPORT MARKET

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Assessment of Lithuanian road transport service providers' position in the Baltic Sea region identified, that the Lithuanian road transportation market has the tendency of recovery after the economic and financial crisis. Lithuanian transport companies operating in the BSR and EU market are small – average 7 HGV in the company but they remain competitive in the area of quality service offered. It is defined significant renewal of HGVs fleet – more than thirty percent's of vehicles have EURO-4 and EURO-5. Big transport companies are extending their service package and in the parallel with the transportation are proposing to the customers' logistics service package or dedicated services.

Keywords: transport, service quality, security

1. Introduction

The road freight market has been under a serious reconstruction. The strong economic growth during the first years of the 21st century together with the expansion of the European Union attracted a number of new entrants to the market. The changes, which are taking place in the international transport services market demand not only the modernization of the current infrastructure, by releasing intended development projects, but also the application of modern transportation technologies. The Lithuanian geopolitical state and well-developed transportation infrastructure provide a possibility not to remain in the background of current changes in the transit services market, but to act as a mediator in the expansion of trade connections of the most important transportation corridors between East and West. The objective of this paper is to explore how the prevailing market conditions in the Baltic Sea Region have affected Lithuania transport service providers.

2. Design/Methodology/Approach

In this paper is summarized data from interviews conducted in the Lithuania between in the beginning of 2011 as part of an EU funded project "Connecting Authorities for Safer Heavy Goods Traffic in the Baltic Sea Region" (C.A.S.H.). The interviews in early 2011 were conducted with Lithuanian public authorities and companies engaged in border-crossing road transport.

The aim of the interviews in Lithuania was to provide an understanding of how the prevailing market conditions in the Baltic Sea Region may have affected:

A. The market for international road freight transport in the BSR;
B. Traffic safety of border-crossing freight transport and safety enforcement;
C. Traffic safety and safety culture in border-crossing freight transport;
D. Security of drivers, trucks and cargo in the BSR.

The interviews aimed to provide general understanding of possible differences in the enforcement of HGV traffic and the compliance of regulations particularly:

- during the past 4–5 years (years 2005–2006);
- by the end of 2010 ("current situation").

3. Market for International Lithuania HGV Road Freight Transport

According to general assessments, situation by the beginning of 2011, compared to 2005–2006, didn't change. The absence of changes in Lithuania could be explained as follows: the economic development curves during the period under analysis must have been similar (consequently, transport market trends were more or less the same): the years 2005–2006 were the period of "growth"; in order to meet the growing demand all companies tried to supply themselves with capacities (from own or borrowed funds); at the beginning of 2011 the signs of "recovery" emerged and determined recovery (increase) of capacities.

According to the assessment of general availability of the international HGV road transport capacity from the shipper's perspective in Lithuania in 2005 and at the beginning of 2011, in 2011 the shipper could get access to transportation services easier than in 2005 since the supply of services in 2011 exceeded the demand. With the increasing service development level in Russia and Belarus availability of transport services also improved. Therefore the situation in 2011 was evaluated better than five years ago. The trade balance in the neighbouring countries, e.g. in Poland, Latvia and Estonia, had a positive impact on the availability of capacity, yet in 2011 the countries didn't reach the level of 2005–2006.

According to general assessments, operational quality of transport companies during the period under analysis has improved nearly in all BSR countries. When assessing the operational quality of Lithuanian companies, the majority of respondents stated that it has improved, therefore in the general assessment quality from "neither poor nor good" turned into "good". The change was not significant: according to respondents, only large companies can improve/ensure high quality. Since Lithuania has few large companies, general level of quality has improved slightly.

All respondents noted that situation of operational quality of the international HGV transport in Lithuania and in Estonia, Latvia, Poland improved significantly.

According to the majority of respondents, the estimation of general assessments demonstrated that economic entities were more profitable in 2005–2006 compared at the beginning of 2011. The years 2005–2006 were related to the period of "recovery" and have been successful for the entire transport market: transport demand has increased and companies which managed to meet the demand worked profitably. Here it is necessary to mention Lithuania, since the phenomenon of a growing "bubble" was especially evident in the country: the growing demand determined the increase of capacities by carriers; being able to increase transportation volumes for lower price they received higher profit during a certain period of time. However, as soon as the economic recession began (in 2007) the "bubble" blowed: the demand for transportation decreased and companies were unable to use the capacities. Consequently, profitability has decreased significantly. At the beginning of 2010 obvious signs of "recovery" were observed, therefore the change related to the impact of the above factor is not very high.

With regard to general reduction in the profitability of companies, it was not only due to the economic recession but also to higher prices of energy resources which also increased transportation costs.

When speaking about competitiveness, experts also noted that all companies which experienced recession by distributing funds in a more rational way could be treated as competitive. Therefore by at the beginning of 2011 competitiveness of companies was related to lower transportation costs. According to general assessments, currently Lithuanian and Polish carriers were more advanced, yet Lithuania's competitiveness was based not on small transportation costs but on a favourable geographic location (territory of the country is passed by huge transit flows).

While speaking about competitiveness among companies, experts in Lithuania discerned major competition (both, today and during the period of 2005–2006. It is significant to note that assessment of competitiveness by the representatives of public institutions was nearly the same (i.e. the situation in 2005–2006 and 2011 is very similar), whereas experts representing transport companies evaluated changes in competitiveness drastically (major changes).

Both public authorities and transport associations did not indicate considerable changes with regard to competitiveness in Lithuania.

4. The Balance between Supply and Demand in the International Road Transport in Lithuania in Autumn

When evaluating the balance between the supply and demand the experts highlighted that the season of autumn cannot be evaluated unambiguously: during the first period of the season the supply is usually higher; the demand is higher during the second period (pre-holiday period).

The general conclusion could be as follows: the autumn of 2010 was not very successful for the Lithuanian transport market: the majority of respondents highlighted higher supply volumes.

In view of the above it could be said that the increased consumption determined the demand for transportation services and that supply could not meet the demand. After experiencing the period of recession the transport sector didn’t hurry to increase volumes of services, therefore the demand for transportation could not be met. This determined a temporary jump in transportation prices.

When asked to assess the balance between the supply and demand in the international road transport in Lithuania in autumn 2010, the respondents said that transport demand was higher due to the lack of vehicles.

All respondents mentioned that Lithuanian road freight transport fleet fully satisfied Lithuania’s import and export service requirements. HGV fleet comprised nearly 22 000 vehicles. More than 50 percent of HGV operated in other EU Member States or transported goods between the EU and Russia. Regarding Lithuanian transport, high competition was due to “cheap” transport in other countries (Belarus, Ukraine). In view of this transport companies had to reduce transportation costs.

5. The Main Changes in the Market Structure of the International Road Freight Transport in Lithuania during the Past 5 Years

When evaluating the freight transportation market, respondents highlighted that during the recent five years Lithuania experienced many changes. The most important included:

- high number of bankruptcies: during the crisis the majority of companies had to terminate their activity. According to respondents small companies and economy entities the main part of service package of which consisted of warehousing services, suffered from the recession most of all;
- consolidation: in order to survive during the period of crisis companies were forced to merge and pursue common activity;
- reduced vehicle fleet, i.e. reduction of available capacities (by own will or under compulsion). Some companies had to do this in order to optimise operations, the others because of inability to pay credits;
- reduced sales are related to lower demand and higher transportation costs;
- reduction in the number of employees: during the economic downturn this is a natural phenomenon: in case of the fall in demand (and capacities) it is necessary to optimise operations; therefore the reduction in the number of employees is inevitable.

Other respondents tried to dissociate from the recession and discerned positive changes:

- after elimination of the permit and visa regime transportation procedures to certain countries have been simplified;
- Recovery was observed in 2010: the demand for transportation was increasing, companies increased their capacities.

Respondents highlighted main changes in the market structure for international road freight transport in Lithuania during the recent five years. The number of companies and employees has decreased, majority of them either went bankrupt or merged the international networks (companies). Several companies acquired DSV, consolidated logistics services and could offer a wide spectrum of services (signs of 3 PL business). Considerable reduction in the number of forwarders has been observed. High number of transport companies experiencing real of fake bankruptcy. These factors were determined by changing customer’s needs. The focus was given to CIS countries. It was necessary to increase the speed of services directed toward transit flows. There were also multiple political and economical reasons: changing export and import markets and transportation trends included the changes in the customs tariffs and attitudes.

In summary, it could be stated that main changes in the market structure for international road freight transportation in Lithuania during the recent five years were: high number of bankrupt transport companies in 2009 (about 20 percent), big number of unpaid and returned (to credit institutions) freight vehicles. During the pre-crisis period transport companies employed about 80 000 employees. During the downturn this number has decreased and now it has been again increasing. Today the market has less weak and small companies and large transport companies have improved their operations. The role of forwarders has also increased because of a smaller size of goods consignments. This resulted in a more frequent transportation of partial freight and consolidation of services.

Changes identified by respondents:

- Essential liquidations and bankruptcies of the small companies;
- Lack of HGV drivers in own country;
- Some companies established their subsidiaries in the Kaliningrad district; this helped to solve the problem of permits to Russia;
- Foreign transport companies didn't appear in Lithuania;
- Transport fleet underwent significant improvements. Near 30 percent of HGV have Euro 4 and Euro 5 certificates.

According to respondents the main factors which determined the changes are as follows:

- Global economic downturn;
- Lack of permits to Russia since main international transport flows are between Western Europe and Eastern Europe (Russia, Belarus);
- Smuggling (invoice counterfeiting when transported cargo and cargo in the documentation differed). This determined more frequent checks by relevant services (time and other costs have also increased).

Other reasons included:

- Strong influence of the financial crisis;
- Pressure by the international transport market.

4. Conclusions

Operational quality of companies during the period under analysis has improved in Lithuania and nearly in all BSR countries.

Transport companies worked more profitably in 2005–2006 compared to the end of 2010; after "overcoming" the crisis they didn't manage to reach the initial level; besides lower profitability was also determined by growing prices of energy resources which increased transportation costs.

By the end of 2010 competitiveness of companies was related to lower transportation costs and high quality.

During the recent years many changes occurred in freight transport market, but the most significant are: increased number of transport company bankruptcies and reduced vehicle fleet. The market during the above period both expanded and shrunk (natural selection – only the strongest survived). This was determined by the economic factors (global recession).

The current market conditions have positive impact on the Lithuanian freight transport market: the volumes of export, import and transit flows are increasing; the vehicle fleet also expanded.

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PASSENGER CAR AS COMPLEX EXPERIENCE

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Passenger cars are complex products that consist of millions of parts. Cars have different shapes and colours giving persons different emotional feelings. Therefore the car as a complex product is suitable for marketing specialist for comparing other products through cars. Authors are describing the mathematical background of the theoretical investigation and the practical results of such examination.

Keywords: cars, emotions, experience

1. Introduction

Passenger cars are very complex products. Passenger cars consist of millions of parts. Furthermore passenger cars are not only a complex mechanical and technical product but they are also as a complex meaning psychology. Cars have different shapes, colours, sounds, volume giving persons different emotional feelings. Therefore the car as a complex product is suitable for marketing specialist for comparing other products through cars. Authors are describing the theoretical investigation of such a qualitative examination and the practical results. This comparison possibility that is associations based as a tool is developed in psychology but the usage with stricter regulation in marketing investigation is far more suitable in projective techniques. Everyone has an opinion about cars; most of us even have experience as well. In this paper, authors have introduced a general framework for experience of passenger car as a product that applies to all affective responses that can be experienced in human-product interaction. The passenger cars as products have influence to all human sensors (visual, auditory, tactile, taste, smell, movement) in fact the further more beyond sense passenger cars cause emotions (social factors, emotions, behaviour). Distinct components or levels of product experiences are discussed. All level is distinguished in having their lawful underlying process [1].

Product experience

Before starting the discussion on human-product experience from passenger cars and marketing perspectives it is important to summarize the theoretical background of product experience. Product experience is always resulting from some interaction of the user and a product. This interaction is not necessarily restricted to instrumental or non-instrumental physical action, but mostly also consists of passive (often visual) perception, or even remembering or thinking of a product [1]. Human-product interaction and product experience is closely interwoven. Figure 1 provides a model of human-product interaction [2].

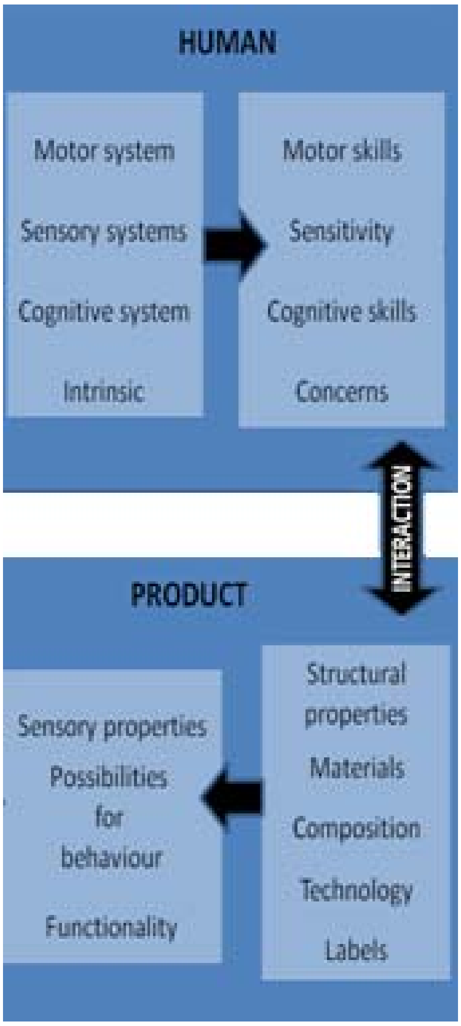

Figure 1. Model of human-product interaction
(*source*: [2])

Humans are able to interact with their environment (and the products) by motor system, sensory systems, cognitive system and instinct. Passenger cars have countless relationships with humans from the point of view of product experience. They interact with humans through concrete levels: visual appearance (shape, colour, material, display), tactual experience (touch of controls, seats, etc.), audio experience of the passenger car (for example, buzzing of the engine or the sound of closing the door), smell (for example, "smell of the new car") and the multi-sensory experience (like driving experience). On the other hand, cars interact with humans mostly by abstract, subjective way or emotional "symbolic" level, and they helps create the "owner loyalty" like aesthetic experience (for example, the subjective meaning of "beauty"), brand experience (like the producer image, or the consumers self image when possessing the car), social level (the experience of belonging to a certain group), shopping experience, and the satisfaction with dealer service. It is clearly visible that passenger cars product experience is significantly more than the using experience.

Colours, shapes, sounds (or music) and words almost always have an emotional meaning. This emotional meaning is in part innate but also learned from our cultural environment. It is a question of design: design elements will only be successful if they hit the desired emotional spot. Nowadays dealers are selling complex product experience instead of cars, and therefore designers have to plan experiences for customers, and the producers have to design the whole production, dealing and service process around the consumers' product experience. Cues, sensory, verbal and visual stimuli must be optimised not only the level of product, but also the whole purchase and consumption process. In this area is particularly difficult to compete with merely the quality of product therefore new management solutions are formed focusing on emotional experiences. This new focus appears as emotional and symbolic product attributes emphasizing positioning, and these decisions of product development in which aim at to impress all senses of the customer. (Cue-management) from Porsche design process it is a good example for cue-management approach to the acoustic design planning [3]. They employ more than 80 “tuner” (acoustic expert) in order to develop the best audio experiences, like 911 characteristic motor “buzzing” sounds or the typical and unique “blubb” sound when the car is closing. All sound and every acoustic effect is a message, which increases or decreases the product’s value. In order to be successful on the market, the brand of a car must have a clear emotional place in the mind of the consumer. This emotional brand essence results from the sum of all experiences that come from human-product interaction in both tangible and abstract levels. The subsequent implementation in marketing and brand communication is derived from the emotional brand positioning.

2. Methodology

The projective techniques derived from the practice of psychology. Projective techniques that were originally developed by clinical psychologists were adapted for use in consumer and marketing research. In marketing the projective technique is used with limited boundary conditions than in psychology. Passenger cars as complex systems are well known base of projection due to their technical and caused emotion complexity. The passenger cars as complex systems are devoted as complex product experience. In psychology, a projective test is a type of test in which the individual offers response to ambiguous scenes, words or images or make connection between two different types of products. This type of test emerged from the psychoanalytic school of thought, which suggested that people had unconscious thoughts or urges. Firstly, the feelings about the explanatory products are questioned. Then the connection between the explanatory products and the investigated products is analysed. As the connection revealed explanation could be done about the feelings of investigated products. These projective tests were intended to uncover such unconscious desires that were hidden from conscious awareness. Specifically, cars were used as a means of projective techniques. Authors in this article are only dealing with human feelings about passenger cars (*Fig. 2*). On the figure it can be seen that one man can have opinion on multiple mediate product. Each product can be connected with multiple revealed preferences. All this chain is designed in order to get to the examined products. With this type of complex association chain the end product could be investigated through other products and hidden preferences can be revealed by the mediate products.

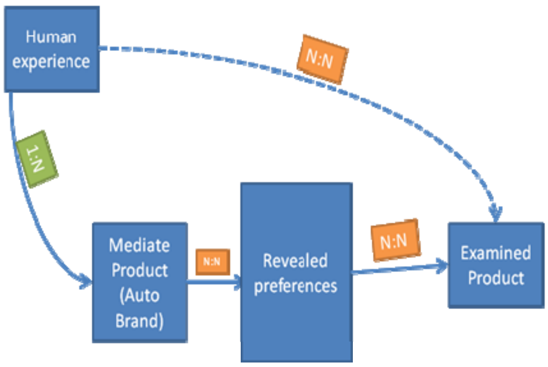

Figure 2. Model of methodology
(source: own compilation)

Passenger cars are really good mediating products. They can be used as a media in order to reveal hidden preferences of other investigated products. That is, why cars and transport vehicles are good media.

3. Analysis

A sample of 18-person in the preliminary investigation were used to test the car related emotions. 28 different cars were selected (*Table 1*).

Table 1. Investigated auto brands

Alfa Romeo
Audi
BMW
Citroen
Dacia
Fiat
Ford
Honda
Hyundai
Jeep
Kia
Land Rover
Lexus
Mazda
Mercedes
Mini
Mitsubishi
Nissan
Opel
Peugeot
Renault
Saab
Seat
Skoda
Suzuki
Toyota
Volvo
VW

(source: own compilation)

The aim is to subsequently identify associations related to the product, to the passenger cars, to their level of experience. Authors have investigated the revealed associations that are invited by the varieties of car brands. Experience is shaped by the characteristics of the user (e.g., personality, skills, background, cultural values, and motives) and those of the product (e.g., shape, texture, colour, and behaviour). All actions and processes that are involved, such as physical actions and perceptual and cognitive processes (e.g., perceiving, exploring, using, remembering, comparing, and understanding), will contribute to the experience [4]. In addition, the experience is always influenced by the context (e.g., physical, social, economical) in which the interaction takes place. The association questioners have been statistically analysed; frequency (Eq. 1):

$$\varphi_i = \frac{v_i}{\sum_{i=1}^{n} v_i}, \tag{1}$$

where

φ_i: frequency of auto brands in the sample [-]

v_i: number of answers in the sample [-]

n: total number of brands in the sample

and cumulated frequency (Eq. 2) is calculated:

$$\Phi_j = \sum_{k=1}^{j} \varphi_k, \tag{2}$$

where

Φ_j: cumulated frequency of auto brands in the sample [-]

φ_k: number of answers in the sample [-]

In addition frequency the emotional content of responses is examined. Four different cases are distinguished for emotional content:

1) **Positive emotional content**: respondents described positive feelings or experiences with auto brand. For example: "*This brand refers with high quality for me!*", "*It is my favourite auto brand, because it is very hot and smart*!", "*It is a luxury car brand, and I like it very much!*" etc.
2) **Neutral emotional content**: respondent formulated feelings without positive or negative content. For example: "*It is an average auto brand, I think it is reliable but not excellent!* " etc.
3) **Negative emotional content**: respondents described their negative feelings with chosen auto brands. For example: "*This type of cars are poor quality of level!*", "*Poor people like this auto brand!*" etc.
4) **Ambivalent emotions**: sometimes respondent cannot formulate clear emotional content; they use a car brand and speak about their reasons. For example: "*It is high quality and prestige car brand, but when I could have bought one I choose another brand!*", "*People like this brand, and I believe it is a good car, but it is not enough attractive for me!*"

Further on attitude (negative, neutral, positive, ambivalent), it has been investigated by gender. This equation (*Eq. 3*) can be described by a number of evaluator as the function of brand of autos and attitude.

$$N = f(\alpha, \beta), \tag{3}$$

where

N: number of evaluators [-]
α: attitude [-]
β: brand of autos [-]

In order to analyse the changes and differences the gradient function has been derived from Eq. 3:

$$\nabla N = \frac{\delta N}{\delta \alpha} i + \frac{\delta N}{\delta \beta} j, \tag{4}$$

where

∇N is a matrix returns the α and β components of the two-dimensional numerical gradient.
$\partial N/\partial \alpha$ refers to the differences and changes in α direction, which means how the number of evaluators changed with the changing of attitude when the brand of autos remained constant.
i: is the unit of α
$\partial N/\partial \beta$, refers to the differences and changes in β direction, which means how the number of evaluators changed with the changing of auto brands when the attitude remained constant.
j: is the unit of β.

Unfortunately in our case the function is not continuous. In order to solve the problem Eq. 4 need to be rewritten in a discrete form:

$$\nabla \widetilde{N_k} = \frac{N_{k+1} - N_k}{\alpha_{k+1} - \alpha_k} i + \frac{N_{k+1} - N_k}{\beta_{k+1} - \beta_k} j, \tag{5}$$

where

$\nabla \widetilde{N_k}$ is a matrix of discrete function that returns the α and β components of the two-dimensional numerical gradient.
$\frac{N_{k+1} - N_k}{\alpha_{k+1} - \alpha_k}$, refers to the differences and changes in α direction, which means how the number of evaluators changed with the changing of attitude when the brand of autos remained constant.
i: is the unit of α.
$\frac{N_{k+1} - N_k}{\beta_{k+1} - \beta_k}$, refers the differences and changes in β direction, which means how the number of evaluators changed with the changing of auto brands when the attitude remained constant?
j: is the unit of β.

4. Results

Firstly, the descriptive statistics are presented (*Fig. 3*).

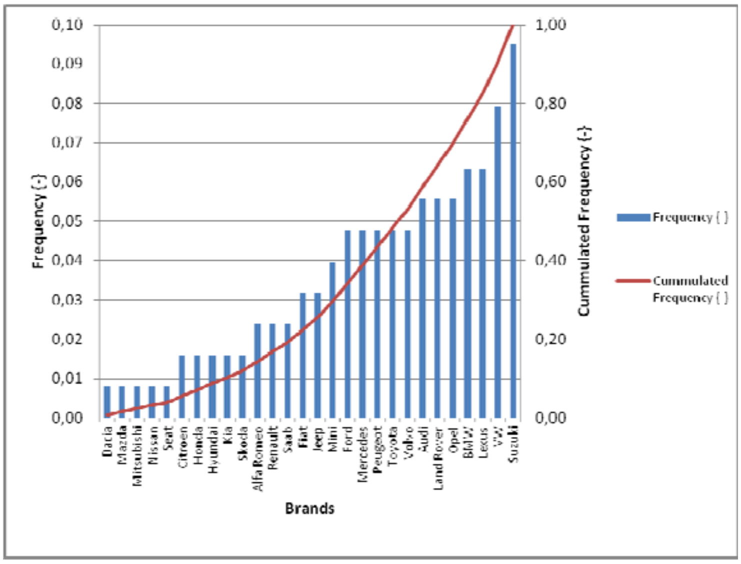

Figure 3. Frequency of Auto Brands in association questionnaire
(source: own compilation)

As it can be seen from Figure 3 in the association questionnaire Suzuki, WV and Lexus were mentioned mostly; represented auto brands and the frequency of emotional content in the responses from Fig. 4. It can be seen Audi and Lexus were used frequently to describe Positive feelings or experiences. Very interesting and Hungarian characteristic reflected in the ambivalent responses, because BMW and Opel were the mediate product to formulate respondents ambivalent feelings. Opel is a very (or too) average family car, and BMW often identify the "not honest business men" car; with Suzuki and VW mixed feelings and emotions are described.

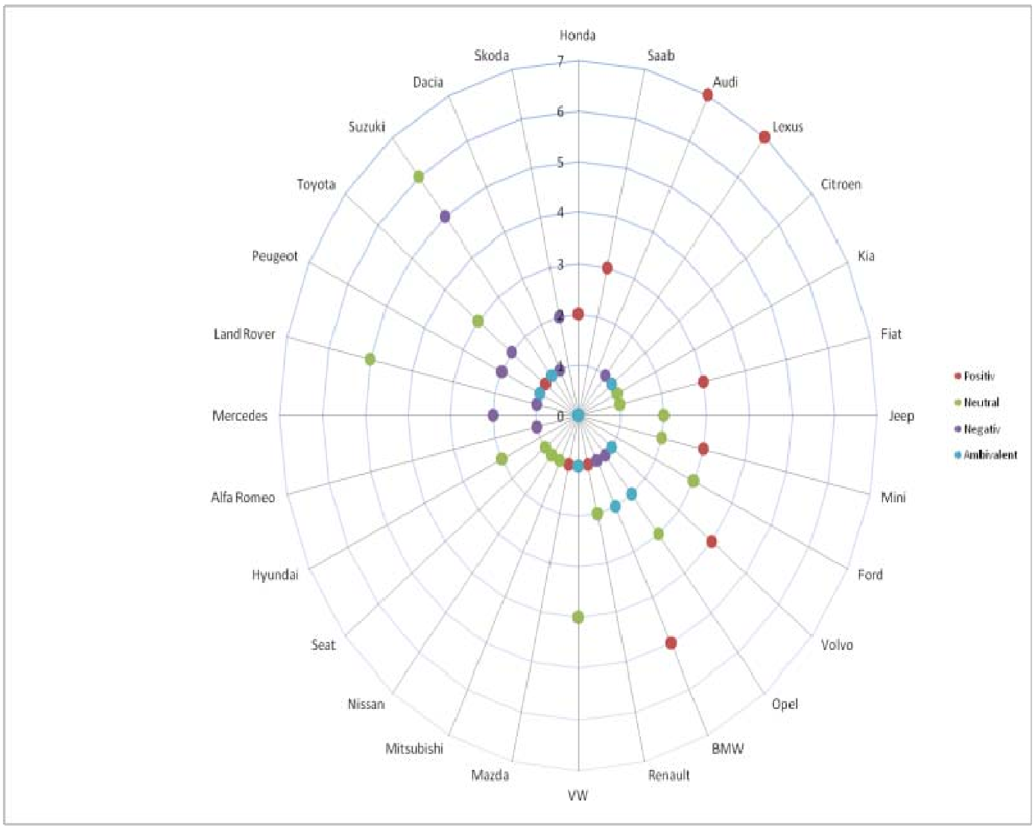

Figure 4. Frequency of Auto Brands in association questionnaire
(source: own compilation)

Significantly different attitude has been found by gender (*Fig. 5*). Negative attitude was coded with –1, neutral with 0, positive with 1 and ambivalent with 2.

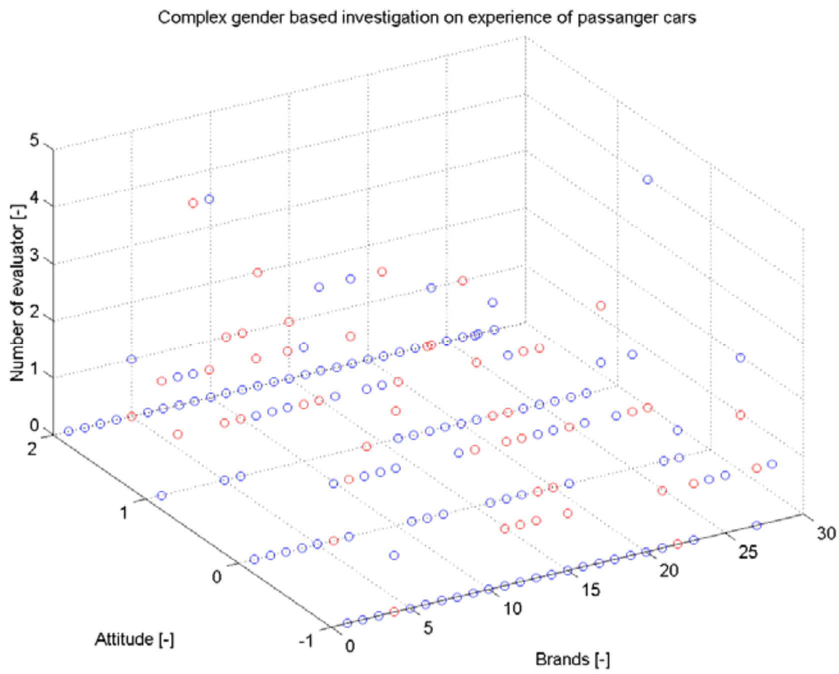

Figure 5. Differences of attitudes connected to Auto Brands
(source: own compilation)

Vectors as arrows has been displayed. The origin of vectors refers the attitude and auto brands and the combining components are ($\dfrac{N_{k+1}-N_k}{\alpha_{k+1}-\alpha_k}i+\dfrac{N_{k+1}-N_k}{\beta_{k+1}-\beta_k}j$) as described in methodology. By definition arrows can overlap that sometimes makes the understanding harder.

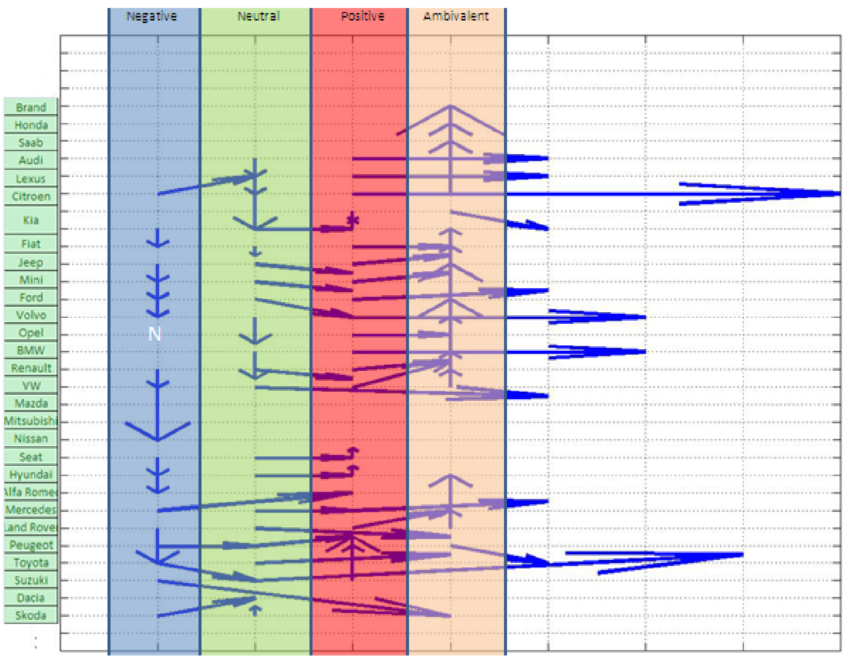

Figure 6. Visualisation of male gradient matrix
(source: own compilation)

As it can be seen from Figure 6 Lexus, Volvo, BMW, Audi, Saab have the major positive attitude in decreasing order VW and Land Rover have the major negative attitude in Hungary by male evaluators.

Figure 7. Visualisation of female gradient matrix
(source: own compilation)

As it can be seen from Figure 7 Lexus, Saab, Citroen have the major positive attitude in decreasing order VW and Opel have the major negative attitude in Hungary by female evaluators.

5. Conclusions

Passenger cars are very complex products. Furthermore passenger cars are not only a complex mechanical and technical product but they are also as a complex meaning psychology. Cars have different shapes, colours, sounds and volume giving persons different emotional feelings. Therefore the car as a complex product is suitable for marketing specialist to compare other products through cars. Authors are describing the theoretical investigation of such a qualitative examination and the practical results. This comparison possibility that is associations based as a tool is developed in psychology. Everyone has an opinion about cars most of us even have an experience as well. In this paper, authors have introduced a general framework for experience of passenger car as a product that applies to all affective responses that can be experienced in human-product interaction. Authors have investigated the attitudes that are connected to passenger car brands. Further on authors have investigated the gender factor of such psychological environment and found significant differences.

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TRANSPORTATION OF LIQUEFIED GASES: ASSESSING THE RISK OF THERMAL DAMAGE TO ROADSIDE INFRASTRUCTURE FROM A ROAD TANK "BLEVE"

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An assessment of risk posed by a road transportation of liquefied gases to roadside property is considered. The attention is focussed on an estimation of the probability of thermal damage to a roadside object. Such damage can be caused by a boiling-liquid expanding-vapour explosion (BLEVE) of a road tank. It is suggested to estimate this probability by a combined application of stochastic simulation and deterministic models used to predict a thermal effect of a BLEVE fireball. A development of a fragility function expressing the probability of ignition of the roadside object is discussed. The fragility function is integrated into the simulation-based procedure of an estimation of the thermal damage probability. The approach proposed in this study is illustrated by an example which considers an assessment of thermal damage to a reservoir built in the vicinity of a road used for transportation of liquefied gases.

Keywords: hazmat transportation, road tank, liquefied gas, BLEVE, thermal damage, risk

1. Introduction

Every day large amounts of liquefied gasses (LGs) are shipped by road to ensure a small-scale distribution to end-consumers. The increasing consumption of gas in Europe and construction of new gas terminals will drive up LG transportation by road vehicles [1]. Accidents of such vehicles pose serious risk to people and infrastructure located in the roadside territory [2]. A traffic accident of a road tank can escalate in a severe and highly hazardous explosion known as a boiling-liquid expanding-vapour explosion (BLEVE) [3]. Such an explosion can be a stand-alone accident or, alternatively, cause secondary or "knock-on" accidents in the roadside territory. Accidents involving BLEVEs of road tankers, which carried LGs, are reported by T. Abassi and S. A. Abassi [3], Planas-Cuchi *et al.* [4], Tauseef *et al.* [5].

Thermal and mechanical effects of BLEVE on roadside objects can be predicted by mathematical models, most of which are strictly deterministic. These models cover blast, fireballs, and projection of fragments (projectiles) generated by BLEVEs [6-10]. The models of BLEVE effects can be applied to predicting damage to roadside objects. A methodological framework for such predicting is available in the field of transportation risk assessment [11]. An example of an application of TRA to an assessment of individual and societal risk due to LG transportation was reported by Paltrinieri *et al.* [12]. TRA is a widely developed methodology. However, our impression is that applications of TRA lack "attention to detail", where a potential damage to build roadside objects is of concern [13]. An assessment of such damage will require considering two aspects of a BLEVE accident: transportation aspect (potential position of the explosion within the road segment from which it can endanger a roadside object in question) and structural aspect (response of the roadside object to potential BLEVE effects).

The present study attempts to give guidance on assessing the damage to built roadside objects from thermal radiation emitted by BLEVE fireballs. Such a radiation is not the furthest reaching BLEVE effect. However, it can be very intense in the roadside territory and, unlike blast and projectiles from an LG tank vessel fragmentation, it will impinge on objects build relatively close to the road from high elevation. The thermal radiation can be very problematic in terms of fire safety. The study focuses on a stochastic (Monte Carlo) simulation of position of road tanks before they undergo a BLEVE and thermal radiation from a BLEVE which can cause the thermal damage. The simulation results can be useful for a design of future objects and protection of existing objects located in the vicinity of the roads used for LG transportation.

2. The Exposure of Roadside Property to Effects Generated by a Road Tank BLEVE

An accident occurring as a BLEVE of a road tank will be initiated by a traffic accident, in which the tank vehicle is involved (Block 1, Fig. 1). Then the initiator can be followed by two typical sequences of events leading to an engulfment of a tank by a fire and BLEVE of the tank (Blocks 2 to 7, Fig. 1). The fire can be fed by LG leaking from the tank or by other source, most probably, fuel of a tank truck. A fire of both LG and fuel is also possible [4].

A BLEVE can be external or internal event with respect to exposed roadside infrastructure. An external exposure to BLEVE hazard can result from a transportation of LGs over adjacent public (off-site) roads or access roads. An example of an external exposure to a BLEVE is given on Figure 2. The internal expose will take place during the transportation of LGs over on-site roads. In congested vulnerable industrial areas adjoined by on-site roads, the on-site transportation of LGs can be more hazardous than the transportation over off-site, public roads.

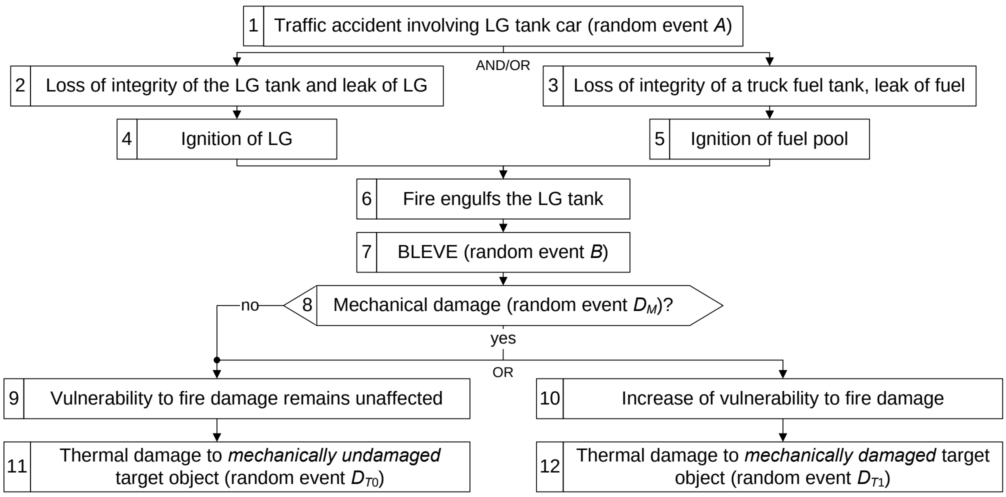


Figure 1. Sequences of the events leading to a road tank BLEVE and subsequent damage to a roadside object

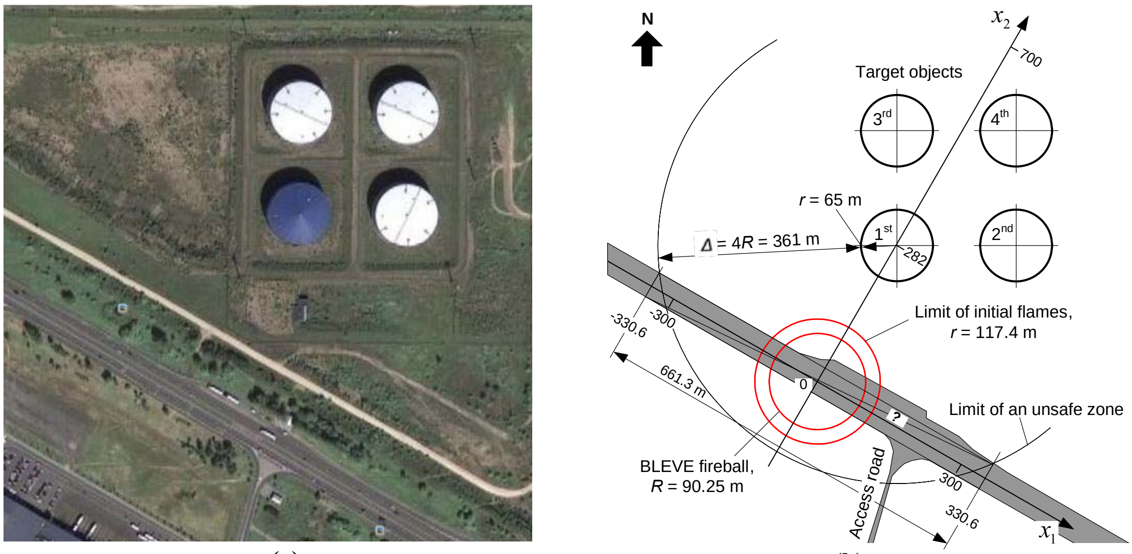
BLEVE damage to a roadside object can be caused by three effects generated this explosion: blast, projectile impact and thermal radiation from a fireball. Blasts from BLEVEs are localised and not as far reaching as fireball and projectile effects. If safe distances between the road and roadside objects can be established for fireballs then they will be safe for the blast. Such distances are also known as separation distances [14]. A separation distance equal to four times the potential fireball radius R is suggested as reasonable for thermal radiation effects and blast effects [15]. An illustration of the distance $4R$ is given on Figures 2 and 3. However, at this distance the hazard from projectiles is still very significant. At a distance of $4R$ from the side of a tank, approximately 80-90% of fragments should fall. A compensation for less than desired separation distances can be safety barriers built alongside the road. If designed properly, the safety barriers will provide protection against blast and projectiles. For effective protection, the potential BLEVE epicentre should be at relatively short range from the front of the barrier [16].

Unfortunately, barriers can provide no protection against fireball radiation because dimensions of fireballs from BLEVEs of road tanks exceed any reasonable dimensions of barriers. An illustration of these dimensions is given on Figure 3. The geometry of the fireball shown on Figure 3 was calculated for a typical tank semi-trailer carrying 24.7 tons of propane by applying the so-called TNO fireball model [17]. The model and the data used for the calculation are presented in Tables 1 and 2.

A protection of roadside objects against thermal radiation from BLEVE fireballs should be based on either providing adequate separation distances or compensating less than desired safety distances by adequate resistance of target objects to thermal radiation. The latter option can be achieved by shielding the target objects from thermal radiation or making them inherently more resistant to such radiation. Both options require to predict intensity of thermal radiation from a road tank BLEVE and to assess the risk of thermal damage to exposed roadside object. An assessment of this risk will require dealing with transportation and structural aspect of the problem.

3. Contribution of Thermal Damage to the Risk Posed by a Road Tank BLEVE

Blast and projectiles generated by a road tank BLEVE can cause mechanical damage, whereas the thermal radiation can ignite combustible parts of the exposed object and so the damage will be caused by a subsequent, secondary fire. Many combustible materials ignite at ten-second exposure to 50 kW/m^2 radiation [18]. The duration of a fireball generated by a BLEVE of a typical road tank is up to 20 seconds. Blast and projectiles will reach the target object within first two or three seconds after the explosion and act a very short time. Thermal radiation from a fireball will act on the object a longer time and will increase from zero to a maximum value during the first third of fireball duration [10]. If the events of mechanical and thermal damage are modelled by the respective random events D_M and D_T, the event D_M will occur first and D_T will follow D_M (Blocks 8 to 11, Fig. 1).



(a) **(b)**

Figure 2. An example of external exposure of a potential target to a BLEVE on road:
(**a**) an aerial view of four reservoirs of flammable materials in the vicinity of a road with a frequent transportation of LGs;
(**b**) schematic view with a coordinate system $\{0; x_1, x_2\}$ based on road centreline and one of the reservoirs

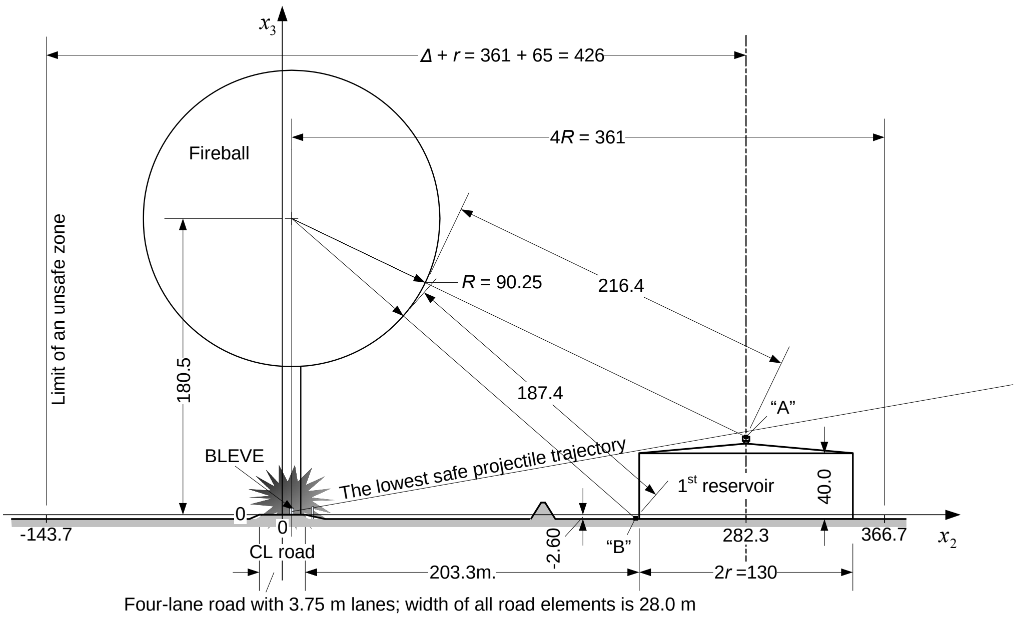


*Figure 3***.** Exposure of a roadside object (target) to the fireball generated by a BLEVE of a road tanker carrying 24.7 tons of propane (the dimensions of the fireball were estimated by means of the TNO model, see Table 2 and [17])

Table 1. Input vector x of the model $\psi(x)$ described in Table 2

Component of $\boldsymbol{x}$	Description	Units	Value
x_1	Position of the BLEVE centre along the axis $\{0; x_1\}$* (Fig. 2b)	m	0
x_2	Position of the BLEVE centre along the axis $\{0; x_2\}$ (Figs. 2b and 3)	m	5.65
x_3	Position of the BLEVE centre along the axis $\{0; x_3\}$ (Fig. 3)	m	0
x_4	Capacity of the tank	m^3	56.14
x_5	Pressure in the vessel just before the explosion*	N/m^2	20×10^5
x_6	Degree of tank filling	%	85
x_7	Density of LG (propane)	kg/m^3	585
x_8	Combustion heat of LG at its boiling point	J/kg	46.0×10^6
x_9	Vaporisation heat of LG at its boiling point	J/kg	0.426×10^6
x_{10}	Specific heat capacity at constant pressure	J/(kg°K)	0.002582
x_{11}	Temperature of the fireball flame	°K	2000
x_{12}	Partial vapour pressure of carbon dioxide in the atmosphere	N/m^2	30.39
x_{13}	Ambient temperature	°C	10
x_{14}	Relative humidity	%	70

* Relief pressure of the safety valve can be assumed as the pressure at the instant of explosion [10]

Table 2. Components (sub-models) of the model $\psi(x) = (\psi_1(x), \psi_2(x))$ developed in by the Dutch organisation TNO [17] (components of the input vector x are explained in Table 1)

Component of $\psi(\boldsymbol{x})$	Description	Expression of the sub-model
$\psi_1(\boldsymbol{x})$	Intensity of thermal radiation	$\psi_1(\boldsymbol{x}) = E(\boldsymbol{x})\, F_{view}(\boldsymbol{x})\, \tau_a(\boldsymbol{x})$*
$\psi_2(\boldsymbol{x})$	Fireball duration	$\psi_2(\boldsymbol{x}) = 0.852(x_4x_5x_6)^{0.8}$

* $E(\boldsymbol{x}) \equiv E(x_1, x_2, \dots, x_{12})$ is the emissive power of the fireball surface; $F_{view}(\boldsymbol{x}) \equiv F_{view}(x_1, x_2, \dots, x_6)$ is the view factor; $\tau_a(\boldsymbol{x}) \equiv \tau_a(x_1, x_2, \dots, x_6, x_{13}, x_{14},)$ is the atmospheric transitivity; see [17] for a detailed description of the sub-models $E(\cdot)$, $F_{view}(\cdot)$ and $\tau_a(\cdot)$

An occurrence of the mechanical damage event D_M can lead to two conditions of the target object with respect to the vulnerability of this object to thermal radiation:

1. An occurrence of D_M does not change the vulnerability to fire damage (Block 9, Fig. 1) (e.g., a local damage to a masonry wall of an industrial building hit by a projectile from a tank vessel fragmentation will not affect the vulnerability of its roof to thermal radiation, Fig. 4a). The events D_M and D_T can be considered independent and so the probability $P(D_T \mid B)$ estimated independently from $P(D_M \mid B)$, where B denotes the random event of BLEVE (Block 7, Fig. 1).
2. An occurrence of D_M increases abruptly the vulnerability to fire damage (Block 10, Fig. 1) (e.g., loss of containment by a reservoir used to store flammable liquid due to a projectile impact and so spill and exposure of this liquid to the direct action of thermal radiation will increase the chance of fire, Fig. 4b). The events D_M and D_T can not be considered to be independent and so $P(D_T \mid D_M \cap B) > P(D_T \mid B)$.

The probabilities $P(D_T \mid B)$ and $P(D_T \mid D_M \cap B)$ represent two different accident scenarios. They can be related to the frequency of thermal damage, $Fr(D_T)$, by a simple expression

$$Fr(D_T) = Fr(T) \times P(A \mid T) \times P(B \mid A) \times P(D_T \mid B) \text{ (or } \times P(D_T \mid D_M \cap B)), \quad (1)$$

where $Fr(T)$ is the usually annual frequency of LG transportation through the road segment under analysis (event T); $P(A \mid T)$ is the conditional probability of a traffic accident (event A) given T (the random event A is shown in Block 1, Fig. 1) and $P(B \mid A)$ is the probability of a BLEVE given A.

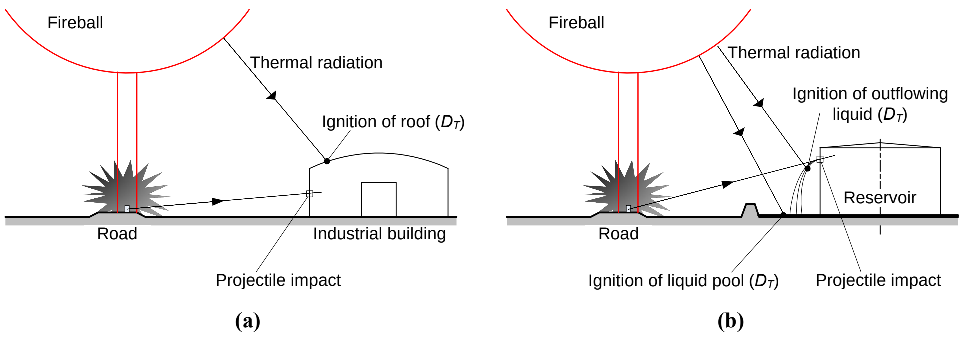


Figure 4. An illustration of the thermal damage event D_T: (a) the case of an independent occurrence of D_T with respect to the mechanical damage by a projectile; (b) the case where D_T (ignition of flammable liquid) is dependent on an occurrence of mechanical damage (perforation of a reservoir wall by a projectile and subsequent leak of liquid)

If D_T is a stand-alone event, a vector of consequence severities, $\boldsymbol{S}$, can be assigned to $Fr(D_T)$ and the pair $\{Fr(D_T), \boldsymbol{S}\}$ considered a simple expression of risk. In the case of an escalation of D_T into a larger, domino accident, the estimation of the frequency $Fr(D_T)$ can be treated as an estimation of frequency of an initiating event which triggers out a domino sequence. In both cases, the estimation of $Fr(D_T)$ will involve an estimation of the thermal damage probabilities $P(D_T \mid B)$ and $P(D_T \mid D_M \cap B)$.

4. Vulnerability of Roadside Object to the Thermal Damage from the Road Tank BLEVE

The estimation of the conditional thermal damage probability $P(D_T \mid B)$ is similar to that of $P(D_T \mid D_M \cap B)$, with the difference that the first probability must be estimated for a mechanically undamaged target object and the second one for an object in a damaged state and so more vulnerable to a thermal impact. Due to this similarity and for the sake of brevity, the symbol $P(D_T \mid B)$ will represent both probabilities. The thermal damage probability $P(D_T \mid B)$ can be expressed as follows [19]:

$$P(D_T \mid B) = \int_{\text{all } \boldsymbol{y}} P(D_T \mid \boldsymbol{y}) f(\boldsymbol{y}) \mathrm{d}\boldsymbol{y} = \int_{\text{all } \boldsymbol{x}} P(D_T \mid \boldsymbol{\psi}(\boldsymbol{x})) f(\boldsymbol{x}) \mathrm{d}\boldsymbol{x}, \tag{2}$$

where $\boldsymbol{y} = (y_1, y_2)$ is a two-component vector, the first component of which, y_1, expresses a thermal radiation intensity (heat flux) and the second, y_2, the duration of exposure to this radiation (fireball duration); $P(D_T \mid \boldsymbol{y})$ is the fragility function relating the probability of D_T to $\boldsymbol{y}$; $\boldsymbol{x}$ is the vector of characteristics of BLEVE accident resulting in the impact expressed by $\boldsymbol{y}$; $\boldsymbol{\psi}(\boldsymbol{x})$ is the vector-function which relates $\boldsymbol{x}$ to $\boldsymbol{y}$ (i.e., $\boldsymbol{y} = \boldsymbol{\psi}(\boldsymbol{x})$); and $f(\boldsymbol{x})$ and $f(\boldsymbol{y})$ are the joint probability density functions (p.d.f.s) of $\boldsymbol{x}$ and $\boldsymbol{y}$, respectively.

The development of the fragility function $P(D_T \mid \boldsymbol{y})$ is a highly case-specific task of probabilistic structural analysis. Fragility functions are widely applied to seismic risk assessment and extreme-wind risk assessment. However, any attempts to develop a fragility function for thermal actions of external fires are not known to us. What is more, recipes allowing relating the thermal radiation y_1 and duration y_2 to a specific thermal damage are very sparse and deterministic in nature. It is stated in the books CCPS [6] and CCPS [7] that the radiation of 37.5 kW/m^2 is sufficient to cause damage to process equipment and 12.5 kW/m^2 is the minimum energy required for ignition of wood and melting of plastic tubing. Most sources interpret the thermal damage simply as an ignition of materials exposed to thermal radiation and distinguish between ignition and non-ignition by specifying a pair of fixed threshold values ($y_{1,min}$, $y_{2,min}$) [10, 18, 20, 21]. Unfortunately, such values are insufficient to easily develop a fragility function $P(D_T \mid y_1, y_2)$, especially for short-term exposures (values of y_2 ranging roughly between 5 and 20 seconds). It is highly probable that at present the analyst will have to rely on a simplified fragility function expressed as

$$P(D_T \mid y_1, y_2) = \begin{cases} 1 & \text{if } y_1 \geq y_{1,min} \text{ and } y_2 \geq y_{2,min} \\ 0 & \text{otherwise} \end{cases}. \tag{3}$$

Fitting a well-known bivariate density $f(\boldsymbol{y})$ to the direct data on BLEVE effects can be problematic. BLEVE accidents on road are unique, short-lasting and unexpected events. The post mortem data on them is too sparse for fitting $f(\boldsymbol{y})$. However, the density $f(\boldsymbol{y})$ and so the probability $P(D_T \mid B)$ can be estimated by propagating uncertainties expressed by the lower-level density $f(\boldsymbol{x})$ through the model $\boldsymbol{\psi}(\boldsymbol{x})$ [19]. The function $\boldsymbol{\psi}(\boldsymbol{x})$ can be composed of a relatively large number of models available currently for the prediction of individual effects of BLEVE. These models are strictly deterministic, some are in competition for modelling individual characteristics of BLEVE fireballs [3]. Table 2 contains an example of $\boldsymbol{\psi}(\boldsymbol{x})$ composed of two sub-models $\psi_1(\boldsymbol{x})$ and $\psi_2(\boldsymbol{x})$ developed for a prediction of fireball radiation y_1 and duration y_2, respectively.

5. Transportation Aspect of Estimating the Probability of Thermal Damage

The estimation of the thermal damage probability $P(D_T \mid B)$ has an apparent transportation aspect. The thermal effect from a BLEVE fireball depends on a number of transportation-specific characteristics which can be taken as components of the input vector $\boldsymbol{x}$ in the model $\boldsymbol{\psi}(\boldsymbol{x})$. A list of these characteristics depends on the type of the model used to predict the thermal radiation $\psi_1(\boldsymbol{x})$ and the fireball duration $\psi_2(\boldsymbol{x})$. For instance, the TNO model described in Tables 1 and 2 allows classifying transportation- specific components of $\boldsymbol{x}$ as follows:

1. The position of exploding tank in respect to a target object.
2. The segment of road from which a road tank BLEVE can endanger the target object (unsafe road segment).
3. Characteristics of the tank vessel used to ship LG: capacity, degree of filling, relief pressure of the safety valve built into the vessel and, more generally, mechanical characteristics of the vessel metal heated by an external fire preceding BLEVE.
4. Characteristics of LG being shipped in the vessel: type and density of LG, combustion and vaporization heat, specific heat. Temperature of the fireball flame can also be attributed to the characteristics of LG.

The tank position can be defined by applying a coordinate system fixed to both road and target object. An example of such a coordinate system denoted by $\{0; x_1, x_2\}$ is shown on Figure 2b. If the altitudes of BLEVE centre and target object differ much and/or the road has a non-negligible gradient, a three-dimensional coordinate system $\{0; x_1, x_2, x_3\}$ must be used (e.g., Fig. 3). Unlike scattering of projectiles from a cylindrical vessel BLEVE and blast generated by such an explosion, the propagation of the thermal radiation is not directional [15]. Therefore there is no need to model the orientation of the exploding tank (the angle of tank axis in relation to the road axis) in the coordinate system $\{0; x_1, x_2\}$ [13].

The unsafe road segment denoted by, say, $\boldsymbol{\omega}$ can be determined by plotting a safety distance around the target object. If this object has a relatively simple geometry in plan, the safety distance can be determined a single variable, say, Δ. Figs. 2b and 3 illustrate such a distance for the cylindrical tank “1”. It was assumed that Δ is equal to four fireball radii R estimated by applying the deterministic model and data given in Tables 1 and 2. The safety distance Δ plotted around the target object formed a road segment $\boldsymbol{\omega}$ with the length of 661.3 m (Fig. 2b). The geometry and of a target object and road network in the vicinity of the object can be irregular. However, the unsafe road segment $\boldsymbol{\omega}$ can be identified also in such a case [22].

Generally, all component of the input vector $\boldsymbol{x}$ should be considered random and modelled by random variables. However, the variability of some components can be expected to be small one and so these components can be represented by fixed values. The position of the BLEVE centre in the road segment $\boldsymbol{\omega}$ in undoubtedly uncertain and must be modelled by two random variables X_1 and X_2. For the model $\boldsymbol{\psi}(\boldsymbol{x})$ described in Tables 1 and 2, they will be the first two random input variables. The altitude of the explosion centre with respect to the target, x_3, can be expressed as a linear function of X_1 if the road within $\boldsymbol{\omega}$ has a longitudinal gradient. Consequently, X_3 will have the same probability distribution as X_1. The capacity of the tank, x_4, and the relief pressure of the safety valve, x_5, can be assumed to be fixed values if it is known what type of the tank vessel will undergo a BLEVE. However, the degree of tank filling, x_6, can vary more than x_4 and x_5 and so this degree should be modelled by a random variable X_6.

The characteristics of LG expressed by the components x_7 to x_{10} will depend on the type of LG and chemical composition of LG (Table 1). The variability of x_7 to x_{10} must be determined by tests of LGs shipped by road tanks. If a specific material shipped by a road tank, which may undergo a BLEVE, is known in advance, the LG characteristics x_7 to x_{10} can be assumed to be fixed. However, the temperature of fireball flame, x_{11}, should be modelled as a random variable X_{11}. This temperature is influenced by several random factors and, in addition, is difficult to measure it in experiments [21, 23].

The ambient conditions in the TNO model are expressed by the input variables x_{12} to x_{14} (Table 1). Partial vapour pressure of carbon dioxide in the atmosphere, x_{11}, does not vary much and can be considered non-random and equal to a fixed value given in Table 1 [17]. The ambient temperature at the instant of BLEVE, x_{13}, and the corresponding relative humidity x_{14} are clearly uncertain values and they must be modelled by the respective random variables X_{13} and X_{14}. These variables are not inherent characteristics of the LG transportation process. They can be attributed to the target object because depend on the location of a potential BLEVE accident. However, certain combinations of values of X_{13} and X_{14} can create dangerous traffic conditions, say, impaired visibility due to fog or icy road surface. They may increase the chance of traffic accident, in which the road tank car will be involved, and so the chance of BLEVE. Consequently, the input variables X_{13} and X_{14} can not be completely detached from the transportation aspect of the damage prediction problem.

The uncertainties related to the components of the input vector $\boldsymbol{x}$ call for replacing this vector by a vector with some random components, namely,

$$\boldsymbol{X} = (X_1, X_2, X_3, x_4, x_5, X_6, x_7, x_8, x_9, x_{10}, X_{11}, x_{12}, X_{13}, X_{14}). \tag{4}$$

With the random input vector $\boldsymbol{X}$, the output of the model $\boldsymbol{\psi}(\boldsymbol{X}) = (\psi_1(\boldsymbol{X}), \psi_2(\boldsymbol{X}))$ will be random and can be modelled by two random variables: random thermal radiation $Y_1 = \psi_1(\boldsymbol{X})$ and random fireball duration $Y_2 = \psi_2(\boldsymbol{X})$. The probability distributions of Y_1 and Y_2 can be estimated by applying a simulation-based propagation of uncertainties through the model $\boldsymbol{\psi}(\cdot)$. Values of the random input vector, $\boldsymbol{x}_j$, can be sampled from probability distributions of the random components of $\boldsymbol{X}$ and the corresponding output values y_{1j} and y_{2j} calculated by means of $\boldsymbol{\psi}(\cdot)$. A repetition of this process a large number of times, say, N will yield an estimate of the damage probability $P(D_T \mid B)$, namely,

$$P_e(D_T \mid B) = N^{-1} \sum_{j=1}^{N} P(D_T \mid y_{1j}, y_{2j}), \tag{5}$$

where $P(D_T \mid y_{1j}, y_{2j})$ is a value of the fragility function $P(D_T \mid \boldsymbol{y})$ computed for the pair (y_{1j}, y_{2j}).

6. Example

The potential thermal damage from a road tank BLEVE fireball to the 1st of the four reservoirs shown on Figure 2 will be analysed. The thermal radiation will be estimated at the centre of reservoir roof, where system components sensitive to thermal radiation are installed (point “A”), and at the bottom of the dike area around the reservoirs, were piping and other system components are attached to the reservoir (point “B”) (Fig. 3). Characteristics of the points “A” and “B” are given in Table 3. A BLEVE of a road tank semi-truck carrying 24.7 tons of propane will be considered. The BLEVE can occur on an unsafe road segment $\boldsymbol{\omega}$ with the length of 661.3 m (Fig. 2b). The area between the road and the reservoirs is flat; the road segment $\boldsymbol{\omega}$ has no gradient. The road has four lanes, each 3.75 m wide and a 5,5 m wide median which separates opposing lanes of traffic (Fig. 5). The LG is transported along the road segment $\boldsymbol{\omega}$ with relative frequencies $\pi_1 = 0.35$, $\pi_2 = 0.04$, $\pi_3 = 0.07$ and $\pi_4 = 0.54$ shown on Figure 5a. These frequencies were obtained from an observation of traffic in the road segment $\boldsymbol{\omega}$.

Table 3. Characteristics of two vulnerable points in the reservoir system that can be ignited by a BLEVE fireball

Point	Position in the coordinate system $\{0; x_1, x_2, x_3\}$	Condition of thermal damage		Estimate of damage probability, $P_e(D_T \mid B)$* (see Eq.(5))
		$y_{1,min}$ (kW/m^2)	$y_{2,min}$ (s)	
A	(0 m, 282.3 m, 47.5 m), Fig. 3	25	10	1.021×10^{-3}
B	(0 m, 215 m, –2.17 m) , Fig. 3	30	10	0.1814
* Computed with $N = 1\times10^5$				

The BLEVE accident is described by the vector $\boldsymbol{X}$ defined by Eq. (4). Values of the deterministic components of this vector, x_4, x_5, x_7, x_8, x_9, x_{10} and x_{12}, are given in Table 1. The probability distribution of the longitudinal rest position of the road tank and so the position of a potential BLEVE centre, X_1, was assumed to be uniformly distributed over the length of $\boldsymbol{\omega}$ (Fig. 2b). This distribution expresses maximum uncertainty related to a potential BLEVE centre along the axis $\{0; x_1\}$. The road segment did not experienced tank car accidents in previous years. The probability distribution of the transverse tank position after it comes to a complete stop and can explode, X_2, depends on the lane of intended travel. Our previous analysis of tank car accident data led to the result that the transverse rest position of the tank centre with respect to the centreline of intended travel lane can be modelled by a logistic distribution Logistic(2.02 m, 3.10 m) [13]. The positive location parameter of this distribution, 2.02 m, means that the transverse rest position lays in average 2.02 m outwards the travel lane centreline. The distribution Logistic(2.02 m, 3.10 m) can be associated with each of the four lanes of the road under consideration by adding (subtracting) its location parameter to (from) the coordinate of the lane centreline along the axis $\{0; x_2\}$ (Fig. 6a). This will allow constructing a mixed p.d.f. of X_2, in which the frequencies π_1 to π_4 will play the role of probabilistic weights:

$$\varphi(x_2) = \pi_1 f_1(x_2 \mid -10.4, 3.10) + \pi_2 f_2(x_2 \mid -6.65, 3.10) + \pi_3 f_3(x_2 \mid 6.65, 3.10) + \pi_4 f_4(x_2 \mid 10.4, 3.10), \tag{6}$$

where $\varphi(x_2)$ denotes the mixed p.d.f. of X_2 and $f_l(x_2 \mid \cdot, \cdot)$ ($l = 1, 2, 3, 4$) are the logistic p.d.f.s related to the respective travel lanes. Parameters of the densities $f_l(x_2 \mid \cdot, \cdot)$ in Eq. (6) are in meters. The graph of the bimodal density $\varphi(x_2)$ is shown on Figure 6a.

The probability distributions of the remaining random variables considered in the present example, X_6, X_{11}, X_{13} and X_{14}, were assumed by following the recommendations given by Papazoglou and Aneziris [24] who considered the quantification of uncertainties related to the BLEVE thermal radiation.

Table 4. Probability distributions of the random components of the vector X used to describe a road tank BLEVE accident

Random variable	Mean	Coefficient of variation (standard deviation)	Probability distribution
X_1	335.1* m	0.577 (193.4 m)	Uniform over the length of **ω**
X_2	2.174 m	5.20 (11.31 m)	Mixed distribution
X_6	0.85	0.05 (0.0425)	Normal
X_{11}	2000 °K	0.11 (220 °K)	Lognormal
X_{13}	15 °C	0.20 (3 °C)	Normal
X_{14}	70%	0.1 (7%)	Normal

* In the accident simulation the mean value of X_1 was shifted to the zero value of the axis $\{0; x_1\}$

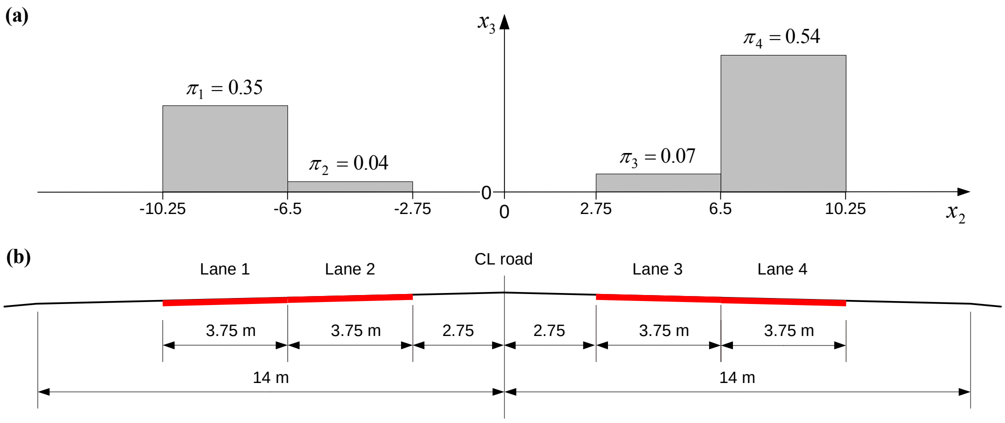


Figure 5. Simulation of the transverse rest position of road tank which can undergo a potential BLEVE: (a) relative frequencies of LG transportation through individual lanes; (b) transverse profile of the road

The values $\boldsymbol{x}_j$ of the random input vector $\boldsymbol{X}$ were sampled by means of a stochastic simulation from the probability distributions given in Table 3. Then the simulated values $\boldsymbol{x}_j$ and the model $\boldsymbol{\psi}(\cdot)$ described in Table 2 were used to compute values of the thermal radiation and fireball duration, y_{1j} and y_{2j}. The simulation was repeated $1{\times}10^5$ times (N = 10 000). Figure 7 shows the scatter diagram of the pairs (x_{1j}, x_{2j}) and (y_{1j}, y_{2j}). With the pairs (y_{1j}, y_{2j}), estimates of the probability of thermal damage, $P_e(D_T|B)$, were computed for points "A" and "B" (Table 3). These estimates indicate that the point "B" is much more vulnerable to thermal radiation than "A" and so thermal insulation (shielding) should be provided in order to protect this part of the reservoir system against BLEVE.

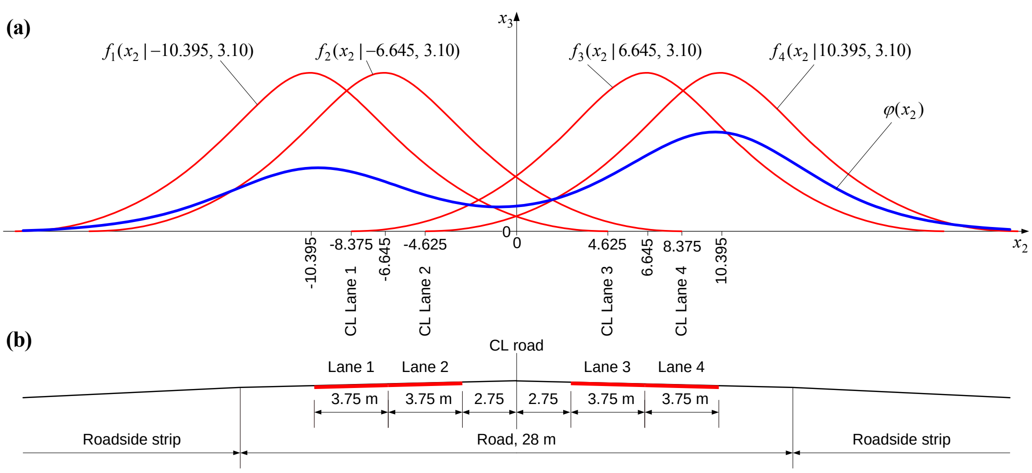


Figure 6. Probabilistic model of the transverse rest position of the tank: (a) densities of the transverse departure from the centrelines of individual lanes and a mixture of these densities, $\varphi(x_2)$; (b) road profile and adjacent roadside territory

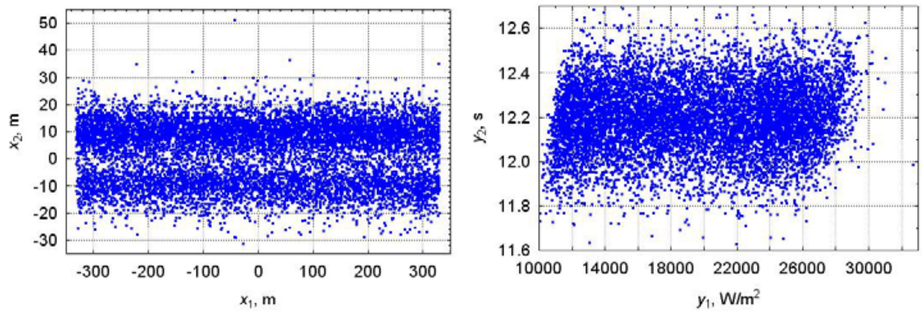


Figure 7. Results of the simulation of a BLEVE thermal radiation at point "B" shown on Figure 3: (a) simulated positions of the road tank, (x_{1j}, x_{2j}); (b) simulated pairs of the thermal radiation and fireball duration, (y_{1j}, y_{2j})

7. Conclusions

An assessment of the risk to roadside property from a boiling-liquid expanding-vapour explosion (BLEVE) of a road tank carrying liquefied gas (LG) has been considered. The attention was focussed on the thermal damage from a radiation generated by a BLEVE fireball. Such damage is usually understood as an ignition of a roadside object. The risk assessment requires estimating the conditional probability of thermal damage to the roadside object under analysis given a BLEVE. The estimate of this probability can be used for assessing the annual frequency of thermal damage. This frequency is a key element in the expression of risk posed to a specific roadside object by LG transportation through an adjacent public (off-site) or on-site road.

The estimation of the thermal damage probability can be a highly case-specific task and has transportation-related aspect and structural aspect. The thermal impact of BLEVE on the roadside object will depend on a generally random position of the vehicle at the instant of explosion. Characteristics of vehicle and properties of LG shipped by it will also influence the thermal impact. In the risk assessment, some of these vehicle and cargo characteristics must be treated as random quantities. Uncertainty related to them can be transformed into uncertainty in characteristics of thermal impact: thermal radiation (heat flux) impinging the roadside object and duration of this radiation. Such uncertainty propagation can be carried out by applying deterministic models describing BLEVE fireballs and stochastic simulation.

The structural aspect of the assessment of risk posed by a road tank BLEVE will consist in developing a fragility function for a potential target. The demand variables in this function must be intensity and duration of thermal radiation. The fragility function itself must quantify the probability of ignition of a roadside object. Literature on ignition of structural materials and materials stored (processed) in structures yields only deterministic and often approximate ignition criteria. They can be used to construct simple fragility functions. However, a fully probabilistic development of such functions remains an unsolved problem of fire and structural engineering.

Results obtained in this study can be applied to a general transportation risk assessment. However, these results can be also useful for specifying separation distances between road and roadside objects and design of shielding for these objects as a compensation for less than desired separation distances.

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DOES THE THEME OF A ROAD SAFETY COMMUNICATION CAMPAIGN AFFECT ITS SUCCESS?

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Road safety communication campaigns are considered as an efficient strategy to approach the wide audience and influence road users towards a safe behavior, with main aim to lead to the reduction of the number and the severity of road accidents. When designing the implementation of a campaign, it is important to plan at the same time its evaluation, so that to enable the assessment of its effectiveness. For the achievement of high reliability and the development of “clear” conclusions, the campaign evaluation should be carefully organized, following a feasible scientific design.

Towards this direction, three road safety campaigns, two local campaigns addressing drink driving and seat belt usage, and one national campaign addressing driving fatigue, were implemented and evaluated. Presenting the design components of the three campaigns and the evaluation results, this paper aims at revealing the similarities and differences of the effectiveness of road safety communication campaigns on driving behavior.

Keywords: road safety communication campaigns, fatigue, drink-driving, seat belt usage, measurement variables, experimental design

Introduction

Transportation is closely associated to the everyday activities occurring in a community, including work, education, social businesses, leisure, etc. Though, as travelling of people occurs on the transportation infrastructure with the use of the provided transportation modes, risks arise, owing to failures, damages, errors, accidents or any other incidents which could be considered intended or unintended events.

Road safety concerns the vehicle, the infrastructure, the user and the environment, and assures elimination of danger for road users and the surroundings, i.e. property and environment. The ultimate aim for communities should be the absence of any risks, accidents, fatalities and injuries during transportation. This is rather an optimistic scenario for the current situation of the European transport, since many safety issues still need to be addressed. Towards this direction, road safety has a significant role in the strategic plans of the European Commission (EC), i.e. the White Paper of 2001 [1], which adopted the ambitious target to reduce the number of persons killed on the roads by 50% by the year 2010. Among other measures, the White Paper [1] supported the realization of pan-European road safety campaigns, and in addition, the development of powerful and innovative tools for the evaluation of campaigns, in order to be able to improve the next ones.

Road safety campaigns, and, more specifically, road safety communication campaigns, are considered as an efficient strategy to approach the wide audience, aiming at the reduction of the number and severity of road crashes, by influencing road users’ behaviour [2, 3]. Two main types of road safety communication campaigns are identified, thus, *public communication campaigns*, which inform the public about new or modified laws, improve knowledge, raise awareness of risk and influence behaviour, and *combined campaigns and integrated programs* that refer to communication campaigns implemented with other activities, i.e. education, enforcement, etc., and cooperation among several organizations for the improvement of road safety, respectively [3].

A large number of road safety campaigns has been implemented in recent years, but still a low proportion of them has been formally evaluated [4, 5, 6]. This lack of studies assessing the impact of road safety campaigns refutes the importance of evaluation and the need of documenting, assessing and disseminating the campaigns’ results, which may contribute to more efficient design, implementation and evaluation of future campaigns [2].

In literature, several approaches or methods of evaluating road safety campaigns are indicated, with the majority of them being developed according to the timing of implementation, i.e. before the campaign starts, during the campaign implementation and after its completion, respectively [7, 8]. In Boulanger et al. [9], four main categories of evaluation, which apply in road safety communication campaigns, are defined, i.e. *formative evaluation*, *summative evaluation*, *economic evaluation* and *meta-analysis*. Formative evaluation is used for the assessment of the strengths and weaknesses of a campaign before it really starts [10], and an indicative type of this category is *process evaluation,* which investigates, for example, whether the resources have been allocated and the activities have been implemented as planned [9]. Summative evaluation, on the other hand, measures the effectiveness of an intervention on the target group, and estimates the degree of the impact of an implemented initiative [7] and the level of reaching the stated goals [11]. Cost-effectiveness analysis and cost-benefit analysis are the two most commonly used methods in economic evaluation [12]. Regarding meta-analysis, the specific type has been used for the assessment of the effects of road safety campaigns on accidents [13, 14, 15, 16].

The impact of road safety communication campaigns on driving behaviour has also been approached in several studies, i.e. in the *"Literature review on best practice with mass media"* [17], in which the significant impact of road safety campaigns on the improvement of road safety was observed, or in the *"A theoretical approach to assess road safety campaigns – Evidence from seven European countries"* [18], which presented the results of the evaluation of seven campaigns showing that the adoption of a well-structured model when selecting and assessing parameters, like attitudes, intentions, etc., works in the positive direction when predicting driving behaviour.

Taking into consideration the significant need for evaluating road safety campaigns [2, 9], three road safety campaigns, two local road safety communication campaigns addressing drink driving and seat belt usage, and one national campaign addressing driving fatigue have been designed, implemented and evaluated. Each of the campaigns differ in the road safety problem addressed, thus the theme of the campaign, the context, the target groups, the means and the scope, however they all follow a common theoretical model, i.e. the extended or modified version of the Theory of Planned Behaviour [19].

Presenting the design components of the three campaigns, as well as the evaluation results, the present paper aims at revealing the similarities and differences in the effectiveness of road safety communication campaigns on driving behaviour.

Methodological Approach

Theoretical background

Although there is strong evidence in the literature that the use of a theoretical background works effectively when designing and evaluating a road safety campaign [3, 6, 13, 18, 20], yet few road safety communication campaigns are designed, based on theoretical behavioural models [21]. Examples of studies on road safety campaigns that were approached through theoretical models is the "Foolspeed" anti-speeding campaign [22], which was based on the Theory of Planned Behaviour [19], and the study of Simsekoglu & Lajunen (2008) [23] who explained self-reported seat belt use among front seat passengers comparing the Theory of Planned Behaviour [19] and the Health Belief Model [24]. In addition, in the seven campaigns evaluated in the "A Theoretical approach to assess road safety campaigns" [18], a theoretical basis was used, i.e. the Theory of Planned Behaviour [19] and the Transtheoretical Model [25].

Following the above recommended by literature concept of using theoretical models, the problem behaviour, the definition of the objectives and the measurement variables [5] of the evaluation, in the three campaigns of the present study, were addressed through the Theory of Planned Behaviour (TPB), which argues that the personal decisions to perform a behaviour (intentions) are based on attitudes toward the behaviour, subjective norms, and perceived behavioural control, taking into consideration, social norms [19]. TPB was selected as the theoretical model for the specific analysis, since it associates road user behaviour with attitude and intention, addressing, in parallel, the impact of social norms when predicting behaviour. The principle of the specific model is that person's behaviour is determined by his/her intention, which, in turn, is defined by person's attitude, subjective norms and perceived behavioural control. At the same time, knowledge on these attributes may predict intention and therefore behaviour [19].

Implementation of the campaigns

In the framework of the European research project CAST (Campaigns and Awareness raising Strategies in Traffic Safety) (http://www.cast-eu.org/), the Transportation Engineering Laboratory of the University of Thessaly, Greece, designed, implemented and evaluated three road safety communication campaigns, two local campaigns addressing drink driving and seat belt usage, and one national campaign addressing driving fatigue.

The ***local campaigns*** were launched on April 14th 2008 and lasted for four weeks. The scope of the campaigns was local; thus, the campus of the University of Thessaly was the test bed of the campaigns, and the target group composed of young students (between 18 and 30 years old), both drivers and passengers. The campaigns aimed at increasing the awareness proportion on the permissible alcohol level while driving or the obligation to wear seat belt both as a driver and passenger, increasing the awareness on the potential risks when drinking or not wearing seat belt when driving, investigating the measures that could influence road users to have a safer behaviour on the road, and decreasing the number of drivers that drink and drive or do not use their seat belts, respectively. The implementation of the campaigns included the distribution of 500 brochures and 50 posters, and the organizing of an open workshop, regarding the improvement of road safety (avoidance of drink and drive and seat belt usage), that took place during the same period.

The ***national*** fatigue campaign ran in two time periods, the first one starting on the 15th of December 2008 and ending on the 31st of January 2009, lasting for six weeks, and the second one, starting on the 6th of April 2009 and lasting for two weeks, thus, till the 20th of April 2009. Professional drivers were chosen as the primary target group of the specific campaign, and non-professional drivers, as the secondary target group, respectively. Among the objectives of the campaign were the increase in the percentage of drivers who are aware of the severity of the circumstances of driving tired, the increase of the number of drivers who believe that taking a short break is the most effective solution when tired and a relative decrease in the number of drivers who believe that other countermeasures (i.e. drinking a coffee or opening the window) are also effective solutions when driving tired, etc. The implementation of the campaign included the production of a television and radio spot, insertions in national newspapers, the distribution of leaflets, the display of posters and an on-line campaign, hosted by the website of the Transportation Engineering Laboratory of the University of Thessaly.

Data Collection and Analysis

Evaluation design

For the achievement of high reliability, the design of the evaluation of a campaign should be based on a scientific design, i.e. non-experimental, quasi-experimental, experimental or single-case experimental, while the development of "clear" conclusions requires that the campaign is evaluated with at least two measurements, one of which should occur before the campaign implementation [9]. The scope of the campaigns determined the evaluation design, thus, the evaluation of the local campaigns was based on experimental and quasi-experimental designs, since it was feasible to use both intervention and control groups, something that was "prohibitive" in the national campaign due to its implementation over a wider audience. For this reason, in the case of the national campaign, non-experimental design was used.

For the data collection, face-to-face questionnaire surveys were conducted, before and after the implementation of the campaigns. The surveys for the local campaigns were conducted for the "before" phase in March 2008 and lasted for two weeks, and for the "after" phase in June 2008 and lasted, also, for two weeks. Regarding the national campaign, the first survey took place in November 2008 and lasted for two weeks, and the second one in June 2009 and lasted, also, for two weeks, in order to collect data before and after the campaign implementation, respectively. Assuming a confidence interval of 0.1 and a confidence level of 95%, the minimum sample for the local campaigns was defined to 400, based on a population of 1587 persons, and was separated to 200 for the before measurements and 200 for the after measurements. The interviewees were 193 drivers and 207 passengers in the drink driving campaign, and 209 drivers and 191 passengers in the seat belt campaign. The 77.8% of the drivers and the 37.7% of passengers were male. The average age of the sample was 21.65 years old, and more specifically, in the driver group the average age and standard deviation (SD) of the sample was 22.69 (SD 2.33) and 22.38 (SD 2.05) years for the control and intervention groups, respectively. Passenger age average was 22.19 (SD 2.21) and 20.95 (SD 184) years old for the control and intervention groups, respectively. In the case of the national campaign, the sample was separated into two groups, thus, non-professional drivers and professional drivers. The characteristics of the sample are as follows: the sample of the before phase consisted of 1000 non-professional drivers with age 38.74 ± 12.36 years (mean ± SD) and 1000 professional drivers with age 41.27 ± 9.52 years (mean ± SD), and the after measurements included 799 non-professional drivers with age 39.4 ± 11.9 years (mean ± SD) and 700 professional drivers with age 41.5 ± 10.04 (mean ± SD).

Both process and outcome evaluations were conducted for the three campaigns [9]. Focusing on the process evaluation, relative variables were addressed, like the types of the activities carried out, the number, frequency and duration of the messages distributed, etc., in order to measure the objective exposure, as well as the subjective exposure through the reach, recognition, recall and appreciation of the campaigns. For the outcome evaluation, respective variables addressed were knowledge, behavioral beliefs, behavioral intentions, behavior, etc. The structure of the questionnaires included the appropriate questions in order to measure the above variables, and other background/demographic questions (age, frequency of driving, etc.). The core part of the questionnaire was answered using a 7-point scale [26], ranging from 1 (Totally disagree/very unlikely/not at all/never) to 7 (Totally agree/very likely/a lot/always), depending on the topic addressed. The subjective exposure of the process evaluation was investigated through questions, such as "Did you remember to have seen or heard a drink driving/seat belt/fatigue campaign in the last couple of weeks?" for the variable reach or "Did you generally like the campaign?" for appreciation. In the outcome evaluation, examples of questions and statements for the variable knowledge were "Do you know that the most effective solution to fatigue is to stop and rest or take a 15 minute powernap?", for the behavioral beliefs "How much in favor are you of drinking while having drunk?" or "To drink a coffee will reduce or avoid fatigue while driving", for the behavioral intentions "I plan to drive after having drunk a drink in the next month" or I intend to stop and rest when tired in the next month" and for behavior "When I get tired while driving, I stop and rest".

Data analysis

The data analysis was based on both descriptive and inferential statistics [27]. In the first case, parameters like the sample size and population, age and gender, percentage of participants being involved in an accident, etc, were analysed, by estimating the frequency distribution per gender and age, as well as the mean values and standard deviations.

In the second case, when analysing the data with inferential statistics, Chi-square (X^2) test for homogeneity was used to test differences in characteristics measured by categorical variables (i.e. "yes", "no"), while Mann-Whitney two-sample U-testing was performed to assess differences between samples in characteristics measured on the 7-point scale [28].

Cross-Campaign Impact Assessment

In this section, the evaluation results for each of the three campaigns are presented, assessing the degree of each circumstance addressed in the questionnaire, as regards the tested variables, i.e. knowledge, behavioural beliefs, etc. In addition, a cross-campaign analysis is conducted, so as to unveil similarities and differences in the above variables, as a result of the specific design and implementation aspects of the three campaigns, such as theme, scope, etc.

For the purposes of the present paper and the cohesion of the results that are presented, the following assumptions are taken into consideration:

- The variables that were common in the three campaigns are discussed, thus, knowledge, behavioural beliefs, behavioural intentions and behaviour.
- Regarding target groups, in the national campaign, the total sample (both professional and non-professional drivers) is used, while in the local campaigns, only the intervention group of drivers (and not passengers) is considered. The intervention group refers to the sample that was exposed to the materials of the campaign and stated in the "after" phase of the questionnaire survey that they had seen or heard about the campaign. For the drink-driving campaign, the number of these drivers was 35 before and 18 after the campaign and for the seat-belt campaign 39 before and 36 after the campaign implementation.

The proportion of positive responses, applied to knowledge, the median ratings of their perceived seriousness on the 7-point scale, applied to the ordinal variables during the two phases, before (B) and after (A), as well as the p-values that indicate the strength of the respective evidence and the direction of the relationship that is identified as statistically significant (r_{phase} stands for the median rating in that phase, and p_{phase} signifies the proportion of positive responses in that phase), are presented in tables 1, 2 and 3, for the drink-driving, the seat belt and the fatigue campaign, respectively. It has to be mentioned that in the case of the seat belt campaign, when testing knowledge, the percentage of the respondents who knew that the usage of seat belt is compulsory by drivers and passengers was 100% both before and after the campaign, and for this reason the specific categorical variable, thus, knowledge, is not presented in table 2.

Table 1: Proportion of positive responses, median rating and summary of the before-after comparison – Drink driving campaign

Categorical Variables	Proportion of positive responses		p-value	Test parameters relation
	B	A	B vs A	
Knowledge:				
About the upper permissible limit of alcohol while driving	57.14%	44.44%	0.380 *	p_B=p_A
That the permissible limit is equivalent to a glass of alcohol	71.43%	83.33%	0.340 *	p_B=p_A
Ordinal Variables	**Median rating**			
	B	**A**		
Behavioural beliefs:				
Do you agree with the upper limit of alcohol at 0.25 mgr/l?	4.49	4.83	0.578 *	$r_B = r_A$
What is the likeliness of driving after having one drink?	3.80	4.89	0.111 *	$r_B = r_A$
Even if I have drunk, I can still drive safely	4.29	4.28	0.990 *	$r_B = r_A$
To drink and drive will increase the likelihood of being involved in an accident	5.63	6.39	0.157 *	$r_B = r_A$
To drink and drive will increase the likelihood of being fined	6.03	6.39	0.395 *	$r_B = r_A$
Behavioural intentions:				
I plan to drive after having drunk one drink in the next month	2.89	3.28	0.542 *	$r_B = r_A$
Behavior:				
Frequency of drinking and driving in an urban area	3.34	3.89	0.419 *	$r_B = r_A$
Frequency of drinking and driving in motorway	5.43	5.56	0.834 *	$r_B = r_A$
Frequency of drinking and driving in familiar route	3.14	3.78	0.349 *	$r_B = r_A$
Frequency of drinking and driving in unknown route	5.00	5.00	1.000 *	$r_B = r_A$
Frequency of drinking and driving in near route	2.94	3.44	0.448 *	$r_B = r_A$
Frequency of drinking and driving in long route	4.9	5.1	0.777 *	$r_B = r_A$

Note: B: before; A: after ; *p*: proportion of positive responses; *r*: median rating; * not statistically significant (p-value>0.1)

Table 2: Median rating and summary of the before-after comparison – Seat belt campaign

Ordinal Variables	Average rating		p-value	Test parameters relation
	B	A	B vs A	
Behavioural beliefs:				
Do you agree with the seat belt use by the driver?	6.64	6.89	0.210*	$r_B = r_A$
Do you agree with the seat belt use by the front passenger?	6.62	6.83	0.286*	$r_B = r_A$
Do you agree with the seat belt use by the back passenger?	4.51	5.63	0.060	$r_B < r_A$
How much do you believe the following statement is valid: Without my seatbelt I feel unsafe, as if something is missing	5.41	5.42	0.990*	$r_B = r_A$
How much do you believe the following statement is valid: Fastening seatbelts is really only useful when travelling a long distance	5.46	5.53	0.891*	$r_B = r_A$
How much do you believe the following statement is valid: If a speeding accident occurs, seatbelts won't make a difference	5.64	5.67	0.952*	$r_B = r_A$
How much do you believe the following statement is valid: I sometimes use my seatbelt when asked by a relative or friend	4.72	5.00	0.500*	$r_B = r_A$
How much do you believe the following statement is valid: If you drive carefully, you don't really need seatbelts	6.28	6.38	0.745*	$r_B = r_A$
Behavioural intentions:				
How often do you intend to wear your seat belt in the following month?	5.97	6.47	0.139*	$r_B = r_A$
Behaviour:				
Frequency of wearing seat belt in an urban area	5.59	6.25	0.139*	$r_B = r_A$
Frequency of wearing seat belt in motorway	6.97	6.86	0.125*	$r_B = r_A$
Frequency of wearing seat belt in familiar route	5.51	6.39	0.055	$r_B < r_A$
Frequency of wearing seat belt in unknown route	6.10	6.50	0.283*	$r_B = r_A$
Frequency of wearing seat belt in near route	4.97	6.08	0.025	$r_B < r_A$
Frequency of wearing seat belt in long route	6.74	6.69	0.819*	$r_B = r_A$

Note: B: before; A: after; *p*: proportion of positive responses; *r*: rating median; * not statistically significant (p – value > 0.1)

Table 3. Proportion of positive responses, average rating and summary of the comparisons between the phases of the campaign – Fatigue campaign

Categorical Variables	**Proportion of positive responses**		**p-value**	**Test parameters relation**
	B	**A**	**B vs A**	
Knowledge for:				
Fatigue causes	95.9%	98.8%	<0.001	$p_A > p_B$
Fatigue effects	95.2%	97.7%	<0.001	$p_A > p_B$
Most effective countermeasure	88.1%	95.3%	<0.001	$p_A > p_B$
Fatigue & involvement in accidents	98.3%	99.8%	<0.001	$p_A > p_B$
Ordinal Variables	**Median rating**			
	B	**A**		
Behavioural beliefs: "A good solution to fatigue is to..."				
Drink a coffee	4.26	3.94	<0.001	$r_B > r_A$
Talk to passengers	4.54	4.57	0.65*	$r_B = r_A$
Open the window for fresh air	5.71	5.47	<0.001	$r_B > r_A$
Listen to music	4.43	4.32	0.108*	$r_B = r_A$
Stop and rest for 15 minutes	6.49	6.76	<0.001	$r_B < r_A$
Plan your trip	6.24	6.45	<0.001	$r_B < r_A$
Behavioural intentions: "When tired in the next month, I intend to..."				
Stop and rest for 15 minutes	5.94	6.35	<0.001	$r_B < r_A$
Plan my trip	5.61	5.92	<0.001	$r_B < r_A$
Follow other countermeasures	4.97	4.03	<0.001	$r_B > r_A$
Drive anyway	3.50	2.90	<0.001	$r_B > r_A$
Behavior: "When I get tired..."				
I stop and rest for 15 minutes	5.59	6.11	<0.001	$r_B < r_A$
I drink a coffee	4.68	4.73	0.432 *	$r_B = r_A$
I listen to music	4.81	5.02	0.001	$r_B < r_A$
I talk to passengers	4.65	4.93	<0.001	$r_B < r_A$
I open the window	5.93	5.85	0.017	$r_B < r_A$
I do not drive at all	5.26	5.70	<0.001	$r_B < r_A$

Note: B: before; A: after ; *p*: proportion of positive responses; *r*: rating median; * not statistically significant (p-value>0.1)

The results for each variable tested are discussed in the following paragraphs.

Knowledge

In the case of the drink-driving campaign, an increase of the proportion of the respondents who were aware that the upper permissible limit of alcohol is equivalent to a glass of alcohol was indicated after the campaign implementation (83.33%) compared to the "before" phase (71.43%), but this increase was not statistically significant.

On the other hand, the results of the seat belt campaign when testing knowledge did not show any differences, since both before and after the specific campaign, the percentage of the respondents who knew that the usage of seat belt by drivers and passengers is compulsory, was 100%.

In the case of the national campaign, results showed an increase of the proportion of the respondents who were aware of the causes of fatigue, before (95.9%) and after (98.8%) the campaign. Similar results were indicated, when testing the proportion of the respondents who were aware of the effects of fatigue while driving, and the relative rates, were 95.2% in the before phase, and 97.7% in the after phase. Also, the percentage of the respondents who were aware of the most effective countermeasure for fatigue while driving, thus, "to stop and rest", was increased after the campaign (95.3%) compared to the before phase (88.1%), addressing the positive impact of the specific campaign, which urged drivers to stop and rest when fatigued. The last variable regarding knowledge, thus, that fatigue raises the likelihood of being involved in an accident, was also increased, and the relative proportions for the before and after phase, were 98.3% and 99.8% , respectively. Lastly, statistically significant differences were observed between the before and after the campaign implementation in the proportion of drivers that were aware of the causes and effects of fatigue, of the most effective countermeasure ("to stop and rest") and that when driving fatigued they may get involved in a crash.

Behavioural beliefs

The assessment of changes in behavioral beliefs in the drink driving campaign was tested through five variables, in which, although the median rating of the responses was increased due to the campaign implementation, this increase was not statistically significant.

The eight variables addressing behavioral beliefs in the seat belt campaign showed, once again, an increase in the median rating of the responses in the after phase compared to the before phase, but, these differences were not statistically significant, except of the agreement of the respondents that the back passengers should also wear seat belts.

In the fatigue campaign, the positive impact of the campaign was observed, when testing behavioral beliefs, and, more specifically, the median rating follows "positive" direction of change, thus, the adoption of effective countermeasures for fatigue, such as trip planning (or the postponement of trip) and powernap, while, other countermeasures that are falsely used, such as coffee drinking, listening to music, etc., seem to be preferred less by drivers, after the campaign. Most of these changes were statistically significant.

Behavioural intentions

When testing behavioral intentions, in both local campaigns, the estimation of the variable which was used, did not show any statistically significant difference in the responses of the subjects.

On the other hand, in the national campaign, statistically significant differences were observed in all four relative variables, and, in fact, an effective impact of the campaign was indicated by the increase in the rates regarding the effective fatigue countermeasures, and the simultaneous decrease in the ineffective countermeasures between the before and after phases.

Behaviour

The last parameter tested was behavior, and results showed that, in the case of drink driving campaign, although an increase was observed in the proportion of respondents who stated that they do not drink and drive in several routes (urban area, motorway, familiar route, unknown route, near route, long route), statistically significant differences were not indicated.

Similarly, in the seat belt campaign, an increase was defined, after the campaign, in the respondents, who stated that they use their seat belt in the above mentioned routes, but statistically significant differences were indicated only in the cases of near route and familiar routes.

Finally, in the case of the fatigue campaign, although drivers preference for the proposed countermeasures (i.e. "to stop and rest") increases, at the same time, their preference for the ineffective countermeasures (to drink coffee, listen to music, open the window, or talk to passengers) also increases, indicating that they comprehend the risk associated to driving under fatigue, but they are not convinced that the proposed countermeasure is more effective than the other.

Conclusions

The present paper reports the findings of the cross-campaign analysis conducted in order to investigate the impact of three road safety communication campaigns on driving behavior and assess whether the campaign components, e.g. the theme, affect their success. The evaluation design of the campaigns formulated was based on the Theory of Planned Behavior [19], and respective variables were tested, such as knowledge, behavioral beliefs, behavioral intentions and behavior.

Results showed that the local campaigns had some, but not significant impact on drivers participating in the questionnaire surveys conducted before and after the implementation of the campaign. This outcome may be explained, for example, by the fact that, although statistics indicate a higher concentration of drunk driving in the local areas, drivers self-reported that do not consider themselves as part of the problematic group, before, as well as, after the drink-driving campaign. In the case of the seat belt campaign, the rates of the respondents in the majority of the questions were high in the positive direction, already before the campaign implementation. Also, in both local campaigns, it may be considered that, the resources limitations deprived some parallel actions or activities, such as brochure distribution and volunteers informing people at alcohol consumption locations, which would have probably worked more effectively for young road users. On the other hand, the national fatigue campaign had a significant impact on drivers, something that was observed in the majority of the variables tested. Parameters such as the wider dissemination through several means, the higher budget and the involvement of stakeholders, can be considered as crucial for the success of the fatigue campaign, compared to the local ones. Also, the specific national campaign was the first road safety communication campaign addressing driving fatigue in Greece, and the interest was high, both from the side of road users, but also, from the side of public authorities, institutions, etc.

In the light of the findings of the present study, it can be concluded that road safety communication campaigns, when designed and implemented properly, can increase the awareness of drivers on critical issues, such as drink driving, seat belt usage and driving fatigue. In addition, both in the local campaigns and the national one, it was indicated that their implementation affected significantly behavioral beliefs and behavioral intentions, while, in the case of behavior, results showed that, although the differences in the responses of drivers before and after the implementation of the campaigns were not significant, though, they were in the positive direction in each safety issue addressed, i.e. not to drink and drive, to wear a seat belt and not to drive when fatigued.

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CALCULATION OF OPTIMAL PATH FOR PARALLEL CAR PARKING

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The problem of calculation of optimal path for reverse parallel parking is examined. Elementary mathematical model of car movement on plane is described. Optimality criterion and restriction on a possible path for parallel parking are formulated. It is offered a way of choice of a quasi-optimal path for reverse parallel parking. Corresponding numerical calculations and graphic example are presented.

Keywords: parking a car, mathematical model, system of differential equations, Cauchy problem, conditional optimisation

1. Introduction

Lately many key manufacturers of cars pay much attention to work out the subsystems that can help a driver in driving, both at road movement and parking. Such companies as Volkswagen, Toyota, Citroen, BMW, Mercedes, Fords, have even provided automatic parking subsystems that is car parking without participation of a person (hands free). However such subsystems have still cost quite expensive and the parking process itself takes a lot of time because the system constantly scans surrounding territory to except collisions. Wherefore, it is possible to work out the subsystems which do not replace the person completely but only prompt an optimal path, displaying it on the screen of any device (for example, GPS). Such parking subsystems should be much cheaper than automatic ones because the main work is made by a driver. Besides, widespread introduction of such subsystems would also promote economy of fuel, and so less environmental contamination by exhaust gases because they allow to cut time of car parking.

It is natural that you need a mathematical model of the car movement to create subsystems of car control. Recently many researchers have been engaged in the development and improvement of such a model [1–7]. Meanwhile, computer simulators and robots that realize mathematical models of car movement control in various operating conditions are developed [4–7]. One of the research directions is a logical design of parallel parking [6, 7].

2. Modelling and Research of Parallel Parking Process

2.1. Elementary mathematical model of car movement

Position of a standard car on plane is definitely determined by its sizes (length and width) and coordinates (x, y, θ), where (x, y) are coordinates of point M on the plane xOy, θ is a corner between a car longitudinal axle and axis Ox (Figure 1).

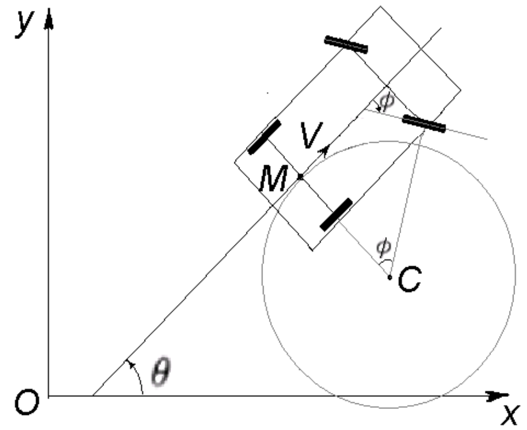

Figure 1. Model of car movement on plane

The repositioning of a car depends on its speed V and steering angle of front wheels relative to the longitudinal axle of a car ϕ. In this case the turning radius R for the point M is $W\,\mathrm{Ctg}\phi + \frac{w}{2}$, where W is a distance between front axle and back axle (wheel base), w is a distance between car wheels on the back axle (rear track).

As the rate of angle θ change is equal-in-magnitude to the angular rate of the point M and it is opposite to it in direction, that is $\frac{\partial\theta}{\partial t} = -\frac{V}{R}$, the car movement process on plane in the most elementary case can be described with the following differential equation system:

$$\begin{aligned} \frac{\partial x}{\partial t} &= V\cos\theta, \\ \frac{\partial y}{\partial t} &= V\sin\theta, \\ \frac{\partial\theta}{\partial t} &= -\frac{V}{W\,\mathrm{Ctg}\phi + \frac{w}{2}}. \end{aligned} \tag{1}$$

The examined model of car movement on plane (1) slightly differs from the kinematics model offered in the work of P. Mellodge [1]. The basic difference is that in the model (1) we use the distance between car wheels on back axle w, which isn't considered in the model of P. Mellodge.

2.2. Statement of problem of optimal parallel car parking

Now we will examine the problem of parallel parking in case of right driving (Figure 2).

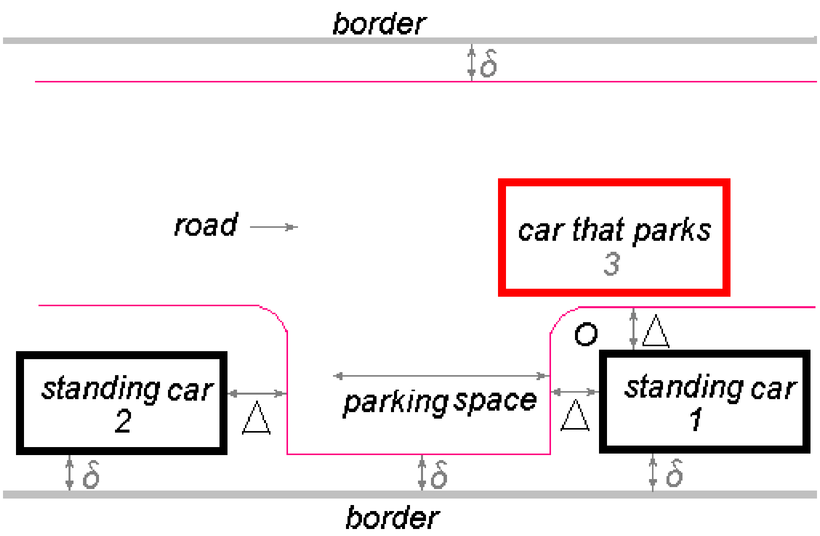

Figure 2. Parallel car parking

It is necessary to park a car in a parking space without approaching to the standing cars and right border nearer than at a distance of Δ and δ, correspondingly, and without going outside the left border. The area which is not allowed to leave is limited on the Figure 2 with lines of lilac colour.

We will understand as optimal parking such a parking when the length of car 3 passing in a parking space, concerning the standing car 1, is minimum. Here it is supposed that the parking car backs up, because (as is known from practical experience) it is more optimal than passing forward. In such formulation of parking optimality it is also determined the minimum possible distance between standing cars 1 and 2 that supposes possibility of car 3 parking.

In the statement formulated above the problem of optimal parking is a problem of optimal control [8], where the control actions are car speed $V = V(t)$ and steering angle of front wheels relative to the car longitudinal axle $\phi = \phi(t)$ For mathematical notation of optimal parking problem we will examine t he coordinate system xOy, oriented in such a way that the reference point O is in back corner point of the standing car 1, and the axle Ox is parallel to the road (Figure 2). At that we introduce the following signs:

$$z(t) = \begin{pmatrix} x(t) \\ y(t) \\ \theta(t) \end{pmatrix},\ u(t) = \begin{pmatrix} V(t) \\ \phi(t) \end{pmatrix},\ F(z(t), u(t), t) = \begin{pmatrix} u_1(t)\cos(t) \\ u_1(t)\sin(t) \\ -\dfrac{u_1(t)}{W\,Ctg(u_2(t)) + \dfrac{w}{2}} \end{pmatrix}.$$

Then the system (1) will be written in such a way:

$$\frac{\partial z(t)}{\partial t} = F(z(t), u(t), t). \tag{2}$$

The objective function for the formulated problem of optimal parking is:

$$-z_1(T) \to \min, \tag{3}$$

where T is a moment of control time when the car 3stands on the parking space (Figure 2). Then $t \in [0, T]$ and $t = 0$ stands for the point of time when the car 3 starts to back upstanding next to the car 1.

It is necessary to notice that in the problem (2)–(3) the limits of motion path which secure parking (you cannot leave the admissible area (Figure 2)) should be observed.

2.3. How to choose a quasi-optimal path for parallel car parking

Considering the position and motion of the car in abounded space in whole depends on its physical sizes and technical features, for the further consideration of the problem of parking path calculation it is necessary to introduce the following parameters (in addition to the above introduced ones): L is a car length (m), B is a car width (m), ϕ_{max} is a maximum steering angle of front wheels (radian), b is a distance from the point M to the edge of back bumper (m). Also, with Bs we mark the width of standing car 1, and with S we mark the road width.

In case of reverse parallel parking the *S*–shaped motion path of the point M is obvious. To provide it the analogous conduct must be in case of change of angle ϕ, therefore we will consider a variant of path calculation when the change of angle ϕ is described with the function

$$\phi_1(t) = \frac{\phi_{max}}{\frac{\pi}{2}} \operatorname{arctg}(a_1 t + a_0), \tag{4}$$

where a_0, a_1 are function parameters $\phi_1(t)$ .In such a variant of calculation the angle ϕ is near to ϕ_{max} at the initial time, and it is near to the angle $-\phi_{max}$ at the end time. Here it is also supposed that the parking car is parallel to the standing car 1 at the initial time that is $z_3(0) = \theta(0) = 0$.

When choosing the optimal parking path the initial position of the parking car is important, that is the distance from the standing car 1 (we mark it a_3) and the value of its passing ahead concerning the car 1. Therefore with a_2 we mark *x*-coordinate of the point *M* at the initial time. There by the initial situation in the Cauchy problem for the system (2) is the following:

$$z(0) = \begin{pmatrix} a_2 \\ a_3 + \dfrac{B}{2} \\ 0 \end{pmatrix}. \tag{5}$$

The final time T of the Cauchy problem solution is determined with the position when the car is in the parking space parallel to the border that is when $z_3(T) = \theta(T) = 0$.

The speed of the car V at normal (that is non-extreme) parking should not be high and there fore its change cannot be decisive at short time, and so we will consider it constant and mark with a_4.

Considering the suppositions above the choice of optimal path in parallel parking comes to the determination of parameters a_0, a_1 of the function $\phi_1(t)$, parameters of the initial car position a_2, a_3 and car speed a_4, that provide condition (2), criterion optimality (3) and satisfaction of limits for safe motion path. The latter limits we can write as following:

$$z_1(T) + (L - b) \le -\Delta, \tag{6}$$

$$\min_{t\in[0,T]}\left\{\sqrt{(z_1(t)+(L-b)\cos(z_3(t))+\frac{B}{2}\sin(z_3(t)))^2+(z_2(t)+(L-b)\sin(z_3(t))-\frac{B}{2}\cos(z_3(t)))^2}\right\}\ge\Delta, \tag{7}$$

$$\min_{t\in[0,T]}\left\{z_2(t)+(-b)\sin(z_3(t))+\frac{B}{2}\cos(z_3(t))\right\}\ge -Bs, \tag{8}$$

$$\max_{t\in[0,T]}\left\{z_2(t)+(L-b)\sin(z_3(t))+\frac{B}{2}\cos(z_3(t))\right\}\le S-Bs-\delta. \tag{9}$$

The limit (6) provides that after parking termination the front bumper of the parking car will be at a distance not less than Δ from the standing car 1. The limit (7) provides that in the parking process the right front wing of the parking car will not approach at a distance less than Δ to the left back wing of the standing car 1. The limit (8) provides that in the parking process the right back wing of the parking car will not approach at a distance less than δ to the right road border. The limit (9) provides that in the parking process the left front wing of the parking car will not approach at a distance less than δ to the left road border.

With suppositions above the problem (2), (3), (6)–(9) can be considered as a problem of conditional optimisation relative to 5 optimisation parameters $a = (a_0, a_1, a_2, a_3, a_4)^T$ [9].

2.4. Example of calculation of optimal parking path

For example we will examine three cars of different classes which have the following technical features that are interesting for us:

- Class A – Volkswagen Polo Hatchback (length $L = 3.97$ m, width $B = 1.682$ m, wheelbase $W = 2.47$ m, track of back wheels $w = 1.456$ m, maximum angle of front wheels turning $\phi_{max} = 0.785$ radian (45^0, approximately),distance from the point M to the edge of back bumper $b = 0.6$ m);
- Class B – Seat Leon (length $L = 4.315$ m, width $B = 1.768$ m, wheelbase $W = 2.578$ м, track of back wheels $w = 1.517$ m, maximum angle of front wheels turning $\phi_{max} = 0.785$ radian (45^0, approximately), distance from the point M to the edge of back bumper $b = 0.796$ m);
- Class C – Skoda Superb Sedan (length $L = 4.838$ м, width $B = 1.817$ m, wheelbase $W = 2.761$ м, track of back wheels $w = 1.518$ m, maximum angle of front wheels turning $\phi_{max} = 0.785$ radian (45^0, approximately), distance from the point M to the edge of back bumper $b = 1.119$ m).

At that we will consider the following values of safety parameters when parking: $\Delta = 0.5$ m, $\delta = 0.2$ m and width of the standing car $Bs = 1.75$ m. We will examine the road width S for two cases: $S = 5.5$ m и $S = 8$ m to research influence of the available space on the left from the parking car.

The calculations we remade with the mathematical packet MATLAB.

The results of calculation of optimal path for parallel parking are in the Table 1and on the Figures 3–6. At that on the Figures 3–4 we can see the motion paths only for Volkswagen Polo, because for other cars the type of these paths does not differ in the main.

Table 1. Results of calculations

Road width	Car model	ΔX, m	$\frac{\Delta X}{L}$	a_2, m	a_3, m	a_4, km/h
5.5 m	VW Polo	5.846	1.472	-0.2968	0.638	-1
	Seat Leon	6.437	1.492	-0.1876	0.6102	-1
	Skoda Superb	7.147	1.477	-0.6	0.45	-1-
8 m	VW Polo	5.817	1.465	0.6213	3.1171	-1
	Seat Leon	6.261	1.451	0.9744	2.9864	-1
	Skoda Superb	6.947	1.436	-0.4	0.5	-1-

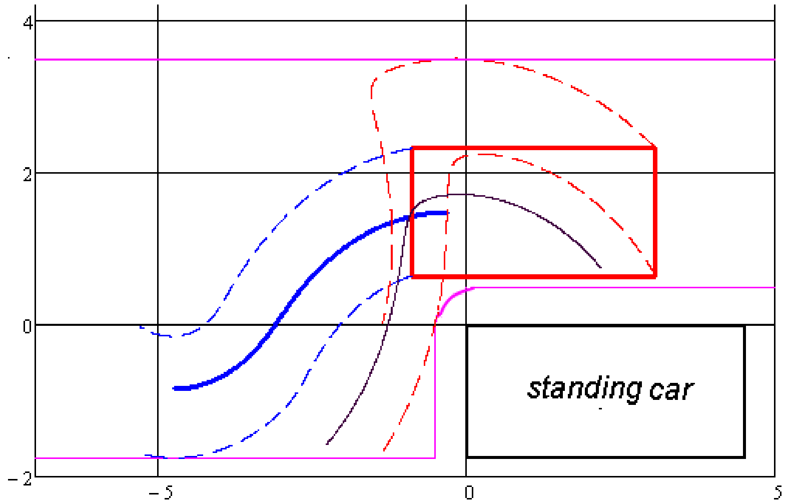

Figure 3. Parking path of Volkswagen Polo at the road width 5.5m

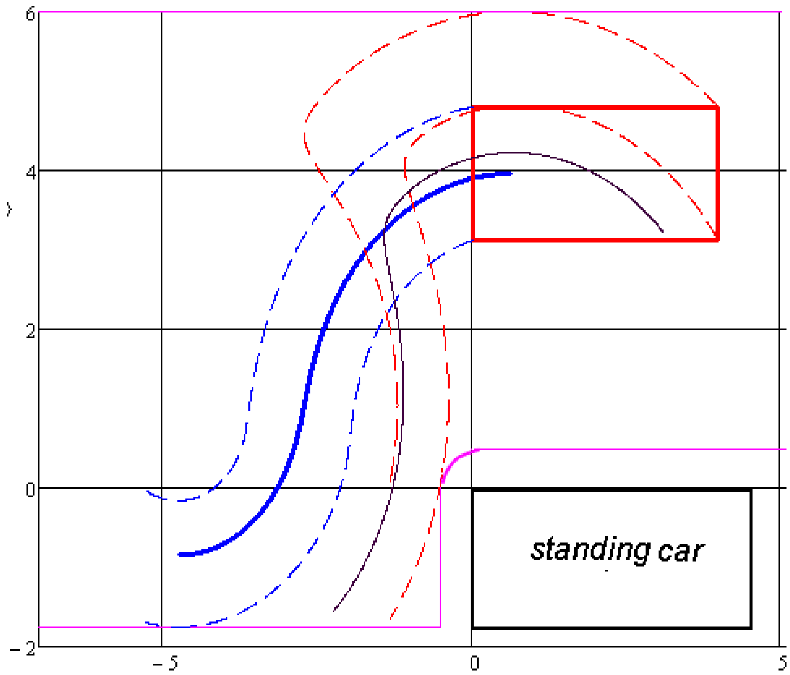

Figure 4. Parking path of Volkswagen Polo at the road width 8 m

On the Figures 3–4 the blue solid thick line shows the path of the point M, the black solid line shows the path of the front right wheel, the red dashed line shows the path of front overall points of the car, the blue dashed line shows the path of back overall points of the car.

In the Table 1 the following signs are used: ΔX– is a minimum distance between the standing cars that is necessary for parking in view of the safety parameter Δ; $\frac{\Delta X}{L}$ is a relation of this distance to the car length.

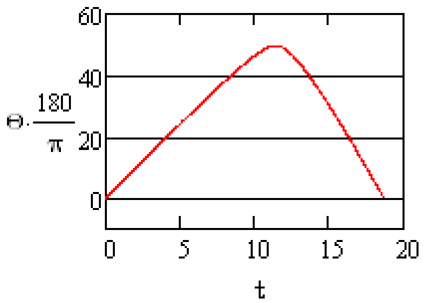

Figure 5. Graphof the angle θ change when parking Volkswagen Polo and at the road width of 5.5 meters

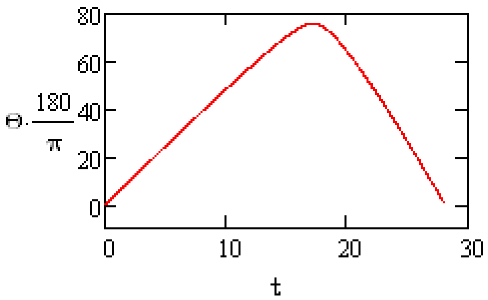

Figure 6. Graphof the angle θ change when parking Volkswagen Polo and at the road width of 8 meters

The results of calculation have showed that the car speed must be very slow, about 1km/hour. Therefore in the calculations, finally, it was fixed in the value of $a_4 = -1$ km/hour.

On the figures 5–6 you can see the graphs of the angle θ change when parking Volkswagen Polo and at the road width of 5.5m and 8m. As it is seen in the graph 5, at first the angle θ grows slowly almost till 50 degrees, and then with high speed it falls till zero. At the road width of 8m the value of the angle θ reaches almost 80 degrees.

2.5. Interpretation of results

Results of calculation allow us to draw conclusions about adequacy of the created mathematical model of car motion at low speeds.

The analysis of calculation results (Table 1) allows drawing the following theoretical conclusions for parallel car parking:

- length of a parking space should be practically not less than 1.5 of car length;
- for big cars, the more space for manoeuvre on the left, the better. The availability of large space on the left from the standing car is not of great importance for cars of A class, because it does not give any essential benefit (only some centimetres);
- if the space on the left is limited the passing forward concerning the standing car should be little;
- speed of the parking car should be as minimum as possible;
- inclination of the car axle relative to the road in optimal parking reaches 50 degrees and more.

3. Conclusions

It is proposed an algorithm of optimal path of car movement in the parallel parking on the basis of functions (4).

We want to notice that the path of car movement in the parallel parking calculated with the function (4) won't be optimal generally and it is only its approximation. Besides, in practice it is possible to make the movement path in two stages: at first backing and then forward and to the right. The calculation of such combined path also can be realized using the method described above.

On the basis of the offered approach a computer simulator could be developed for beginning (inexperienced) drivers. Using this simulator a driver can choose for himself an algorithm of optimal behaviour when parking.

The proposed algorithm for choosing an optimal path in the parallel parking can be used in design of inexpensive car systems that can help a driver to choose the best path for parallel parking.

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USING PRINCIPLE OF COMPLEMENTARITY WHEN DIAGNOSING COMPLEX LOGISTIC ACTIVITIES BY APPLYING ALTERNATIVE APPROACH

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The paper considers the problem of obtaining new data in process of diagnostics of a recognized transportation company. Such knowledge should not contradict to existing theories and objective means, but should be aimed instead at improving the diagnoses issued. By investigating the methodological problem by virtue of the principle of complementarity, the goals of making fundamental changes are achieved without disturbing the efficiency of the enterprise activities.

Keywords: uniformity, integrity, value-based management, ratio analysis, object domain, compensatory measures

1. Introduction

This methodologically-orientated investigation considers the principle of complementarity when diagnosing the activity of a transportation enterprise. Such a principle is based on the property of reproduction of integrity of enterprise financial status within a definite period of the enterprise activities. When applying complementarity principle, some mutually exclusive "additional" classes of notions must be used in process of interpretation of complicated situations. In particular, we deal with acquisition of new experimental data describing enterprise value in the long run. Such data is accumulated in process of presenting a data set on a system of coefficients describing sustainability of enterprise operation within a short term. Using complementarity principle allows one to set equivalence existing between two classes of notions. On the one hand, we mean the enterprise value integrating the enterprise's activities covering a ten-year period; on the other hand, the values of more than twenty coefficients calculated annually are investigated. The two classes of notions enable one to make a complex description of contradictory situations in two various cognition domains: general activity within a sufficiently long period, and piecemeal actions performed within a year's time. In the first case, decision-making is based on deductive analysis; in the second case, we deal with an opposite approach – i.e., inductive analysis performed on a short-term basis.

In our interpretation, complementarity principle expresses a change in understanding of the subject of knowledge, which is necessary when diagnosing activities of an enterprise. Such interpretation implies that we deal with two different slices, with each of them being set through different prisms of accepted abstract and empirical tools. At the same time, we avoid realizing the realities in its "precise form", and focus on approximations made by experts instead. Such representations allow one to become cognizant of one and the same process investigated under mutually exclusive conditions. We interact with one and the same specific object, with respect of which, however, two different contents are formed according to a known pattern. Moreover, those contents are reproduced in various properties. The fact of the object properties manifesting themselves in different ways is based on legitimacy and equal status of two scientific descriptions of the object. Such descriptions are made on the basis of two different theories representing the same object and the same object domain.

It is important to emphasize that one and the same object domain is described by two different theories according to the complementary principle. In this case, the classic theory of ratio analysis and the theory of value-based management are used. Characterizing the first of those theories, we have to mention well-known methodologies for financial diagnostics by Altmann, Olivier, Blank, Kovalev et al. [1–4], – which are expanded in the context of balance and sustainability by some papers of Kaplan and Norton, Jones, van Horn and Vakhovich, Finnerty and Chang, etc. [15–24]. The second theory is developed on the basis of investigations performed by Copeland, Coller, Murin, Doyle, Dolgoff, Gryaznova, Egerev, Ivashkovskaya and others [25–32].

The two theories differ in their source positions. The source positions are variables characterizing things taken as undefined magnitudes – i.e., value and sustainability state. The two theories are investigated by way of constructing mathematical models using various branches of mathematics – differential equations, theory of chance, games theory, etc. At that, interpretation of simulation results of the same phenomena described by one process using different mathematical tools, yields statements, which are close to each other, but, nevertheless, comes to different conclusions. In this research paper, the revealed contradiction is used as a supplement to complementarity principle. Compensatory measures put forward by one of those theories are considered as basic requirements to the creation of compensatory mechanisms applied within the framework of the other. The compensatory mechanisms application results are checked in the context of improvement of the enterprise activities diagnostics. Thus, the goal of research is posed which consists of using different sets of compensatory diagnostic measures to complement two different theories. The object of diagnostics is activity, while the subject of diagnostics is the process by virtue of which the diagnosed activity should be described unequivocally. Within the framework of this research paper, one of the authors (Lev Faingloz) has introduced the notion of complex logistic activity.

2. The Unity of Complex Logistic Activity and Complex Logistic Process

Any activity constitutes a totality of sequential operations which are individual actions. Objects of activity are actual actions consisting of operations. As a result of the notions of activity investigated in the paper [34–39] it has become necessary – in process of diagnosing a certain activity – not only to present integrated activity fairly as a system of chains forming it, but also to define a precise name for the activity. It was determined in process of the investigation conducted within the context of the above-mentioned aspects that any such activity should be of integrated nature and should extend from the moment of occurrence of finished products. As far as a name is concerned, the category "logistic activity" suggested by Igor Ansoff [40] may be best qualified as integral activity. This author rightfully considered as the Founding Father of the notion of strategy [38] has defined logistic activity as a detailed stepwise transformation of resources into products. This implies that it is referred to an integrated tool of management supporting the achievement of strategic goals of business organization at the expense of an efficient management of actions allowing one to perform optimal operations of product flow advance. In terms of management science, such an activity is not integral one, since it does not take into account any actions taken from the moment of shaping the idea to development of the strategic goal; furthermore, actions taken after the output of final products are neglected. In this paper it is suggested to expand the view on logistic activities, setting therein the effect of transformation of a certain idea into the final product characterizing a certain change in the management system performed. Let us call such a kind of activity a complex logistic activity. To interpret any activity, it is supplemented by the process which is a description of integrated activity made according to uniform requirements. By analogy, such a process will be called an integral logistic process. Therefore, the management system development and change stand, on the one hand, as a complex logistic activity irrespective of people, which seizes their occupation and compels it to its spontaneous laws of development, – and, on the other hand, as an integral logistic process implying a conscious and purposeful behaviour of people united into a specific structure. Such a structure allows one to adjust the description to reality, within the framework of which, correspondence between elements of the activity and the process is maintained at the level of requirements posed (Fig. 1).

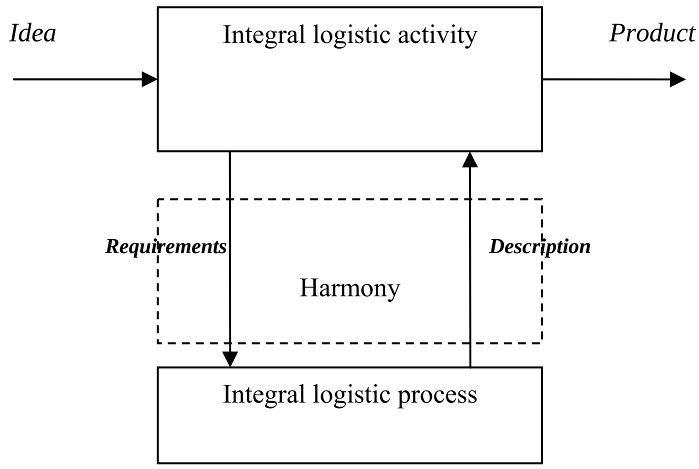


Figure 1. Unity of integral logistic activity and integral logistic process

The designated correspondence is not only reduced to supplementing the integrated logistic activity with the integrated logistic process but is connected with possessing some information on integral activity. Such information should be sufficient to build a unique process. The availability of reliable information meeting the requirements allows one not to avoid any errors in the process that would materially and adversely affect the efficiency of the activity. That's exactly why the primary concern of creating an effective management system is achieving readiness to timely refutation of discrepancies revealed between the description and the requirements. Such readiness provides for a harmony of integrity and unity of the management system. The system manageability manifests itself in proportion to removal of uncertainty eliminated in process of additional complication of multivariate structure of communication and relations. The multivariate structure requires understanding of the place occupied by the principle of complementarity within the general system of management principles.

3. Research Methodology

The methodology of this research paper is based on looking for a new knowledge enabling one to organize diagnostics of integral logistic using complementarity principle. Fig. 2 shows the place of complementarity principle within the diagnostics system. This diagram, wherein complementarity principle is the core item, has a holistic foundation with four faces.

When considering the first face of integrity, the determinism principle should be taken into account. According to that principle, all forms of actually existing interrelationships between phenomena are eventually shaped, based on the overall active causality, outside of which not a single phenomenon of reality exists, including events called stochastic; the totality of those events reveals statistical laws. Integrated logistic activity and integrated logistic process are studied under the conditions of removal of uncertainty.

The second face of integrity claims for taking into account the conformity principle – in particular, the succession of scientific theories. New theoretical constructions are helpful for the development of diagnostics system, but, if they don't correlate with the preceding ones, the system ceases to be integral, and experts and employees will soon stop to understand each other at all. In this case, the theory applied to pose requirements to integral logistic activities should not contradict to the theory of their description applied when studying the complex logistic process.

The third face of integrity is characterized by polarity principle wherein each of the polarities complements another one. Integral logistic activity and integral logistic process are needed to provide for a sustainable balanced operation of an enterprise. Each of theoretical inceptions included into the diagnostics system is built with due consideration for definite rules and each of them gains certain utility due to shortcomings of another one. Provisions of each inception should be expressed with the same freedom and substantiated with equal credibility. Otherwise neither of the two will be preferred.

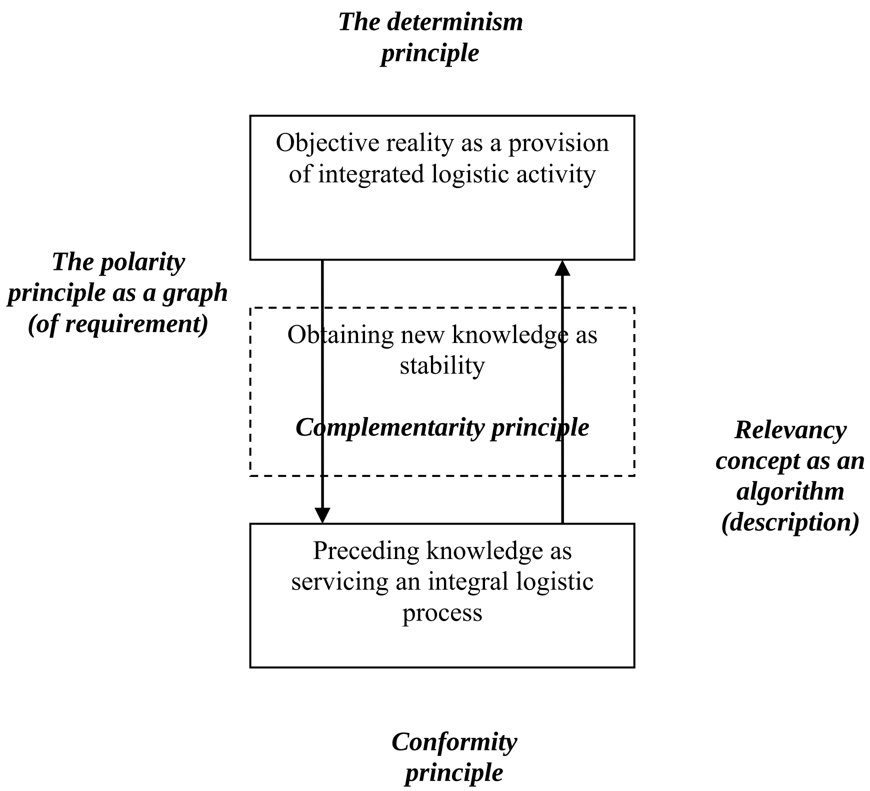


Figure 2. The place of complementarity principle within diagnostics system

The fourth face of integrity is based on the relevancy concept which depends on living conditions and the environment. Integral logistic activity and integral logistic process should be associated with the context that is determined by observation circumstances.

The four faces of the integral whole are reflected in usual interpretation of complementarity [37, 38, 41, 42] under which boundary conditions of the enterprise existence are defined. Such conditions having polar attributes (an energy-pulse picture of integral logistic activity and a space-time picture of integral logistic process) yield a third state in the interval between them – as a synthesis with a new attributes (new knowledge under Design Technical Merit in the form of a graph and an algorithm.

In our case, the integral logistic activity complements to the whole the integral logistic process which is opposing with respect to the activity, and vice versa. Thus, compensatory measures of one theory, taken in practice, should be complemented with another theory. Let’s assume that the ratio analysis theory at the level of complex logistic activity suggests passing some economic reforms. In this case, ethic norms should be studied within the framework of value-based management theory, at the level of an integral logistic process. Therefore, classic schemes of well-known theories are complemented with spontaneity of benchmark circumstances brought about by taking non-traditional measures from other theories.

The highlighted two integers are considered as supplements but in no way as “not good” or “bad”. In process of the complement, one of the elements is given tacit preference. This is connected with the fact that each phenomenon is not perceived by us in its “pure form” but rather through a definite intention. Exactly through the prism of that intention, reflection of reality takes place as a certain condition presented in the form of a set graph. Such a graph represents integral units of problem-heuristic direction. Imperfection, incompleteness, and uncertainty are typical features of such a unit; elimination of these aspects is accomplished at the lowest level. This takes place in the process of final debugging of algorithm, performed under refining conditions where elementary units of scientific knowledge of classic theory are used.

The methodology considered has been applied when investigating the activity of a European transportation company. The factual material exploration period is 10 years: from 2001 to 2010. The official data of the Register of enterprise are used – specifically, the published financial reporting data of a well-known carrier.

4. Diagnostics of Company State Relying on the Tools of Value-Based Management

Managing the integral logistic process with the diagnostics of integral logistic activity is exercised, based on the enterprise value $\widetilde{P}v_{project}$. The diagnostics procedure is reduced to evaluation of factors forming the enterprise values:

$$\widetilde{P}v_{project} = \widetilde{P}v_{project}\left(\widetilde{F}_1,...,\widetilde{F}_i,...\right), \tag{1}$$

wherein $\widetilde{F}_i$ is the i-th factor of value.

Let us split the value into two components: the non-random component (it is designated by original brackets «< >») and the random component (it is designated by the symbol «^»):

$$\begin{aligned} &\widetilde{P}v_{project} = \left\langle Pv_{project}\right\rangle + \hat{P}v_{project}, \\ &\widetilde{F}_i = \left\langle F_i\right\rangle + \hat{F}_i, \quad i = 1,...,N. \end{aligned} \tag{2}$$

Further, the solution of the problem is reduced to evaluating the enterprise value at the level of:

- productivity;
- variability.

To evaluate them, calculations of sensitivity index are required. Sensitivity to cost factors should be interpreted as increment or decrease percentage of the enterprise value if the factor value is increased by 1%. All in all, we obtain the expression as follows on the finite number of factors:

$$\frac{\Delta\widetilde{P}v_{project}}{\left\langle Pv_{proect}\right\rangle} = \sum_{i=1}^{N} Kf_i \frac{\Delta\widetilde{F}_i}{\left\langle F_i\right\rangle}, \tag{3}$$

wherein N is the number of essential factors;

Kf_i – sensitivity factor of the *i*-th factor;

$\Delta\widetilde{P}v_{project}$ – increment of the enterprise value;

$\left\langle Pv_{project}\right\rangle$ – expected value of the enterprise;

$\Delta\widetilde{F}_i$ – increment of the *i*-th factor;

$\left\langle F_i\right\rangle$ – expected value of the *i*-th factor.

The factor productivity is defined as the degree of increment of the expected factor with respect to the increment of investments made into mechanisms of management to improve integral logistic activities in accordance with the substantiated scenarios of the enterprise development.

The formula for the factor influence upon enterprise value, taking into account sensitivity and productivity of $Kp_{i,j}$ for the *i*-th factor by the j-th effort, assumes the form as follows:

$$\frac{\left\langle \Delta Pv_{project}\right\rangle}{\left\langle Pv_{project}\right\rangle} = \sum_{i=1}^{N} Kf_i \sum_{j=1}^{M} Kp_{i,j} \frac{\left\langle \Delta P_{i,j}\right\rangle}{\left\langle P_{i,j}\right\rangle}. \tag{4}$$

Variability is defined as a degree of increment of the factor's random component relative to ancillary costs brought about by the occurrence of contingencies. Such contingencies normally lead to changes in the state of the management system.

As a result, the enterprise value, with due consideration for sensitivity and variability $Kc_{i,j}$ for the *i*-th factor by the j-th contingency $\frac{\Delta \hat{C}_{i,j}}{\langle C_{i,j} \rangle}$ is calculated according to the formula as follows:

$$\frac{\Delta \hat{P}v_{project}}{\langle Pv_{project} \rangle} = \sum_{i=1}^{N} Kf_i \sum_{j=1}^{K} Kc_{i,j} \frac{\Delta \hat{C}_{i,j}}{\langle C_{i,j} \rangle}. \tag{5}$$

The more description and details on the value, productivity and variability calculation according to formulas (1), (2), (3), (4), (5) is developed in the past published works of the article's authors [43].

Let us collect the calculated results of sensitivity, productivity, and variability ratios into summary (see Table 1).

Table 1. Summary table containing sensitivity, productivity, and variability ratios

Index	Scenario No 1	Scenario No 2	Scenario No 3
Sensitivity ratios	2,62	0,09	0,80
Productivity ratios	3,58	0,92	-4,53
Variability ratios	6,52	0,02	-17,19

For the sake of illustration, let us present the data from Table 4 in the form of diagram (see Figure 3):

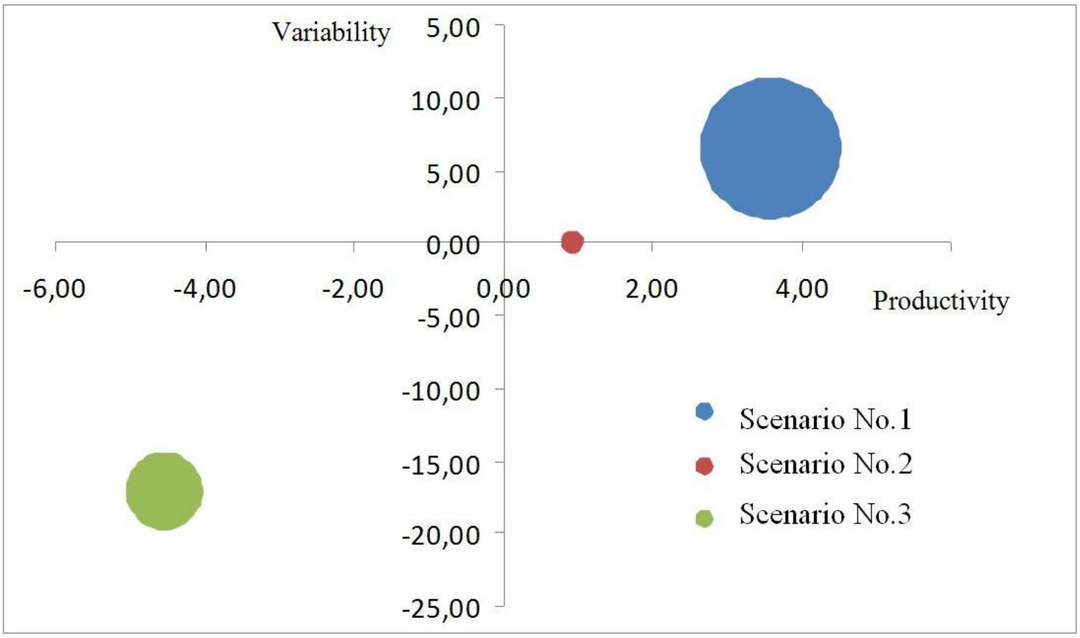


Figure 3. Diagram showing sensitivity, productivity, and variability ratios

According to Figure 3, the most preferred scenario for making improvements is scenario No 1. This decision is taken because Scenario No.1 features the highest sensitivity and productivity as against the second and the third scenarios. It should be noted that the decision was not taken in favour of Scenario No 3 since, despite a high productivity, that scenario features a high variability level, attesting to the highest level of uncertainty. When performing a detailed analysis accompanying investigation of the enterprise value from 2001 to 2010, a set of compensatory measures, shown in Table 2, was suggested.

Table 2. Suggested compensatory effects within the period from 2008 to 2010

Year	Indices	Steps
2008	Goods and raw materials purchase expenses	Reduction by 9%
	Administrative costs	Reduction by 10%
	Circulating capital (floating assets)	Reduction by 10%
2009	Goods and raw materials purchase expenses	Reduction by 10%
	Administrative costs	Reduction by 11%
2010	Goods and raw materials purchase expenses	Reduction by 11%
	Administrative costs	Reduction by 11%

In case of the above-stated compensatory actions were taken, the investigated indices could assume the following form presented on Figure 2.

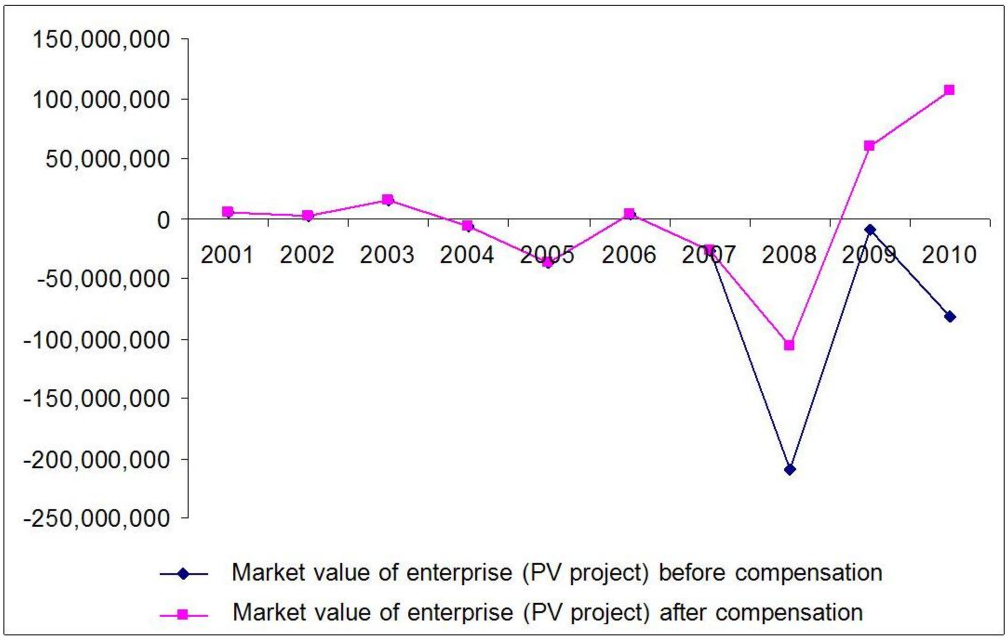


Figure 2. Enterprise value changing diagram within the period from 2001 to 2010 before and after compensatory actions

Analysing the data presented on Figure 2 shows that if the enterprise had started to take compensatory actions suggested in Table 8, it would have managed to cut down losses in value, while in 2009 and 2010 the enterprise would have managed to transfer the value to the positive zone from the negative one.

5. Diagnostic of Enterprise State Based on Tools of Ratio Analysis

In process of estimating the financial potential of the enterprise, a group of indices is used reflecting the extent of the enterprise's capabilities of incurring the current financial liabilities and for supporting the optimum capital structure. In this respect, financial conditions of enterprise's activities should be estimated, based on two key indicators: liquidity, financial solvency, and financial instability.

Liquidity and financial solvency are in essence non-identical notions. The integral logistic process investigation has shown that, in practice, situations occur frequently wherein values of liquidity ratio are lying within a preset interval; naturally, the fact attests to a normal financial condition of enterprise. However, such a conclusion may be false, since the largest share percentage within the summarized current assets falls upon illiquid assets or overdue receivables. Therefore, the enterprise under investigation is short of funds to repay current payables. So far as the activity is stabilized, a fully developed structure of current (circulating) assets and their formation sources is established at the enterprise. That's why the liquidity ratio values are changing within the framework of preset ranges. Tracing those ratios on a permanent basis would enable one to work out sufficiently good benchmarks to be used subsequently in process of diagnostics of the enterprise activities.

The financial stability of the enterprise is a balanced interaction of activity and processes within a long period of time; the financial stability is provided by performing a multi-level procedure of stabilization, based on financial instability and financial uncertainty ratios.

Based on the assumption that an absolutely stable system can not be encountered in practice, it was decided to measure the degree of instability when describing integral logistic activity. To measure instability and determine its degree, one of the authors of this paper (K. Chernavsky) has suggested two quantitative coefficients to be used. Since direct relationship, feedback, and some barriers exist between integral logistic activities and integral logistic process, the first "financial instability coefficient" is aimed mostly at reflecting the results of activity, while the second "financial uncertainty coefficient" takes the process impacts into account. For that reason, coefficients must not be considered separately when tracing the interaction; each of the coefficients should contain factors describing both the activity and the processes.

The financial instability coefficient is calculated according to the formula as follows:

$$NS = X_1 + X_2 + X_3 + X_4 + X_5, \tag{6}$$

wherein:
X_1 – the rate of loss of free cash flow;
X_2 – the rate of loss of profit;
X_3 – the rate of loss of turnover;
X_4 – the rate of loss of circulating assets;
X_5 – the rate of loss of equity capital.

The financial uncertainty coefficient is characterized by the formula as follows:

$$NN = D \times T \times [P-1] \times [Y_1 + Y_2 + Y_3 + Y_4 + Y_5], \tag{7}$$

wherein:
D – the depth or level of variability;
T – the trend or speed of changes;
P – the probability or predictability of changes;
Y_1 – the rate of change of economic standing as a whole;
Y_2 – the inflation change rate;
Y_3 – the rate of loss of investments;
Y_4 – the rate of loss of core markets;
Y_5 – the rate of loss of intellectual capital.

Based on the suggested coefficients, the "imbalance quadrants" matrix is developed, characterizing the state of a specific enterprise as of a specific moment of time in terms of the "stability-instability" approach; using this approach can present results of simultaneous diagnostics of activity and process of the given enterprise. With respect to the object under investigation, the integral logistic activity is acknowledged as instable one.

According to the established standards, the operating rates of the enterprise do not fit into the domain of recommended values; using formula (6), this fact attests to financial instability of the enterprise activities within the long-run period from 2001 to 2010. Neither liquidity coefficients, nor financial solvency coefficients and current assets to equity ratio fit into the established standards. Using formula (7) in the diagnostics of financial capacity shows the strong uncertainty of environment, valuating the activity of the enterprise. However, the dynamics of sustainable growth rate (SGR) attests to the fact that the enterprise activity has begun to stabilize due to the sales volume increase. Within the period from 2008 to 2010, the sales growth took place at the expense of two main factors: assets turnover increase and capitalization of earnings.

The main results of the countermeasures developed, aimed at changing the obtained critical values of indices, are presented in the form of analytical table shown below (Table 3):

Table 3. The proposed enforcement actions over the period from 2002 to 2010

Year	Essence of change	Compensatory measures
2002	Liquidity enhancement; improving current assets to equity ratio (CAER); provision of stock cover to a large extent	Taking measures aimed at maintaining financial solvency; assessing risks of possible investments
2003	Liquidity enhancement; achieving balance between the CAER and the main assets; worsening of stock cover	Achieving balance between liquidity and profitability by means of increasing sales volumes at the expense of enlarging the volume of carriage
2004	Worsening of liquidity; a strong worsening of CAER	Revising the asset finance policy – first of all, unmarketable stock (illiquid assets) and overdue receivables
2005	Assets leverage optimisation; a strong enhancement of CAER; worsening of absolute liquidity	Promoting sales by way of price and marketing strategy. Performing a forecast of Free Cash Flow over a 5-year horizon
2006	The growth rate slows down; strong deregulation of assets leverage; liquidity is maximal	Increasing the rate of turnover of floating assets, increasing profitability, investing into the main assets and development projects
2007	Increasing the growth rate; a successful balancing of assets leverage; worsening of CAER and liquidity	Achieving balance between the growth rate and liquidity; finding the optimal proportion for the preset standard of sustainable growth ratio (SGR). Within at least a 5-year horizon, drawing a comparison between the estimated and the actual SGR index
2008	Critical downfall of growth; ideal leverage and very bad liquidity	If predictive estimate of the growth rate justifies the financial resources invested into the assets – performing the CAER and the borrowed capital restructuring An urgent fund rising is possible by way of increasing CAER (bond issuance) and by way of refinancing
2009	Achieving an intensive growth rate, capitalization of profit, improvement of financial solvency and liquidity	Maintaining the balance between profitability and solvency in the ling run – by way of monitoring of internal and external changes
2010	The maximum growth rate at the expense of a strong reduction of solvency, leverage, and liquidity; improvement of stock cover share	Providing for the balance of interests of the three groups of stakeholders: the shareholders. The managerial staff and the employees. Maintain the growth rate as high as possible by way of improvement in turnover of assets and keeping profitability at a preset level

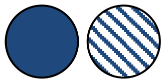
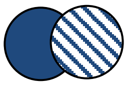
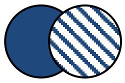
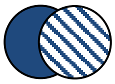
6. Income and Outcome Analysis

It should be noted that, based on the tools used (ratio analysis and value-based management), the same diagnosis has been made: “the enterprise under investigation is under critical situation”. This conclusion is conditioned within the framework of the general specific investigation domain.

In process of research performance, two different packages of measures were proposed, which were subsequently used both within the framework of the existing tools and on the basis of the principle of complementarity. In the first case, compensatory measures are conducted within the framework of the existing theory; in the second case, proposals concerning the improvement of integral logistic activity are worked out based on the requirements of one theory, while their testing at the level of an integral logistic process is performed within the framework of an alternative theory.

Different alternatives of synchronization of the theories used are examined in Table 4.

Table 4. Evaluation of alternatives of compensatory measures

	Realization within the framework of the value-based management theory	**Realization within the framework of the ratio analysis theory**	**Graphic presentation***	**Conclusion**	**Limitations**
Compensatory measures of ratio analysis theory	+	-		Not efficient	No
Compensatory measures of ratio analysis theory	-	+		Of little efficiency	Interference with a stable process
Compensatory measures of the value-based management theory	+	-		Efficient	Some complexities of application under transitional modes
Compensatory measures of the value-based management theory	-	+		Very efficient	No

**The graphic presentation in the Table is demonstrated by intersection of two domains: the dense domain characterized the domain of requirements, while the stroked domain characterized the decisions made. The area of intersection of the two domains characterizes conformity between the requirements and the decisions made. The larger is the intersection domain, the more efficient has been the impact rendered by the compensatory measures upon stabilization of activity.*

As it can be seen from the contents of the Table, the most efficient is the fourth alternative wherein the compensatory measures proposed within the framework of the value-based management theory have been applied when estimating the financial potential based on ratio analysis.

Conclusions

It has been shown in the research paper that using complementarity principle enriches the objective means of diagnosing financial condition by virtue of using alternative theories. This conclusion has been received when investigating the place occupied by complementarity principle within the system of diagnostics. Complementarity principle which was defined as the main one, works within the composition of four principles: determinism, polarity, correspondence, and relevancy. Eventually, an integral logistic activity and integral logistic process synchronization scheme was worked out with due consideration for unity and integrity. Such synchronization not only claimed for substantiated introduction of new concepts but made it necessary to make coordination between the two theories. In the course of coordination, a transition from the formal theory to the content one was made. Presentation of the formal theory, posing requirements to integral logistic activity in the form of an oriented graph, was found. The debugging of the preset algorithm is performed within the framework of the content theory. Using the graph-algorithmic concept by an example of an operating enterprise has shown the efficiency of making basically new generalizations. Such generalizations were built for polar but relevant theories, which enabled one to obtain some refinements fit for tying the value-based management theory and the ratio analysis theory. Thereby, one has managed not only to make an accurate description of a subject domain of the enterprise under investigation by using two different theories, but also to work out compensatory mechanisms for stabilization of the enterprise activities. The compensatory mechanisms application results have allowed one to select the best alternative from the standpoint of diagnostics quality improvement.

This research, bearing a methodological character, can be regarded as an applied one; within its framework, some new objective means of diagnostics of enterprise activities can be worked out at various stages of the enterprise's life cycle and under various operating conditions.

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Transport and Telecommunication Institute, Lomonosov 1, Riga, LV-1019, Latvia

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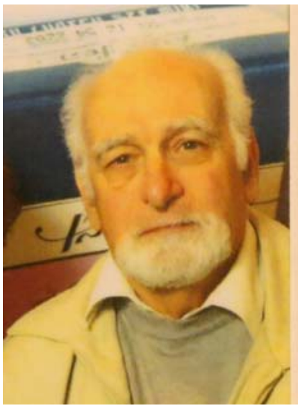

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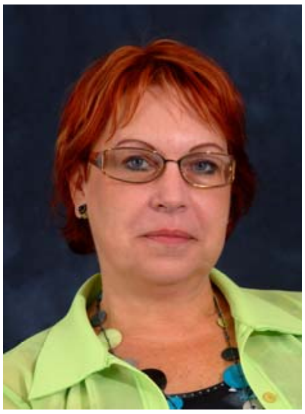

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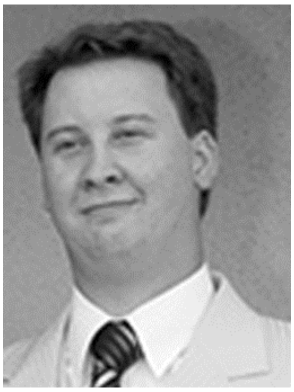

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CUMULATIVE INDEX

TRANSPORT and TELECOMMUNICATION, Volume 13, No 4, 2012 (Abstracts)

We consider a pair of networks *A* and *B* which are subject to failures of their components. In *A,* edges are subject to failure, and *A* fails when it disintegrates into several isolated clusters each containing a single terminal. Edges of *A* fail in random order and their failure moments follow Poisson process. After *A* has failed, terminal α of *A* causes a failure (”attacks”) on R_α randomly chosen non terminal nodes of network *B*. All edges incident to an attacked node are erased. The ”attacks” take negligible time. Network *B* failure takes place if it loses its terminal connectivity. We study the probability that *B* will be in failure state at moment *t* as a function of *t* and $R = \sum R_\alpha$. The main formal tools which we use are the D-spectra (signatures) of networks *A* and *B* and de Moivre’s combinatorial formula.

Keywords: Network terminal connectivity, signature, D-spectrum, Poisson process, Monte Carlo, random allocation, de Moivre formula

Despite all the efforts of Just in Time philosophy, companies are still required to run numerous warehouses to accomplish distribution management objectives, and match supply network to this activity. In this research is being reported state of the warehousing practices in the largest Finnish and Swedish companies relying on longitudinal data gained through five different surveys. Research findings show that together these two countries are still on the cost pressure with respect of transportation. Also companies in these two northern countries are still using mostly semi-trailers on their distribution transportation. However, some evidence is on place that containers are taking higher role. Interestingly, most of the warehouses of these two countries report to be located in the countries of the Baltic Sea Region, finding which is rather striking as we have given so much effort on economical integration of this region in the recent decades. Finnish companies seem to hold much larger interest on Central and Eastern European Countries warehousing. Size of warehouses is likely to increase a little bit, and units located in other continents are much smaller.

Keywords: Warehousing, Transportation, Finland, Sweden, Geographical Coverage, CEEC

Assessment of Lithuanian road transport service providers’ position in the Baltic Sea region identified, that the Lithuanian road transportation market has the tendency of recovery after the economic and financial crisis. Lithuanian transport companies operating in the BSR and EU market are small – average 7 HGV in the company but they remain competitive in the area of quality service offered. It is defined significant renewal of HGVs fleet – more than thirty percent’s of vehicles have EURO-4 and EURO-5. Big transport companies are extending their service package and in the parallel with the transportation are proposing to the customers’ logistics service package or dedicated services.

Keywords: transport, service quality, security

Passenger cars are complex products that consist of millions of parts. Cars have different shapes and colours giving persons different emotional feelings. Therefore the car as a complex product is suitable for marketing specialist for comparing other products through cars. Authors are describing the mathematical background of the theoretical investigation and the practical results of such examination.

Keywords: cars, emotions, experience

Vaidogas, E. R., Kisežauskienė, L. Transportation of Liquefied Gasses: Assessing the Risk of Thermal Damage to Roadside Infrastructure from a Road Tank "Bleve", *Transport and Telecommunication,* Vol. 13, No 4, 2012, pp. 284–293.

An assessment of risk posed by a road transportation of liquefied gases to roadside property is considered. The attention is focussed on an estimation of the probability of thermal damage to a roadside object. Such damage can be caused by a boiling-liquid expanding-vapour explosion (BLEVE) of a road tank. It is suggested to estimate this probability by a combined application of stochastic simulation and deterministic models used to predict a thermal effect of a BLEVE fireball. A development of a fragility function expressing the probability of ignition of the roadside object is discussed. The fragility function is integrated into the simulation-based procedure of an estimation of the thermal damage probability. The approach proposed in this study is illustrated by an example which considers an assessment of thermal damage to a reservoir built in the vicinity of a road used for transportation of liquefied gases.

Keywords: hazmat transportation, road tank, liquefied gas, BLEVE, thermal damage, risk

Adamos, G., Nathanail, E., Kapetanopoulou, P. Does the Theme of a Road Safety Communication Campaign Affect its Success? *Transport and Telecommunication,* Vol. 13, No 4, 2012, pp. 294–302.

Road safety communication campaigns are considered as an efficient strategy to approach the wide audience and influence road users towards a safe behaviour, with main aim to lead to the reduction of the number and the severity of road crashes. When designing the implementation of a campaign, it is important to plan at the same time its evaluation, so that to enable the assessment of its effectiveness. For the achievement of high reliability and the development of "clear" conclusions, the campaign evaluation should be carefully organized, following a feasible scientific design.

Towards this direction, three road safety campaigns, two local campaigns addressing drink driving and seat belt usage and one national campaign addressing driving fatigue, implemented and evaluated. Presenting the design components of the three campaigns and the evaluation results, this paper aims at revealing the similarities and differences of the effectiveness of road safety communication campaigns on driving behaviour.

Keywords: road safety communication campaigns, fatigue, drink-driving, seat belt usage, measurement variables, experimental design.

Zadachyn, V., Dorokhov, O. V. Calculation of Optimal Path for Parallel Car Parking, *Transport and Telecommunication,* Vol. 13, No 4, 2012, pp. 303–309.

The problem of calculation of optimal path for reverse parallel parking is examined. Elementary mathematical model of car movement on plane is described. Optimality criterion and restriction on a possible path for parallel parking are formulated. It is offered a way of choice of a quasi-optimal path for reverse parallel parking. Corresponding numerical calculations and graphic example are presented.

Keywords: parking a car, mathematical model, system of differential equations, Cauchy problem, conditional optimizsation

Kopitov, R., Faingloz, L., Cernavskis, K. Using Principle of Complementarity when Diagnosing Complex Logistic Activities by Applying Alternative Approach,, *Transport and Telecommunication,* Vol. 13, No 4, 2012, pp. 310–321.

The paper considers the problem of obtaining new data in process of diagnostics of a recognized transportation company. Such knowledge should not contradict to existing theories and objective means, but should be aimed instead at improving the diagnoses issued. By investigating the methodological problem by virtue of the principle of complementarity, the goals of making fundamental changes are achieved without disturbing the efficiency of the enterprise activities.

Keywords: uniformity, integrity, value-based management, ratio analysis, object domain, compensatory measures

TRANSPORT and TELECOMMUNICATION, 13.sējums, Nr.4, 2012 (Anotācijas)

Gertsbahs, I., Špungins, J. Networks nespēja attīstīties divu savienotu tīklu sistēmā, *Transport and Telecommunication,* 13.sēj., Nr.4, 2012, 255.–260. lpp.

Darbā tiek izskatīts tīklu pāris *A* un *B*, kuri ir pakļauti to komponentu kļūdām. Tīklā *A* malas ir pakļautas neveiksmēm, un *A* kļūdās, kad tas sadalās vairākās izolētās kopās, kur katrs satur vienu termināli. *A* malas kļūdās jauktā secībā, un tā neveiksmju momenti seko Puasona procesam. Kad *A* ir kļūdījies, terminals α no *A* rada neveiksmi ('uzbrukumus') uz R_α nejauši izvēlēta tīkla *B* ne-termināļa mezgliem. Visas malas incidents mezglam, kuram uzbruka, tiek izdzēsts. Uzbrukumi aizņem nenozīmīgu laiku. Tīkla *B* neveiksmes notiek, ja tas zaudē savu termināļa savienojumu.

Atslēgvārdi: tīkla termināļa savienojums, paraksts, D-spectrum, Puasona process, Monte Karlo, de Moivre formula

Hilmola, Olli-Pekka. Noliktavu vadība somu un zviedru uzņēmumos: darbības vides stāvoklis laika posmā no 2006. līdz 2012. gadam, *Transport and Telecommunication,* 13.sēj., Nr.4, 2012, 261.–270. lpp.

Pretēji visām filozofijas 'tieši laikā' pūlēm, kompānijām tomēr ir jāapkalpo daudzas noliktavas, lai sasniegtu distributīvā menedžmenta mērķus un saskaņotu apgādes tīklu ar šo darbību. Šajā rakstā autori iztirzā noliktavu prakses stāvokli lielākajās somu un zviedru kompānijās, paļaujoties uz garengriezuma datiem, kas gūti piecos dažādos apsekojumos. Izpētes rezultāti parāda, ka šīs divas valstis joprojām ir par izmaksu spiedienu attiecībā uz pārvadājumiem. Visas kompānijas šajās divās ziemeļu valstīs vēl joprojām lielākoties izmanto puspiekabju transportu savos distributīvajos pārvadājumos. Tomēr daži pierādījumi ir vietā, ka konteineri ieņem arvien lielāku lomu. Somijas uzņēmumi, šķiet, uztur daudz lielāku interesi par Centrālās un Austrumeiropas valstu noliktavu darbību. Noliktavu izmēri mēdz nedaudz palielināties, un vienības, kas atrodas citos kontinentos, ir daudz mazākas.

Atslēgvārdi: noliktavu vadība, transports, Somija, Zviedrija, ģeogrāfiskā izplatība

Bazaras, D., Palšaitis, R. Lietuvas transporta pakalpojumu sniedzēju pozīcija Baltijas jūras reģiona transporta tirgū, *Transport and Telecommunication,* 13.sēj., Nr.4, 2012, 271.–274. lpp.

Lietuvas ceļu transporta pakalpojuma sniedzēju stāvokļa novērtējums Baltijas jūras reģionā (BJR) noteica, ka Lietuvas ceļu pārvadājumu tirgum ir atveseļošanās tendence pēc ekonomikas un finanšu krīzes. Lietuvas transporta uzņēmumi, kas darbojas BJR un ES tirgū ir neliels – vidēji 7 *HGV* uzņēmumā, bet tās paliek konkurētspējīgas piedāvātā kvalitātes pakalpojumu jomā. Lielie transporta uzņēmumi paplašina savu pakalpojumu paketi un paralēli ar transportēšanu, ierosina klientiem loģistikas pakalpojumu paketi vai īpašus pakalpojumus.

Atslēgvārdi: transports, servisa kvalitāte, drošība

Logo, E., Petruska, I., Torok, A. Pasažieru auto kā sarežģīta pieredze, *Transport and Telecommunication,* 13.sēj., Nr.4, 2012, 275.–283. lpp.

Vieglie automobiļi ir sarežģīti produkti, kas sastāv no miljoniem daļām. Automašīnām ir dažādas formas un krāsas, kas sniedz personām dažādas emocionālas jūtas. Tāpēc auto kā komplekss produkts ir piemērots mārketinga speciālistam, lai salīdzinātu citus produktus ar automašīnu palīdzību. Autori apraksta sasniegto rezultātu teorētiskās izmeklēšanas matemātisko fonu un praktiskos rezultātus šādām pārbaudēm.

Atslēgvārdi: auto, emocijas, pieredze

Vaidogas, E. R., Kisežauskiene, L. Sašķidrinātās gāzes transportēšana: ceļa infrastukūras termisku bojājumu no cisternauto 'BLEVE' riska noteikšana, *Transport and Telecommunication,* 13.sēj., Nr.4, 2012, 284.–293. lpp.

Rakstā tiek izskatīts riska novērtējums, ko prasa ceļu īpašnieki pie sašķidrinātās gāzes transportēšanas. Uzmanība ir pievērsta termālo bojājumu varbūtības novērtēšanai ceļa objektiem. Šāds bojājums var rasties no sprādziena, kuru var izraisīt cisternas vārīšanās šķidruma tvaiku izplešamās (*BLEVE*).

Pētījumā autori piedāvā novērtēt šo varbūtību stohastiskās simulācijas komplekso pielietojumu un deterministiskiem modeļiem, kas lietoti, lai noteiktu (*BLEVE*) aizdedzināšanas kodola termālo efektu. Tiek diskutēts par nestabilitātes funkcijas veidošanos, kas izteikta ar aizdegšanās varbūtību no ceļa objektiem. Nestabilitātes funkcija ir integrēta simulācijā balstītā termālā bojājuma novērtēšanas procedūrā. Pieeja, kas tiek piedāvāta šajā pētījumā, tiek ilustrēta ar piemēru, kurš izskata termālo bojājumu rezervuāram, uzceltam ceļa apkārtnē, un kuru izmanto sašķidrinātās gāzes transportēšanai.

Atslēgvārdi: transportēšanai bīstamās vielas, cisterna, sašķidrinātā gāze, *BLEVE*, termālais bojājums, risks

Adamos, G., Natanails, E., Kapetanopoulu, P. Vai ceļu satiksmes drošības komunikācijas kampaņa var ietekmēt tās panākumus? *Transport and Telecommunication,* 13.sēj., Nr.4, 2012, 294.–302. lpp.

Ceļu satiksmes drošības komunikācijas kampaņas tiek uzskatītas par efektīvām stratēģijām, lai uzrunātu plašu auditoriju un ietekmētu ceļu satiksmes dalībniekus un, tādējādi, sekmējot drošu uzvedību uz ceļa, kā arī kā galveno mērķi uzstādot ceļu satiksmes negadījumu skaita un smaguma samazināšanu. Projektējot kampaņas ieviešanu, ir svarīgi vienlaicīgi plānot tās novērtēšanu tā, lai iespējotu tās efektivitātes novērtēšanu. Lai sasniegtu augstu uzticamību un 'skaidru' secinājumu attīstību, kampaņas novērtēšana ir rūpīgi jāizstrādā, sekojot īstenojamai zinātniskai izstrādei.

Šajā sakarā ir organizētas trīs ceļu satiksmes drošības kampaņas, kur divas vietēja rakstura kampaņas, kontrolējot braukšanu reibumā un drošības jostu lietošanu un viena valsts kampaņa, vēršot uzmanību braukšanai nogurumā.

Šajā rakstā tiek izskatītas ceļu satiksmes drošības komunikācijas kampaņu efektivitātes līdzības un atšķirības braukšanas uzvedībā.

Atslēgvārdi: ceļu satiksmes drošības komunikācijas kampaņa, nogurums, braukšana reibumā, drošības jostu lietošana, eksperimentālais projekts

Zadachyns, V., Dorohovs, O. Optimāls ceļa aprēķins paralēlai auto novietošanai, *Transport and Telecommunication,* 13.sēj., Nr.4, 2012, 303.–309. lpp.

Rakstā tiek risināts optimālā ceļa aprēķina jautājums par auto reverso paralēlo parkošanos. Tiek aprakstīts auto kustības elementārs matemātisks modelis uz plaknes. Optimalitātes kritērijs un iespējamais ceļa uz paralēlo parkošanos ierobežojums ir formulēts. Tas tiek piedāvāts kā kvazi-optimālais ceļš reversai paralēlai parkošanās izvēles variants. Atbilstoši skaitliskie un grafiskie piemēri tiek piedāvāti dotajā rakstā.

Atslēgvārdi: parkošanās, matemātiskais modelis, diferenci\alvienādiojumu sistēma, Ko\s\i problēma, nosacīta optimizācija

Kopitovs, R., Fainglozs, L., Cernavskis, K. Papildināmības principa izmantošana komplekso loģistikas aktivitātšu diagnosticēšanā, lietojot alternatīvo pieeju, *Transport and Telecommunication,* 13.sēj., Nr.4, 2012, 310.–321. lpp.

Raksts apsver pazīstamas transportēšanas kompānijas diagnosticēšanas problēmu jaunu datu iegūšanas procesā. Šādām zināšanām nebūtu jābūt pretrunā ar esošajām teorijām un objektīviem kritērijiem, bet būtu jābūt vērstām izsniegto diagnožu uzlabošanas vietā. Izmeklējot metodisko problēmu, pamatojoties uz papildināmības principu, fundamentālo izmaiņu veikšanas mērķi ir sasniegti, netraucējot uzņēmuma darbības efektivitāti.

Atslēgvārdi: viendabīgums, integritāte, vērtību balstīt menedžments, attiecību analīze, objektu domēns, kompensējošie pasākumi

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