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INSPECTION PROGRAM DEVELOPMENT FOR AN AIRCRAFT FLEET AND AN AIRLINE ON THE BASIS OF THE ACCEPTANCE FATIGUE TEST RESULT

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An inspection interval planning is considered in order to limit the probability of any fatigue failure (FFP) in a fleet of N aircraft (AC) and to provide an economical effectiveness of airline (AL) under the limitation of fatigue failure rate (FFR). A solution of these two problems is based on the processing of the result of acceptance fatigue test of a new type of aircraft. During this test an estimate of the parameter $\hat{\theta}$, of a fatigue crack growth trajectory has been obtained. If the result of this acceptance test is too bad then this new type of aircraft will not be used in service. A redesign of this project should be done. If the result the acceptance test is pretty good then the reliability of the aircraft fleet and the airline will be provided without inspections. For this strategy there is a maximum of FFP (a maximum of FFR) as a function of an unknown parameter θ. This maximum can be limited by the use of the offered here procedure of the choice of the inspection number. The economic effectiveness of the AL operation is considered using the theory of Markov process with rewords.

Keywords: Monte Carlo, Markov chains, Minimax, inspection program and approval test, fleet reliability, economic effectiveness

1. Introduction

We assume that in the interval (T_d, T_c), where T_d is a random time when the fatigue crack becomes detectable (the corresponding crack size $a(T_d) = a_d$) and T_c is a random time when the crack reaches its critical size (the corresponding crack size $a(T_c) = a_c$), the size of the crack can be approximated by the equation $a(t) = \alpha exp(Qt)$. Then we have:

$$T_c = (\log a_c - \log \alpha) / Q = C_c / Q, \; T_d = (\log a_d - \log \alpha) / Q = C_d / Q. \tag{1}$$

For the calculation of the probability of the fatigue crack detection during an inspection we need to know the distribution of the vector (T_d, T_c). For the considered numerical example here (see the 5-th section) we study the simplest case: a random variable (rv), $\log(Q)$, has a normal distribution with an unknown mean θ and the known standard deviation. And we assume that if θ is known then the distribution of the vector (T_d, T_c) is also known. The estimate $\hat{\theta}$ of the parameter θ can be obtained by the regress analysis of the result of the fatigue test of AC of the same type in the laboratory (i.e. processing the observations of the fatigue crack: pairs {(time, fatigue crack size)$_i$, i=1,…,m}, where m is the number of the fatigue crack observations.

2. Calculation of the probability of a fatigue failure of one aircraft, the fatigue failure rate and the economical effectiveness of the airline for the known θ

For the known θ, there are two decisions: 1) the aircraft is good enough and the operation of this aircraft type can be allowed, 2) the operation of the new type of AC is not allowed and a redesign of AC should be done. In the case of the first decision, the vector $t = (t_1, \ldots, t_n)$, where t_i is the time moment of

i-th inspection, should also be defined. If θ is known the different rules can be offered for the choice of the structure of the vector t:1) every interval between the inspections is equal to the constant $\Delta_t = t_{SL} / (n+1)$, where t_{SL} is the aircraft specified life (SL) (the retirement time), n is the number of inspections, 2) the conditional probabilities of a failure in every interval is equal to the same value $P(T_C < t_{SL})/(n+1)$ … In this paper we assume the first type of the choice and the vector t is defined by the fixed t_{SL} and the choice of n .

For the substantiation of the choice of the inspection number we should know FFP of AC and FFR and the gain of AL as the functions of n . For this purpose the process of an operation of AC can be considered as an absorbing Markov chain (MCh) with $(n+4)$ states. The states $E_1, E_2, \ldots, E_{n+1}$ correspond to the AC operation in the time intervals $[t_0, t_1), [t_1, t_2), \ldots, [t_n, t_{SL})$. States E_{n+2} , E_{n+3} and E_{n+4} are the absorbing states: AC is discarded from the service when the SL is reached or fatigue failure (FF), or fatigue crack detection (CD) take place.

	E_1	E_2	E_3	...	E_{n-1}	E_n	E_{n+1}	E_{n+2} (SL)	E_{n+3} (FF)	E_{n+4} (CD)
E_1	0	u_1	0	...	0	0	0	0	q_1	v_1
E_2	0	0	u_2	...	0	0	0	0	q_2	v_2
E_3	0	0	0	...	0	0	0	0	q_3	v_3
...	...	...	...	...	...	...	...	...	...	...
E_{n-1}	0	0	0	...	0	u_{n-1}	0	0	q_{n-1}	v_{n-1}
E_n	0	0	0	...	0	0	u_n	0	q_n	v_n
E_{n+1}	0	0	0	...	0	0	0	u_{n+1}	q_{n+1}	v_{n+1}
E_{n+2} (SL)	0	0	0	...	0	0	0	1	0	0
E_{n+3} (FF)	0	0	0	...	0	0	0	0	1	0
E_{n+4} (CD)	0	0	0	...	0	0	0	0	0	1

Figure 1. Probability matrix P_{AC}

In the corresponding transition probability matrix, P_{AC} , let v_i be the probability of a crack detection during the inspection number i , let q_i be the probability of the failure in the service time interval $t \in (t_{i-1}, t_i)$, and let $u_i = 1 - v_i - q_i$ be the probability of the successful transition to the next state. In our model we also assume that an aircraft is discarded from the service at t_{SL} even if there are no any cracks discovered by the inspection at the time moment t_{SL} . This inspection at the end of $(n+1)$ -th interval (in state E_{n+1}) does not change the reliability but it is made in order to know the state of the aircraft (whether there is a fatigue crack or there is no fatigue crack). It can be shown that $u_i = P(T_d > t_i | T_d > t_{i-1})$, $q_i = P(t_{i-1} < T_d < T_c < t_i | T_d > t_{i-1})$, $v_i = 1 - u_i - q_i$, $i = 1, \ldots, n+1$. In the three last lines of the matrix P_{AC} there are three units in the matrix diagonal because the states E_{n+2} , E_{n+3} and E_{n+4} are the absorbing states. All the other entries of this matrix are equal to zero.

Q	R
0	I

The structure of the considered matrix can be described in the following way: $P_{AC} = [Q\,R;\ 0\,I]$, where in the second line of this structure the matrix 0 is the sub matrix of zeros, I is the sub matrix of identity corresponding to the absorbing states of the matrix P. Then the matrix of the probabilities of absorbing in the different absorbing states for the different initial transient states $B = (I-Q)^{-1}R$. The failure probability of a new AC is equal to $p_f = aBb$, where the vector row $a = (1,0,\ldots,0)$ means that all the aircraft begin an operation within the first interval (state E_1), the vector column $b = (0,1,0)'$. We need also to know the mean number of steps of MCh up to the absorption $E(T_{AC}) = a(I-Q)^{-1}c$, where $c = (1,\ldots,1)'$ is the vector-column. The mean life of the aircraft will be equal to $\Delta_t E(T_{AC})$.

In the corresponding matrix for the operation process of AL, P_{AL}, the states E_{n+2}, E_{n+3} and E_{n+4} are not absorbing but correspond to the return of MC to the state E_1 (there are the units in the first column of the last 3 rows of the matrix P_{AL}; the AL operation returns to the first interval). The other lines of P_{AC} and P_{AL} are the same .

Using the definition of P_{AL} we can get the vector of stationary probabilities, which is defined by the equation system: $\pi P_{AL} = \pi$, $\sum_{i=1}^{n+4}\pi_i = 1$ and the airline gain $g(n) = \sum_{i=1}^{n+4}\pi_i g_i(n)$ where:

$$g_i(n) = \begin{cases} a_i u_i + b_i q_i + c_i v_i, i = 1,\ldots,n+1, \\ d_i, i = n+2,\ldots,n+4, \end{cases} \qquad (2)$$

a_i is the reward defined by the successful transition from one operation interval to the following one and the cost of one inspection; b_i, c_i and d_i correspond to the transition to the states E_{n+3} (FF), E_{n+4} (CD) and then to the state E_1 (the "cost" of FF of AC, fatigue crack detection, acquisition of the new AC). Let us note that $L_j = 1/\pi_j$ defines the mean step number to return to the same state E_j. So $\lambda_f = \pi_{n+3}/\Delta_t$ is the FFR. Let us note that in the considered case the same value can be calculated in another way. This value is equal to the ratio of the aircraft failure probability, p_f, to the mean life of the new aircraft: $\lambda_f = p_f / \Delta_t E(T_{AC})$ (recall, that $\Delta_t E(T_{AC})$ is the mean time of the renewal operation of AL in the first interval). If θ is known we calculate the gain as the function of n, $g(n,\theta)$, and choose the number n_g corresponding to the maximum of gain: $n_g(\theta) = \arg\max_n g(n,\theta)$. Then we calculate FFR as the function of n, $\lambda_f(n,\theta)$, and choose n_λ in such a way that for any $n \geq n_\lambda$ the function $\lambda_f(n,\theta)$ will be equal or less than some value λ: $n_\lambda(\lambda,\theta) = \min\{n : \lambda_f(n,\theta) \leq \lambda, \text{ for all } n \geq n_\lambda(\lambda,\theta)\}$. And finally we choose $n = n_{g\lambda}(\lambda,\theta) = \max(n_g, n_\lambda)$.

3. Probability of any fatigue failure in the fleet of aircraft for the known θ

We consider the case when the operation of all N aircraft will be stopped if any fatigue crack will be detected. In order to limit the probability of a fatigue failure in the fleet (FFPN), it is enough to find at least one fatigue crack before a failure of any aircraft in the fleet takes place. The corresponding probability is equal to the expected value of the random variable $P_{fNW} = (1-w)^R$, where w is a human factor: a probability, that a planned inspection will be done, R is the total random number of inspections before the first failure in the whole fleet. Let t_k^+, $t_{k-1}^+ < t_k^+$, $t_0^+ = 0$ be the "calendar" time moment when k-th aircraft begin the service, $T_{dk}^+ = t_k^+ + T_{dk}$, $T_{ck}^+ = t_k^+ + T_{ck}$, $k = 1,2,...,N$ be the random calendar time moments when fatigue crack can be discovered and fatigue failure of AC takes place correspondingly, see Fig. 2. And let $K_{SL} = \{k : T_{ck} < t_{SL},\ k = 1,2,...,N\}$ be a set of indexes of the aircraft, the failure of which can take place, if an inspection does not take place, $T_f^+ = \min\{T_{fk}^+ : k \in K_{SL}\}$, $T_{fk}^+ = \min\{T_{ck}^+,\ T_f^+\},\ k \in K_{SL}$, $R = \sum_{k \in K_{SL}} R_k$, where $R_k = \max(\{[(T_{fk}^+ - t_k^+)/\Delta_t] - [(T_{dk}^+ - t_k^+)/\Delta_t]\}, 0),\ k \in K_{SL}$, is the random inspection number of k-th aircraft from the set K_{SL} if inspection interval $\Delta_t = t_{SL}/(n+1)$ (it is supposed a specific "calendar" schedule of the inspections for each aircraft: , $i = 1,2,...,n+1$, $k \in K_{SL}$)

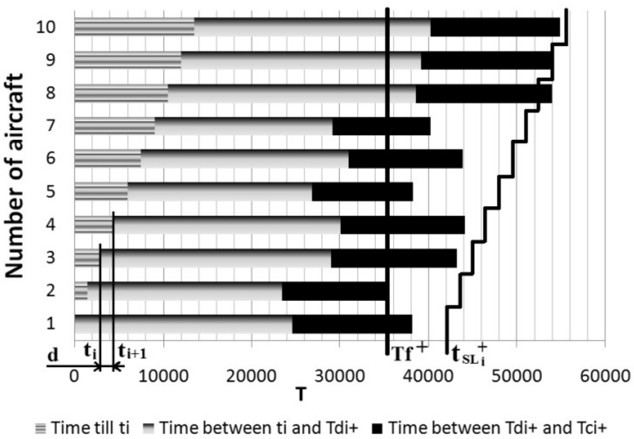

Figure 2. Inspection of N aircraft

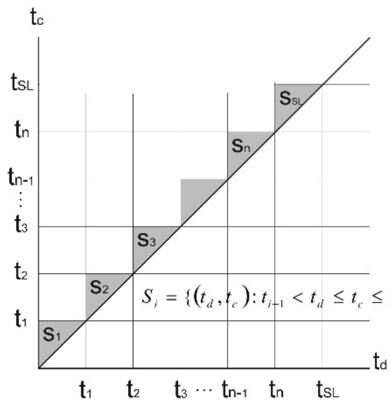

Figure 3. Example of set of sets $S_{Z,i}$

Random variable Q is the speed of the fatigue crack growth in the logarithm scale. It has a specific realization for each aircraft and $Q_1,\ldots,Q_N$ are independent random variables. So, a mean value of a random probability of failure in the fleet

$$E\left(P_{fNW}\right) = p_{fNW}\left(n,\theta\right) = \int_{-\infty}^{\infty} \ldots \int_{-\infty}^{\infty} \left(1-w\right)^{r(q)} dF_{Q_i}\left(q_1\right) \ldots dF_{Q_N}\left(q_N\right), \tag{3}$$

where $q=(q_1,\ldots,q_N)$, $r(q)$, is realization of rv *R*. For a large number *N* the Monte Carlo method is appropriate for the calculation of p_{fNW}. If this function is known then the number of the inspections, $n(p,\theta)$, required to limit the FFPN by value p is defined by the function $n(p,\theta)=\min(r: p_{fNW}(r,\theta)\le p \text{ for all } r>n(p,\theta),\ r=1,2,...)$

4. Solution for unknown θ

First, we consider the problem of the limitation of FFP1 in an operation of one AC with the human factor $w=1$. This means that if there is a detectable fatigue crack, then during the inspection we see it with probability 1 and the limitation of FFP1 of AC is provided by the choice of a specific p-set function, Paramonov *et al* (2011). Let us take into account that the operation of a new type of aircraft will not take place if the result of the acceptance fatigue test in the laboratory is "too bad" (previously, the redesign of a new type of AC should be done). We say that in this case the event $\hat\theta\notin\Theta_0$, $\Theta_0\subset\Theta$, takes place (for example, $\hat\theta\notin\Theta_0$ if fatigue life T_C is lower than some limit; or $n(p,\hat\theta)$ is too large,…). Let us define some set function

$$S(\Theta_0,n)=\begin{cases}\bigcup_{i=1}^{n+1} S_i(n) \ \ if \ \ \hat\theta\in\Theta_0,\\ \varnothing, \ if \ \ \hat\theta\notin\Theta_0\end{cases} \tag{4}$$

where $S_i=\{(t_d,t_c): t_{i-1}<t_d,t_c\le t_i\}$, $t_i=it_{SL}/(n+1)$, $i=1,...,n+1$; $\varnothing$ is an empty set.

It can be shown that for a very wide range of the definition of the set Θ_0 and the requirements to limit FFP1 by the value p^*, where $(1-p^*)$ is the required reliability, there is a preliminary "designed" choice of the allowed FFP1, p_{fD}, such that the corresponding set function $S(\Theta_0,n(p_{fD},\hat\theta))$ is p-set function of the level p^* for the vector $Z=(T_d,T_c)$: $\sup_\theta\sum_{i=1}^{n+1}P(Z\in S_i(n(p_{fD},\theta))=p^*$. This means that FFP1 will be limited by the value p^* for any unknown $\theta\in\Theta$.

In a similar way, there is such λ_{fD} that the choice of $n=n_{g\lambda}(\lambda_{fD},\hat\theta)$ provides the required limitation of the expected value of FFR, $E(\lambda_f(\hat\theta,\lambda_{fD},\Theta_0))$, by a some allowed value FFR, λ^*, for every unknown $\theta\in\Theta$. For the requirement of a high reliability, the choice of the inspection number will be defined by the limitation of FFR but for a very high "cost" of FF of AC the choice will be defined by the maximum of the gain.

Now, we consider the reliability of the fleet of N AC when there is information exchange and the operation of all aircraft is stopped if any fatigue crack is found during the inspection of any AC and, as it has been mentioned, in order to prevent a failure in the fleet, it is enough to find at least one fatigue crack before a failure of any aircraft in the fleet takes place. Let us define a multiple set function:

$$S^+(\Theta_0,n)=\bigcup_{k\in K_{SL}} S_k^+(\Theta_0,n) \tag{5}$$

where

$$S_k^+(\Theta_0,n)=\begin{cases}\bigcup_{i=1}^{n+1} S_{i,k}^+(n) \ \ if \ \ \hat\theta\in\Theta_0,\\ \varnothing, \ if \ \ \hat\theta\notin\Theta_0,\end{cases} \tag{6}$$

$S_{ik}^+=\{(t_{dk}^+,t_{ck}^+): t_{(i-1)k}<t_{dk},t_{ck}\le t_{ik}\}$, $t_{ik}^+=t_k^++t_i$, $t_i=it_{SL}/(n+1)$, $i=1,...,n+1$, $k=1,2,...,N$.
Again, it can be shown that for a very wide range of the definition the set Θ_0 and the requirements to the

limit FFPN by the value p^*, there is a preliminary "designed" choice of allowed FFPN, p_{fD}, such that the corresponding multiple set function $S^+(\Theta_0, n(p_{fD}, \hat{\theta}))$ is p-set function of level p^* for the set of vectors $\{Z_k^+,\ k \in K_{SL}\}$, where $Z_k^+ = (T_{dk}^+, T_{fk}^+)$:

$v(p_{fD}) = p^*$, where (7a)

$$v(p) = \sup_\theta v(\theta, p) \tag{7b}$$

$$v(\theta, p) = E\left\{\sum_{k \in K_{SL}} \sum_{i=1}^{n+1} P(Z_k^+ \in S_{ik}^+(n(p, \hat{\theta})))\right\} \tag{7c}$$

It means that FFPN will be limited by the value p^* for any unknown θ.

5. Numerical example

Here we consider only the problem of aircraft fleet. Assume that $t_{SL} = 40000$, w = 0.99, processing the result of full scale fatigue test we get the estimate of fatigue crack parameters $\hat{\theta}$=-8.5885, the standard deviation of log(Q) is equal to 0.346, α=0.286 mm, and let for considered inspection technology a_d=20 mm, a_c=237 mm (see fatigue crack in Fig. 2.32 in [1]).

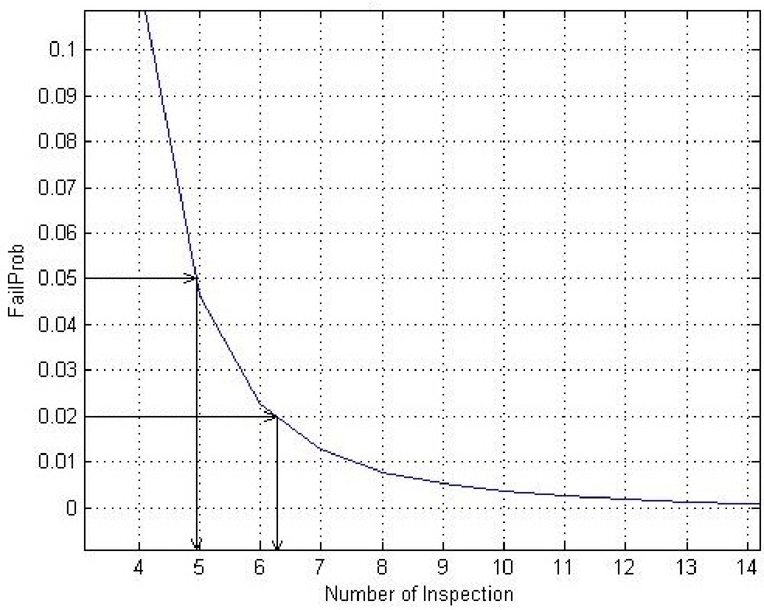

Figure 4. Example of function $p_{fNW}(n, \theta)$ (probability of crack detection) for θ_0=-8.5885

There are 10 aircraft in the fleet, the interval between the aircraft put in operation $d_t = 250$; the allowed failure probability $p^* = 0.05$, the set Θ_0 is defined by the condition : if $\hat{n} = n(0.05, \hat{\theta}) > 20$ then the redesign of AC should be done. Using the Monte Carlo calculation, we get $\hat{n} = n(0.05, \hat{\theta}) = 5$, see Fig.4.

But this calculation is correct only if in the service the same value of θ_0 takes place. In reality we do not know the θ_0. For such case we should limit the maximal possible failure probability for any θ_0. It can be done by the choice of a specific "designed" failure probability. The family of the functions

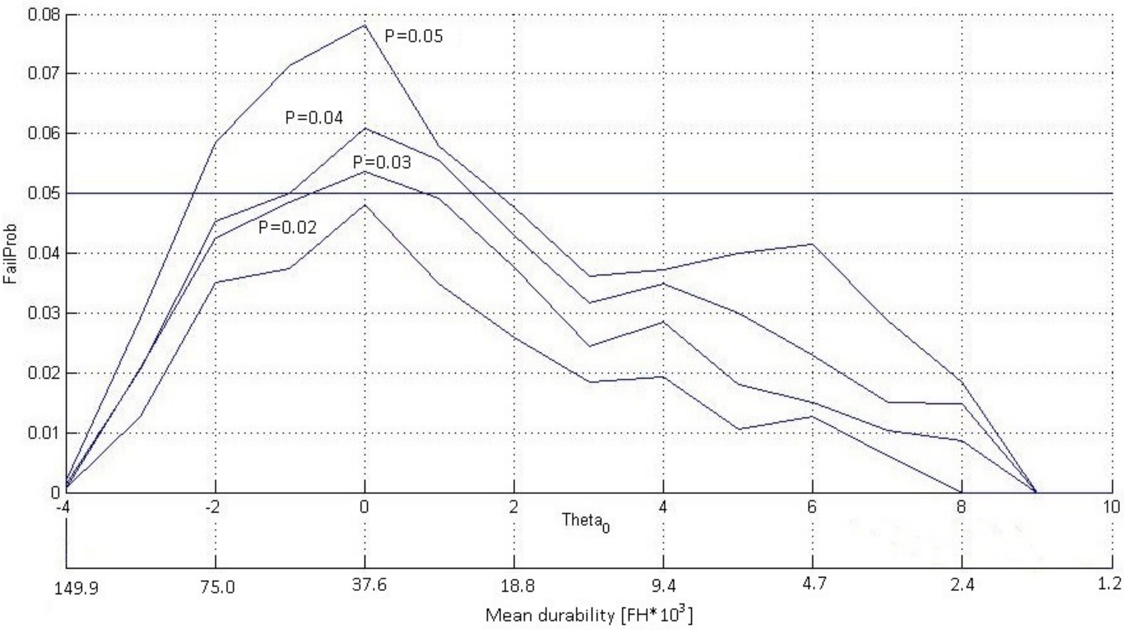

Figure 5. The function v(θ,p) for different p. In parallel axis the flight hours (FH*10^3) of the corresponding "Mean durability" = C_C / Q are given for $C_C = \log a_c - \log \alpha$, $Q = \exp(\theta_0)$

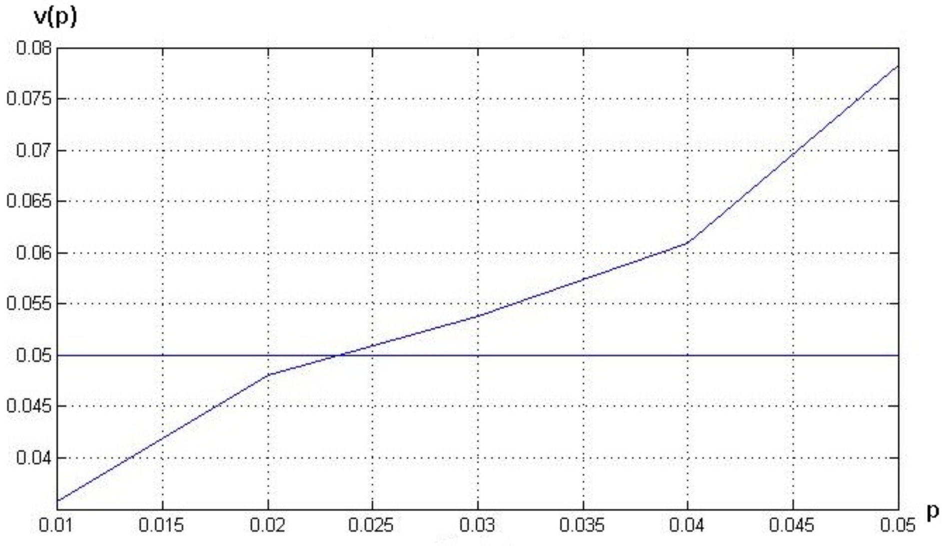

Figure 6. The function v(p)

$v(\theta, p)$ for different p is shown in Fig 5, where the corresponding calculations for parallel axis are done for the corresponding "Mean durability" "$= C_C / Q$ for $C_C = \log a_c - \log \alpha$, $Q = \exp(\theta_0)$,

In Fig.6 the function v(p) is shown for the considered example data. We see that in order to limit FFPN by the value $p^* = 0.05$ the value $p_{fD} = 0.02$ should be chosen. Now, using the function $p_{fNW}(n, \theta)$ which is shown in Fig.4 for the test estimate of the fatigue crack parameters $\hat{\theta}$=-8.5885 , the number of inspections should be chosen to be equal to $\hat{n} = n(0.02, \hat{\theta}) = 7$. More complex examples of the inspection planning can be found in [1-3].

6. Conclusions

It has been found, how, with the use of the estimate of the unknown parameter $\hat{\theta}$ (after the acceptance fatigue test), one of the two decisions should be chosen: 1) to do the redesign of a new type of AC if the result of the test is “too bad” or 2) to make a choice of the number of inspections $n = n(p_{fD}, \hat{\theta})$ as the function of $\hat{\theta}$ and a specific p_{fD}. In this case the required reliability can be provided for any unknown parameter θ and under this condition the maximum of the economic efficiency can be reached.

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HOW TO TRAIN SAFE DRIVERS: SETTING UP AND EVALUATING A FATIGUE TRAINING PROGRAM

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Fatigue is considered as a serious risk driving behavior, causing road accidents, which in many cases involve fatalities and severe injuries. According to CARE database statistics, professional drivers are indicated as a high-risk group to be involved in a fatigue-related accident. Acknowledging these statistics, a training program on driving fatigue was organized, aiming at raising awareness of professional drivers of a leading company in building materials, in Greece. Selected experimental methods were used for collecting data before and after the training program, which allowed monitoring and assessing the potential behavioural changes. A questionnaire survey was conducted before the program implementation to 162 drivers of the company, while two months after the program, the same drivers replied to a second questionnaire. Impact assessment of the program relied on statistical analysis of the responses. Results showed the degree of penetration of the training program in the professional drivers' behavior towards safe driving.

Keywords: fatigue; program; impact assessment; professional drivers.

1. Introduction

Falling asleep at the wheel is one of the leading factors causing road accidents and injuries worldwide. The National Highway Traffic Safety Administration (NHTSA) of the United States of America estimates that there are 56.000 sleep related crashes annually in the USA, resulting in 40.000 injuries and 1.550 fatalities (Royal, 2003). In 2002, in a survey of the same organization, 37% of drivers reported that they had fallen asleep or nodded off, even for a moment, when driving (NHTSA, 1998). In Australia, VicRoads estimates that 25%-35% of road crashes are sleep related (VicRoads, 2014), while the results of a study by Moller of the University Health Network and the University of Toronto Sleep Research Unit in Canada, showed that driver fatigue is a serious factor hindering road safety, since it causes the death of 400 Canadians every year (Yakabuski, 2014). In China, in 2011, the Traffic Administration Bureau of Chinese Ministry of Public Security reported that 1003 out of 1755 recorded fatigue driving accidents were fatal, meaning that there is almost one death for every two fatigue related accidents (Traffic Administration Bureau of Chinese Public Security Ministry, 2010). At a European level, a study by the Sleep Research Center indicates that driver fatigue causes up to 20% of accidents on motorways in United Kingdom (Horne & Reyner, 2000). In Germany, a study of motorway accidents in Bavaria estimated that 35% of fatal motorway crashes were due to reduced vigilance, i.e. driver inattention and fatigue (Hell et al., 1997). In Finland, the proportion of fatal accidents involving fatigue or falling asleep between 1995 and 1999 was ranging between 16-19% (ETSC, 2001).

The above statistics validate that driver fatigue is a contributing factor in many accidents, and the gravity of this contribution can be quantified by an average proportion of 20% of total accidents that are fatigue related (MacLean et al., 2003). Previous studies have also stressed the significant impact of fatigue on driving performance, such as slower reaction times, poor speed control, reduced vigilance, reduced information processing, late corrections to lane positioning, and increased drifting within lane (Otmani et al., 2005).

On the other hand, although drivers do have the ability to recognize when they feel sleepy (Horne & Baulk, 2004), and they also have extensive knowledge about the factors that cause fatigue while driving, still a significant proportion of them chooses to keep driving.

Drivers often keep driving while fatigued, adopting several strategies that they may consider as efficient, such as drink a coffee, open the window, listen to music, talk with passengers, stop and rest, however all these strategies are only partially effective in coping with fatigue (Oron-Gilad & Shinar, 2000). In Royal (2003), it was observed that the most commonly reported coping actions were to pull over and take a nap, open the window and drink a caffeinated drink (Royal, 2003). Mental games or similar actions are also tasks that drivers are engaged in, when they feel fatigued while driving (Maycock, 1997). In the case of professional drivers, a survey conducted by Oron-Gilad and Shinar (2001), showed that over 50% of the surveyed military truck drivers stated that drinking a coffee or water helps them staying awake, while approximately 40% of the drivers reported that drinking caffeinated soft drinks and smoking cigarettes work as solutions to encounter fatigue (Oron-Gilad & Shinar, 2000).

According to literature, specific groups of road users are indicated as of higher risk to be involved in a fatigue-related accident, i.e. young drivers (Horne & Reyner, 1995), shift workers (Gkrizioti et al., 2010), drivers with sleep disorders (Yee et al., 2002), and professional drivers (McKernon, 2008). Nevertheless, in all types of users, fatigue deteriorates the ability of drivers to control their vehicles, by affecting their attention, reaction and vigilance, increasing in such cases the probability of a road accident occurrence. When drivers choose to drive under fatigue, their behavior is apparently dangerous. Such a dangerous behavior, in the case of professional drivers, could be related to economic rewards (Arnold et al., 1997), but also to other factors that influence their driving performance, including continuous driving time (trip duration), sleep deprivation (bad quality of sleep, lack of sleep, sleep apnoea) and work schedule (night trips, shifts). A number of studies have indicated that driving performance is negatively affected by driving time, which stands as the main factor influencing drivers' abilities (Otmani et al., 2005), along with driving in a monotonous environment and circadian effects (Rossi et al., 2011). In the study of Zhang et al. (2014), the effects of circadian rhythms on driving performance were investigated in an on-road experiment, and results showed that a driver was most likely to feel tired between 14:00-16:00 and 02:00-04:00, time periods during which drivers' ability to stay within designated lane lines was significantly reduced (Zhang et al., 2014). The peak period for driver fatigue between midnight and 06:00 was also indicated in an American study (Blower et al., 1993), which revealed that approximately 20% of all fatal crashes and fatalities and 10% of all injuries involving a long-haul truck occurred in this time period.

There is evidence in statistics which shows that professional drivers are at a high risk of road accidents worldwide, i.e. in USA, approximately 25% of fatal work-related accidents are road traffic incidents (Toscano & Windau, 1994), while in European countries i.e. Denmark, Finland and Sweden the relevant proportion reaches 20% (Charbotel et al., 2001). According to CARE database, tiredness is the main factor for 20% of crashes involving commercial vehicles, one fourteenth of fatalities involving heavy goods vehicles, and more than 10% of total fatalities involving professional vehicles (CARE, 2014). Similar findings are revealed from self-reported surveys, i.e. in Norway, 10% of male drivers and 4% of females stated that they had fallen asleep while driving during the last year (Sagberg, 1999), while the 29% of respondents in a study in Great Britain, stated that they had felt close to falling asleep while driving in the past year (Maycock, 1997).

Three main categories of driving fatigue countermeasures are recognized in literature. The first one includes in-car technologies, such as systems that can detect driver sleepiness through monitoring drivers' eye and head movements. However, such systems have a significant limitation, which is the weakness to account for individual driver characteristics (Liu et al., 2009). The second category refers to road-related countermeasures, and the most widely used techniques regard edge or centreline rumble devices (Anund et al., 2008), and surfacing of the road shoulders with different coloured asphalt (Rosey et al., 2008).

Driver related countermeasures, which is the third category of interventions to combat fatigue, seem to be the most logical and probably most effective methods to reduce fatigue related accidents (Merat & Jamson, 2013), since these methods foresee that drivers are sufficiently educated, trained and informed about the risks arising when driving under fatigue, as well as about the scientifically sound means to prevent or encounter fatigue. The ultimate objective of these programs is the elimination or reduction of crashes and the ensurance of drivers' safety and products' security. Even if the concept of safety programmes seems to be inspiring, their practical implementation, mainly affected by economic reasons, is still limited.

Acknowledging the findings of the above state-of-the-art review, which revealed that driving fatigue is a leading factor of road accidents, as well as that professional drivers are at a high risk of road accidents, including those fatigue-related, the aim of this paper is to assess the impact of a training program on driving fatigue, targeting 162 professional drivers of a leading company in building materials in Greece.

2. Method

2.1 Design and realization of the training program

Within the framework of accomplishing educational and research activities and undertaking initiatives for the promotion of traffic safety, the Transportation Engineering Laboratory of the University of Thessaly, organized training program on driving fatigue, aiming at raising awareness of professional drivers on a leading company in building materials in Greece. The one-month educational program took place in eight cities, where the company is established, ensuring national geographical coverage and trained 162 employees in total.

Taking into consideration that, even though drivers have the ability to recognize when they feel tired or sleepy, still a significant number of them keep driving under fatigue (Horne & Baulk, 2004), the objectives of the training program were to raise knowledge of the effective countermeasures for fatigue (i.e. to stop and rest) and persuasion for avoiding ineffective solutions, to increase risk perception when driving tired, to increase intention for taking a short break when feeling tired, and to increase the number of drivers who take a short break when they feel tired, and decrease the proportion of those drivers who use other solutions.

The training program involved a 2-hour lecture by the trainer, which included the following sections: the physiological basis of fatigue (i.e. sleep loss and recovery, influence of the circadian biological clock, the effects of shift work, etc.); the regulatory framework and legislation regarding professional driving (duration of continuous driving, expected breaks, etc.); the impact of fatigue on driving skills and crash risk; recommendations for personal countermeasure strategies and company policies, and introduction to suspected sleep disorders and referral to specialist treatment. An open discussion session followed after the lecture, during which drivers expressed their personal experiences about driving under fatigue and the solutions they usually choose to adopt in order to encounter sleepiness or tiredness. Each driver received a folder with the training materials for later reference.

2.2 Evaluation design

For the achievement of high reliability and the measurability of the effectiveness, the design of the evaluation of an intervention, i.e. training program, should be based on a scientific design, such as experimental (random sampling) or quasi experimental designs (Fylan et al., 2006). At least two periods of measurements, one before and the second after the implementation of the program allow the indication of any changes in driving behavior or accidents rates attributed to the realization of the training program. Such measurements are related to attitudes, subjective and descriptive norms, perceived behavioral control and intentions along with behavior (Fylan et al., 2006).

In addition, there is strong evidence in literature that the adoption of a theoretical background works effectively when designing and evaluating a road safety program, such as campaigns or training activities (Forward et al., 2009). Theory of Planned Behavior (TPB) (Ajzen, 1991) was selected as the theoretical model for the construction of the measurement variables and the development of the questionnaire, which was the technique used for the data collection. TPB associates human behavior with attitude and intention, taking into account the effect of social norms in the prediction of the behavior (Ajzen, 1991).

The measurements of the above constructs were obtained from a structured questionnaire survey, which was conducted before and after the training program. Specifically, right before the beginning of the training lecture that was given in each of the eight venues of the company, a face-to-face questionnaire survey was conducted to the trainees. The total sample that participated in the training program and survey consisted of 162 male drivers with an age of 44.08 ±10.5 years (mean ± standard deviation). The majority of participants (74,4%) drives every day, 17.5% of them 3-5 times a week, 6.9% 2-5 times a week, and the rest of them less frequently thus 0.55% once a week and 0.55% less often. Achieving a response rate of 87.7%, 142 out of the 162 above drivers replied and mailed back to the Laboratory a second questionnaire, which had been distributed to them two months after the program. Although the questionnaires were anonymous, the use of a coding system ensured the pairwise data collection before and after the program implementation.

The structure of the questionnaire, apart from demographics, included the appropriate questions in order to measure specific variables explaining behavior, such as knowledge, behavioral and control beliefs, behavioral intentions, descriptive norms, risk comprehension, past behavior and self-reported behavior. The core part of the questionnaire was responded using a 7-point scale, ranging from 1 (Strongly disagree/very unlikely/not at all/never) to 7 (Strongly agree/very likely/a lot/always), depending on the topic addressed.

Analytically, the variables tested, the statements or questions expressing them and their coding is presented in Table 1:

Table 1: Variable classification

Statements or questions expressing:	**Code**	**Statements or questions expressing:**	**Code**
Knowledge about:	***KN***	***Control beliefs***	***C***
Main factors causing driving fatigue	KN1	I would stop and rest or plan my trip, if there were more police controls	C1
Main signs of fatigue	KN2	I would stop and rest or plan my trip, if I had faced a bad experience in my family or work environment	C2
The most effective solution to fatigue	KN3	I would stop and rest or plan my trip, if there were more information / raising awareness campaigns or training programs	C3
The high likelihood of get involved in a crash when driving tired	KN4	***Descriptive norms***	***DN***
Behavioural beliefs	***BB***	My colleagues stop and rest during their trip	
A good solution to fatigue is to drink a coffee	BB1	***Past behavior***	***PB***
A good solution to fatigue is to open the window for fresh air	BB2	Frequency of driving tried in the last month	PB1
A good solution to fatigue is to listen to music	BB3	Frequency of falling asleep or almost falling asleep at the wheel in the last month	PB2
A good solution to fatigue is to stop and rest	BB4	Frequency of falling asleep at the wheel and got involved in a crash	PB3
A good solution to fatigue is to plan your trip	BB5	Frequency of sleeping less than six hours the night before your trip	PB4
Risk comprehension about:	***RS***	***Self-reported behavior***	***B***
Getting involved in an accident or causing an accident	RS	When I get tired, I stop and rest	B1
Behavioural intentions	***INT***	When I get tired, I drink a coffee	B2
When tired in the next month, I intend to stop and rest	INT1	When I get tired, I listen to music	B3
I intend to plan my next trips	INT2	When I get tired, I open the window	B4
When tired in the next month, I intend to follow other countermeasures	INT3		
When tired in the next month, I intend to drive anyway	INT4		
When tired in the next month, I intend to quit my trip	INT5		

2.3 Data analysis

For the data analysis, both descriptive and inferential statistics were used. In the first case, a number of the sample characteristics, such as age, the years owning a professional driving licence, the frequency of driving, etc. were analyzed, by estimating mean values and standard deviations. Regarding inferential statistics, the statistical analysis of the responses was carried out using nonparametric tests, which are regarded as particularly powerful for analyzing data collected through questionnaire surveys (Siegel & Castellan, 1988).

Hypothesis testing was used to assess any differences in driving behavior before and after the training program realization. The null hypothesis H_0 was that the median difference between the pairs is zero, and the alternative hypothesis H_1 was that the median difference is not zero. Chi-square (X^2) test for homogeneity was used to test differences in characteristics measured by categorical variables (i.e. "yes", "no"), while Wilcoxon Signed-Rank Test was performed to assess differences between the samples in characteristics measured on the 7-point scale. A confidence level of 95% and confidence interval of 5% were assumed.

Lastly, in order to investigate the inter-relationships between the individual measurement variables and their relationship with the self-reported variables, bivariate correlations were conducted. In addition, for the development of prediction modes, linear regression analyses were used.

3. Results

3.1 Impact assessment of the training program on driving behavior

In this section, the results of the assessment of the impact of the training program on driving behavior are presented, addressed by the relevant measurement variables tested. Specifically, knowledge is described by 4 categorical variables, each of which had two mutually exclusive alternatives thus, "Yes" or "No", while, the trainees also indicated their perceptions, on a 7-point scale, in 23 ordinal variables, 5 addressing behavioral beliefs, 1 risk comprehension, 5 behavioral intentions, 3 control beliefs, 1 descriptive norms, 4 past behavior and 4 self-reported behavior.

As far as knowledge is concerned, results showed a significant increase of the proportion of the trainees who were aware of the effects of fatigue on driving after the training program (99.3%), compared to the proportion before the program realization (98.6%) (p-value=0). Similar results were indicated when testing the proportion of the trainees who were aware about the most effective solution to fatigue thus, to stop and rest, and the relevant rates were 92.3% and 99.3% in the before and after phases (p-value=0.001), respectively. As far as the knowledge on the factors that cause fatigue and that driving tired could involve them to a crash, it was observed that all trainees had already this knowledge before the training program implementation.

The positive impact of the training program was, also, observed, when testing the ordinal variables. In this case, Wilcoxon Signed-Rank tests were performed and the results are summarized in Table 1, in which the average ratings for each variable before and after the training program are presented, as well as the z-statistic, the calculated effect size ($r=z/\sqrt{N}$, where N is the total number of observations) and p-value, indicating the strength of the respective evidence. Results showed that the average ratings of behavioral beliefs, risk comprehension and behavioral intentions, follow the "positive" direction of change, thus, the adoption of effective countermeasures for fatigue, such as trip planning and powernap (Van Dongen et al., 2003), while, other countermeasures that are falsely used, such as coffee drinking, listening to music, etc. (Heatherley, 2011) seem to be preferred less by drivers, after the training program.

Also, an increase was indicated in the values of variables addressing control beliefs after the training program, showing that if enforcement was stricter (r=-0.1, p-value=0.077) or if someone of the family or work environment of the trainees had a bad experience on the roads due to fatigue (r=-0.03, p-value=0.614), that would raise their awareness and urge them to safer driving. In addition, results showed an increase after the program implementation in trainees' responses referring to their colleagues who stop and rest when tired (r=-0.04, p-value=0.523).

On the other hand, a decrease was observed in the frequency of the trainees that drive under fatigue (r=-0.05, p-value=0.381), the frequency of falling or almost falling asleep at the wheel (r=-0.04, p-value=0.515) and the frequency of falling asleep and getting involved in a crash (r=-0.05, p-value=0.441). Although these differences before and after the program implementation were not statistically significant, however, the average ratings show that the frequency of risky behavior was already low before the program.

Finally, as regards self-reported behavior, results showed that the training program affected positively the direction of change in the behavior of the trainees, since a significant increase was indicated in the adoption of the proposed by the program effective countermeasure thus to stop and rest when tired (r=-0.17, p-value=0.004), while a relevant significant reduction was observed in other countermeasures that are falsely used, i.e. coffee drinking (r=-0.24, p-value=0), listening to music (r=-0.22, p-value=0) and opening the window (r=-0.26, p-value=0).

Table 2: Average rating and summary of test results for comparison between the phases of the training program

Ordinal variables	Average rating		z-statistic	Effect size (r)	p-value
	B	A			B vs. A
Behavioral beliefs: "A good solution to fatigue is to..."					
Drink a coffee	3.57	2.94	-3.338	-0.2	0.001*
Open the window for fresh air	4.14	3.40	-3.763	-0.22	0*
Listen to music	3.26	2.48	-4.344	-0.26	0*
Stop and rest for 15-20 minutes	5.92	6.13	-1.033	-0.06	0.301
Plan my trip	6.15	6.53	-2.476	-0.15	0.013*
Risk comprehension about:					
Getting involved or causing an accident	6.15	6.51	-1.893	-0.11	0.058
Behavioral intentions: "When tired in the next month, I intend to..."					
Stop and rest for 15-20 minutes	5.15	6.44	-6.054	-0.4	0*
Plan my trip	5.98	6.51	-3.016	-0.18	0.003*
Follow other solutions	4.25	3.61	-2.643	-0.16	0.008*
Drive anyway	3.85	2.86	-4.070	-0.24	0*
Interrupt my trip	4.55	6.09	-6.135	-0.36	0*
Control beliefs: "I would stop and rest or I would plan my trip, if..."					
Enforcement was more strict	4.33	4.75	-1.766	-0.1	0.077
Someone of my family or colleagues had a bad experience	4.83	4.91	-0.504	-0.03	0.614
Campaigns or training programs were implemented more often	5.39	5.36	-0.221	-0.01	0.825
Descriptive norms:					
My colleagues stop and rest during their trip	5.05	5.13	-0.639	-0.04	0.523
Past behavior:					
Frequency of driving under fatigue	2.20	2.09	-0.876	-0.05	0.381
Frequency of falling asleep or almost falling asleep at the wheel	1.29	1.23	-0.652	-0.04	0.515
Frequency of falling asleep and getting involved in a crash	1.11	1.06	-0.770	-0.05	0.441
Frequency of sleeping less than 6 hours before a planned trip	2.94	2.77	-0.768	-0.05	0.443
Self-reported behavior: "When I get tired..."					
I stop and rest for 15-20 minutes	6.15	6.50	-2.880	-0.17	0.004*
I drink a coffee	4.28	3.44	-4.052	-0.24	0*
I listen to music	3.73	2.99	-3.725	-0.22	0*
I open the window	5.01	4.08	-4.452	-0.26	0*
*B:Before, A:After; *Statistically significant, p-value<0.05*					

3.2 Inter-relationships between measurement variables

Based on the main objectives of the training program thus to increase the awareness of the professional drivers (trainees) that the most effective solution to encounter fatigue is to stop and rest when feeling tired, and, on the other hand, to decrease the number of drivers who follow other ineffective countermeasures when tired, i.e. to drink a coffee, listen to music or open the window for fresh air, two alternative tests were run, respectively. For the needs of the present paper, these tests were based on the responses of the drivers after the implementation of the training program. Taking into account the number of trainees who completed all fields of the questionnaire, the sample size was 136 drivers.

Applying the first test, an effort was made to investigate the inter-relationships between a number of measurement variables and their relationship with the variable addressing self-reported behavior towards stopping and resting when tired. In addition, the first test included the development of a model predicting the impact of the training program in terms of affecting drivers to stop and rest whey they get tired.

On the other hand, the aim of the second test was to investigate the inter-relationships between a number of measurement variables and their relationship with the variable addressing self-reported behavior towards following other solutions to fatigue than stopping and resting. Once again, a prediction model was developed associated with the effectiveness of the program to convince drivers not to use ineffective solutions when they have to deal with fatigue.

Table 3 presents the bivariate correlations of the individual variables and their relationship with the variable addressing self-reported behavior towards stopping and resting. In this case, the dependent variable thus self-reported behavior towards stopping and resting (variable B1 of Table 1) was correlated with behavioral belief that a good solution to fatigue is to stop and rest (variable BB4 of Table 1), risk comprehension about getting involved in an accident or causing an accident (variable RS of Table 1), control belief addressing drivers beliefs on whether they would stop and rest or plan their trips in case there were more police controls (variable C1 of Table 1), if they had faced a bad experience in their family or work environment (variable C2 of Table 1) or if there were more information / raising awareness campaigns or training programs (variable C3 of Table 1) and descriptive norm addressing drivers' perception on actual situations, such as "My colleagues stop and rest during their trip" (variable DN of Table 1). Also, B1 was correlated with variables addressing past behavior of drivers, and in this case, using alpha test (Cronbach, 1951) the responses of drivers about the frequency of driving tired in the last month (variable PB1 of Table 1), the frequency of falling asleep or almost asleep at the wheel in the last month (variable PB2 of Table 1) and the frequency of falling asleep at the wheel and got involved in a crash (variable PB3 of Table 1) were combined into one variable, hereinafter PB123, with a value of Cronbach alpha equal to 0.6. The fourth variable (variable PB4 of Table 1) regarding the frequency of sleeping less than six hours the night before the trip was used individually. The last variable was the age of drivers, and three clusters were defined: 18-25 years old, 26-50 years old, and over 50 years old.

Table 3: Bivariate correlations of the individual variables and their relationship with the variable addressing self-reported behavior towards stopping and resting when tired

Variables	Code	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1. Self-reported behavior_1	B1	-										
2. Behavioral belief_4	BB4	.3	-									
3. Risk comprehension	RS	.15	.04	-								
4. Behavioral intention_1	INT1	**.25****	.17	**.31****	-							
5. Control belief_1	C1	-.04	**.28****	.06	.08	-						
6. Control belief_2	C2	-.04	.03	.03	.14	**.29****	-					
7. Control belief_3	C3	-.02	.19*	.16	.12	**.42****	**.26****	-				
8. Past behavior_123	PB123	**-.28****	.14	-.16	**-.27****	-.05	-.09	-.13	-			
9. Past behavior_4	PB4	**-.23****	**-.17***	**-.2***	**-.21***	-.11	-.02	-.12	**.3****	-		
10. Descriptive norm	DN	**.3****	.05	.12	.17	.07	.09	.12	-.13	-.08	-	
11. Age	AGE	.15	-.04	.02	.1	.15	**.22***	**.25****	-.2*	-.1	**.19***	-
**p-value<.05*												
***p-value<.01*												

Results showed that behavioral intention and descriptive norm are significantly correlated with the variable addressing self-reporting behavior towards stopping and resting when tired (Table 3). Positive relationships were also observed between behavior and behavioral belief, risk comprehension and age, however these correlations were not significant. On the other hand, a negative relationship was indicated between behavior and the variables referring to past behavior and intention, showing that when the values of behavior increase, the values of past behavior and control beliefs decrease.

Focusing on the second test that was conducted, the dependent variable was self-reported behavior towards following other solutions to fatigue than stopping and resting, and was constructed by the combination of the variables B2, B3 and B4 of Table 1 (hereinafter B234), which record self-reported behavior of the drivers who choose to drink a coffee, listen to music and open the window for fresh air, when they get tired while driving. For the combination of B2, B3 and B4, alpha test was used again and the Cronbach alpha value was equal to 0.89. Similarly, behavioral beliefs in this case was constructed by the combination of variables BB1, BB2 and BB3 of Table 1 (hereinafter BB123), and Cronbach a was calculated to 0.87. The dependent variable was also correlated with the variable expressing drivers' intention to follow other countermeasures to deal with fatigue (variable INT3 of Table 1), while risk comprehension (RS), control beliefs (C1, C2 and C3), past behavior (PB123 and PB4) and age were the same variables as those used in the first test. The results of the bivariate correlations of the above measurement variables and their relationship with the dependent variable adressing self-reported behavior towards following other solutions to fatigue, i.e. drinking a coffee, listening to music and opening the window for fresh air, are presented in Table 4.

Table 4: Bivariate correlations of the individual variables and their relationship with the variable addressing self-reported behavior towards following other solutions to fatigue than stopping and resting when tired

Variables	Code	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1. Self-reported behavior_234	B234	-										
2. Behavioral belief_123	BB123	**.75****	-									
3. Risk comprehension	RS	**-.17***	-.12	-								
4. Behavioral intention_3	INT3	**.72****	**.69****	**-.26****	-							
5. Control belief_1	C1	.09	.05	.06	.1	-						
6. Control belief_2	C2	**-.2***	-.12	.03	**-.25****	**.29****	-					
7. Control belief_3	C3	-.09	-.02	.16	-.08	**.42****	**.26****	-				
8. Past behavior_123	PB123	**.36****	.16	-.16	**.17***	-.05	-.09	-.13	-			
9. Past behavior_4	PB4	**.26****	**.19***	**-.2***	**.26****	-.11	-.02	-.12	**.33****	-		
10. Descriptive norm	DN	**-.25****	-.14	.12	.13	.07	.09	.12	-.13	-.08	-	
11. Age	AGE	-.09	-.06	.02	-.07	.15	**.22***	**.25****	**-.2***	-.1	**.19***	-
**p-value<.05*												
***p-value<.01*												

Based on the findings of Table 4, it was observed that behavioral belief (BB123), behavioral intention (INT3) and past behavior (PB123, PB4) were significantly correlated with self-reported behavior (B234). Positive relationship was also indicated between behavior and control belief_1 (C1), but this correlation was not significant. On the other hand, negative relationships were observed between behavior and the variables addressing risk comprehension, control belief_2 and descriptive norm, and these negative correlations were significant. Lastly, negative relationships were indicated between behavior and control belief_3 and age, however these correlations were not significant.

3.3 Prediction model development and testing

The last objective of this study was to develop prediction models in order to investigate which factors are associated with the likelihood of drivers to stop and rest when they get tired while driving, as well as the respective likelihood of drivers to follow other solutions to deal with fatigue, such as to drink a coffee, listen to music or open the window for fresh air. The results of the two prediction models are presented in Tables 5 and 6.

In the first case, behavioral belief_4 (BB4), risk comprehension (RS), behavioral intention_1 (INT1), control belief_1 (C1), control belief_2 (C2), control belief_3 (C3), past behavior (PB123 and PB4), descriptive norm (DN) and age were used as predictors of the dependent variable thus self-reported behavior towards stopping and resting when tired. Results showed that the strongest, statistically significant, predictor was descriptive norm. The overall model was a significant predictor of behavior (F(10, 135)=1.955, p-value<.05)) and accounted for 10% of the variance. Analytically, the relationship of each predictor with behavior is presented in Table 5.

Table 5: Linear regression of the individual variables and their relationship with the variable recording self-reported behavior towards stopping and resting when tired

Variable	**Code**	**B**	**Std. Error**	**Beta**	**t**	**Sig.**
Behavioral belief_4	BB4	-.007	.048	-.013	-.140	.889
Risk comprehension	RS	.095	.092	.090	1.032	.304
Behavioral intention_1	INT1	.119	.076	.136	1.560	.121
Control belief_1	C1	.0	.041	-.001	-.012	.991
Control belief_2	C2	-.047	.035	-.119	-1.344	.182
Control belief_3	C3	-.038	.053	-.072	-.730	.467
Past behavior_123	PB123	-.145	.113	-.116	-1.281	.203
Past behavior_4	PB4	-.018	.039	-.041	-.407	.639
Descriptive norm	DN	**.102**	.047	.186	2.174	**.032***
Age	AGE	.185	.157	.105	1.175	.242
Constant		4.886	.921		5.307	0
Adjusted R^2=.1; F(10, 125)=1.955*						
**p-value<.05*						

On the other hand, focusing on the model tested for predicting behavior towards following other solutions to fatigue than stopping and resting, it was observed that behavioral beliefs, behavioral intention and past behavior were significant predictors of behavior, with behavioral belief being the strongest one. The overall model was a significant predictor of behavior (F(10, 135)=30.508, p-value<.01)) and accounted for 69% of the variance. Analytically, the relationship of each predictor with behavior is presented in Table 6.

Table 6: Linear regression of the individual variables and their relationship with the variable recording self-reported behavior towads following other solutions to fatigue than stopping and resting when tired

Variable	**Code**	**B**	**Std. Error**	**Beta**	**t**	**Sig.**
Behavioral belief_123	BB123	**.558**	.075	.490	7.409	**0****
Risk comprehension	RS	.058	.114	.026	0.513	0.609
Behavioral intention_3	INT3	**.259**	.058	.317	4.453	**0****
Control belief_1	C1	.066	.050	.075	1.328	.187
Control belief_2	C2	-.036	.044	-.043	-.810	.420
Control belief_3	C3	-.037	.062	-.033	-.593	.554
Past behavior_123	PB123	**.545**	.135	.209	4.038	**0****
Past behavior_4	PB4	.029	.047	.031	.606	.545
Descriptive norm	DN	**-.139**	.057	-.122	-2.437	**.016***
Age	AGE	.081	.190	.022	.429	.669
Constant		.259	1.004		.258	.797
Adjusted R^2=.69; F(10, 125)=30.508**						
**p-value<.05*						
***p-value<.01*						

4. Summary and Conclusions

Fatigue, resulting in falling asleep at the wheel, is considered as one of the leading factors causing road accidents and injuries worldwide (Royal, 2003; NHTSA, 1998; Yakabuski, 2014; Horne & Reyner, 2000; ETSC, 2001).

The aim of this paper was to assess the impact of a training program on driving fatigue, targeting 162 professional drivers of a leading company in building materials in Greece. For this purpose, a questionnaire survey was conducted, before and after the program realization, and, based on a number of measurement variables, an effort was made to evaluate the degree of penetration of the program on driving performance and the respective proportion of change in driving behavior. In addtion, the inter-realtionships between the individual measuresment variables and their relationship with the self-reported variables were tested through bivariate correlations, as well through the development of prediction models.

Results showed a significant increase of the proportion of the trainees who were aware of the effects of fatigue on driving after the program implementation (99.3%), compared to the proportion before the program (98.6%) (p-value=0). Similar results were observed when testing the proportion of the trainees who were aware about the most effective solution to fatigue, thus to stop and rest, and the relative rates were 92.3% and 99.3% in the before and after phases, respectively (p-value=0.001).

The main message of the program, which was to raise drivers' awareness about the most effective solution to fatigue, was successfully reached by the trainees. Specifically, results showed a significant increase in average rating of drivers' intention to stop and rest for 15-20 minutes (p-value=0) and a significant decrease to follow other less effective solutions (p-value=0.008). The findings of variables testing the self-reported behavior of trainees, revealed that the training program affected their behavior in the positive direction of change, resulting in a statistically significant increase of the average frequency that they stop and rest when they feel tired (p-value=0.004).

In addition, results showed that behavioral intention and descriptive norm were significantly correlated with the variable addressing self-reporting behavior towards stopping and resting when tired, while the stongest predictor of behavior was descriptive norm. The overall model in this case was a significant predictor of behavior ($F(10, 135)=1.955$, p-value<.05)) and accounted for 10% of the variance. On the other hand, focusing on self-reported behavior towards following solutions such as drinking a coffee, listening to music or opening the window for fresh air, it was observed that behavioral beliefs, behavioral intention and past behavior were significantly correlated with behavior, while the strongest predictor of behavior was behavioral belief. The overall model was a significant predictor of behavior ($F(10, 135)=30.508$, p-value<.01)) and accounted for 69% of the variance.

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TRAVEL BEHAVIOUR OF ONLINE SHOPPERS IN SWEDEN

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Online shopping opportunities are transforming travel behaviour for shopping and could potentially reduce the overall travel demand. Despite numerous studies on online shopping, only a few have taken an approach that includes trips for all travel purposes. Based on a web-survey, this paper provides results on travel behaviour for physical shopping for frequent, regular, and infrequent online shoppers in Sweden. The results indicate that frequent online shoppers make as many car trips (for both shopping and other errands) as others. Also, frequent online shoppers in total make as many trips to a physical store as infrequent online shoppers – although by more sustainable modes of transport – and that the time saved from online shopping is spent on both additional shopping trips and trips for other errands. The conclusion is that online shopping might facilitate changing travel behaviour but does not in itself represent a good stand-alone measure for reducing vehicle mileage.

Keywords: Online shopping, travel behaviour, modal split

1. Introduction

The market share of online shopping has been steadily growing in recent years (Fredriksson 2013), and this is to some extent affecting traditional commerce. The phenomenon of shopping through non-local channels is not new, and mail order shopping and travelling salesmen are long-standing examples of this. The Internet, however, has opened up new markets and offers a previously unknown level of accessibility for businesses as well as for consumers.

In theory, online shopping has the potential to lead to dramatic decreases in needs for personal transportation. Personal shopping trips in Sweden account for approximately one of every fifth passenger trip and one of every ten passenger kilometres, and these rates are similar in other European countries (Trivector 2011). Most shopping trips are made by car, and if online shopping can reduce the number and length of those car trips it would provide an interesting way for the transport sector to reduce carbon dioxide emissions and other negative effects of car use.

Online shopping can, in principle, result in three different behavioural impacts. The first possibility is that online shopping can act as a substitute, which means that every aspect of shopping is carried out online and which reduces the number of actual shopping trips (Salomon 1986). However, one must also recognize that shopping can have a recreational function and can serve as an opportunity to meet people and that this could counteract the substitution effect of online shopping (Mokhtarian 2004). The second possibility is that online shopping can act in one of two complementarity fashions that are based on two distinct types of interactions. The first complementarity interaction is enhancement, which implies that online shopping generates additional shopping trips that would not have occurred without the online shopping. The second complementarity interaction is operational efficiency, which refers to situations where online shopping improves traditional shopping to make it more efficient or satisfactory (Salomon 1986; Mokhtarian 1990, 2002). For example, consumers can use the online option to search for product information, which might reduce the time or trips needed for physical shopping trips. The third possibility is that there are only very limited effects in the number of physical shopping trips because each trip has multiple purposes. Thus even if some errands are substituted by online purchases, other physical visits to a store may be necessary (Mokhtarian 2004). In Sweden, most goods purchased online are picked-up at ollecting points that are often located in the same building as a grocery store (Bring 2013). In the Swedish case, online shopping thus generates pick-up trips to these locations and this influences travel behaviour.

Focusing on the total number of passenger trips, one must recognize that online shopping could very well result in no reduction at all or even an increase in trips in line with findings on the effects of telecommuting. In the mid-seventies, telecommuting was predicted to be substitute for traditional forms of transportation for commuting (Niles and Gray 1975). However, the empirical results from, e.g., Niles (2001), de Graaff (2004), and Choo and Mokhtarain (2007), among many other authors, suggest that telecommunications and travel are complementary and even increase total travel. Gould and Golob (1997) argue that, analogous to the finding that saved travel for work is converted into new trips, saved shopping travel might be converted into other types of travel. Thus, the combination of substitution and complementary effects on travel lead to a very complicated picture of the overall effect of online shopping. Even if there is a substitution effect in the number of shopping trips, there might be a rebound effect in other trips. This increase in other types of trips might, of course, occur even if the number of physical shopping trips is unaffected or increases.

A net mobility reduction is not necessarily beneficial for sustainability because this reduction depends on whether shopping trips are made on foot, by bicycle, by public transport, or by car. Even if shopping by car generally is less sustainable than home delivery by delivery vans, shopping trips made by foot, bicycle, and public transport are still more sustainable. Another effect on mobility might be the effect on travel distance, i.e., an increased use of online shopping might result in purchases made further away or closer to home Therefore, it is necessary to include travel frequency, travel distance, and transportation mode in order to fully analyse the effect on travel behaviour. The travel distance combined with an analysis of the transportation mode must be considered as essential for analysing the effects related to sustainability in the transport system. These effects have, however, mostly been ignored in the research field.

There is a growing body of research indicating that online shopping acts as a substitute for personal shopping travel, e.g., Dixon and Marston (2002), Fischter (2002), Corpuz and Peachman (2003), Weltevreden and Van Rietbergen (2007). There are also empirical results indicating that online shopping has a limited or even no impact on the number of trips and total distance travelled for shopping, e.g., Golob and Regan (2001), Sim and Koi (2002), Keskinen et al. (2002), Visser and Lanzendorf (2004), Weltevreden (2007), and Rotem-Mindali and Weltevreden (2013). Focusing on online searching, there are studies claiming that there is a positive effect between online shopping and mobility behaviour resulting in additional travelling due to the online options and accessibility, e.g., Farag et al. (2006) and Farag et al. (2007). Finally, there are studies reporting empirical evidence for both substitution and complementarity behaviour within different groups in the sample population. This is shown, for instance, in Tonn and Hemrick (2004) where the use of e-mail and/or the Internet resulted in some respondents substituting one or more trips to a bookstore but some making more trips to a bookstore.

There are a few studies discussing the effect of increased shopping online in relation to total travel. The study of Ferrel (2005) indicates that there is no reduction in travel as the share of shopping from home increases. Casas et al (2001) show that Internet shoppers make more physical shopping trips than non-Internet uses do, but they found no significant difference between Internet shoppers and non-Internet shoppers in the share of physical shopping trips out of all personal trips. According to Rotem-Mindall and Weltevreden (2013), this indicates that mobile persons tend to shop more online and that online shoppers have a greater affinity for consumerism.

As mentioned earlier, in order to discuss the sustainability potential related to CO2 emissions of increased online shopping there is a need to analyse the effects on travel distances in addition to the total number of trips. There is, however, only a limited number of studies taking the effects on travel distances for shopping into account, e.g., Fogarty (2003), Cairns et al (2004) and Geraghty (2004), but even these have focused on distances saved only for shopping. There are virtually no empirical studies that include the effects of shopping trips as well as all other trips carried out in terms of trip length, frequency, and modal choice based on an entire population.

In this paper, we provide results on travel behaviour for physical shopping trips (for groceries, other purchases, and the pick-up of goods purchased online) by frequent and regular online shoppers in Sweden and compare these with infrequent online shoppers. The analysis of the total number and length of shopping trips is based on a nationwide representative sample of the Swedish population. The results for travel behaviour give an indication as to whether frequent online shoppers differ in travel behaviour related to shopping trips compared to those who shop less frequently online or not at all. In order to analyse whether the same patterns are repeated for trips for other purposes, the analysis is also carried out for total trips made.

2. Material and Method

2.1 Web-based survey

The methods for analysing the effect on mobility due to online shopping have varied significantly. Some studies have used surveys including self-reported data on travel behaviour before and after the use of the Internet. Other studies have used cross-sectional data analysing differences in travel behaviour between various groups by taking individual characteristics into account. There are pros and cons with both methods, and these are discussed, for example, in Rotem-Mindall and Weltevreden (2013).

In this study, a cross-sectional dataset was used to investigate the mobility behaviour of groups with different online shopping behaviours. In a web-based survey, the respondents were asked about their offline and online shopping behaviour as well as their travel behaviour. The study was performed as a web-based survey distributed to a representative panel of the Swedish population aged 18 and over using NOVUS, a web survey agency. The main part of the data collection was carried out in October 2011 and was completed by an additional data collection in October 2012 to ensure the representativeness of the sample. A total of 4,977 potential respondents received an invitation by email to participate in the research and to fill in an online questionnaire in 2011, and a total of 2673 invitations were sent out in 2012. Among the potential respondents, the survey in 2011 (n = 3086 respondents) showed a response rate of 62% and the 2012 survey (n = 1390 respondents) had a response rate of 52%. The data were pooled after an analysis of national statistics showed that conditions in Sweden, such as income, gross domestic product, employment rate, and travel behaviour, did not change considerably between 2011 and 2012.

Post-stratification weights for age group and sex were applied to the pooled data separated by place of residence. Age categories were the same categories used by the Swedish Trade Federation in their follow-ups of online shopping habits, and place of residence was defined according to H-regions, which are homogeneous regions defined as distinct geographical areas in Sweden based on population density (SCB 2003).

2.2 Data collection and questionnaire

The questionnaire included background data, a travel diary, and questions on general shopping habits and attitudes. The questionnaire began with a individual one-day travel diary. The questionnaire was distributed over the week so that data could be collected for weekdays as well as for weekends. In the survey, a trip was defined as a movement from one place to another in order to run an errand. This is the same definition used in the Swedish national travel survey. Following this definition, a change in transport mode is not considered as a separate trip. For each trip, the respondent was asked to state the main mode of transport. All trips were included in the survey regardless of which means of transport mode the respondents used during the day. The design of the survey and the definitions used enable comparison with results from the national travel survey.

The respondents were also asked to answer questions regarding their shopping habits (online and offline) and to grade various delivery systems with respect to how satisfactorily they were perceived. The questions regarding online shopping behaviour were divided into questions on shopping for groceries and on shopping for other purchases (such as clothes, shoes, consumer electronics, furniture, tickets, music, and travel). In this study, online shopping is thus defined in its broad sense and includes all purchases that otherwise (without the Internet) would have normally required physical movement. Thus, this study focuses on physical mobility and does not include searching for information on the Internet or the amount of purchases made on the Internet.

At the end of the questionnaire, the respondents were asked to answer background questions regarding gender, income, family type, possession of a driver's license, access to a car, which municipality they lived in, and the location of their residence in the municipality.

2.3 Classification of online shoppers

The respondents were classified into three different groups of online shoppers based on their stated online shopping habits for groceries and other purchases.

- Frequent online shoppers: shop online (for groceries or other purchases) at least once a week
- Regular online shoppers: shop online (for groceries or other purchases) about once a month
- Not or non-regular online shoppers: shop online (for groceries or other purchases) once every six months or less.

3. Results

3.1 Statistics

Table 1 shows the demographic and background statistics of the survey respondents divided according to their online shopping habits. In the dataset 9% of the respondents shop online frequently, 34% do so regularly, and 57% do so seldom or never. The distribution of observations corresponds to statistics presented by the Swedish Retail Institute (2013).

The survey results show that there are some differences among individuals who shop online frequently and regularly compared to those who do not regularly shop online in terms of gender, age, family type, place of residence in the urban area, and region of residence. There is a larger share of men (statistically significant at the 5% level) among those who shop online frequently, and among those who rarely or never shop online there is a significantly larger share of women. The group that rarely or never shops online also has a slightly older age profile. We also find more pensioners and fewer families with children under 10 years of age in the category of people who rarely or never shop online.

The results further indicate that in Stockholm and in the central parts of larger cities or urban areas there is a larger share of frequent online shoppers than those who do not regularly shop online. Moreover, frequent online shoppers are significantly less likely to have a driver's license or always have access to a car. However, the results also indicate that the number of observations, especially for frequent online shoppers, is low when analysing some subcategories, e.g. geographical distribution, affect the statistical significance.

Looking at the characteristics of frequent online shoppers in Table 1, there are factors speaking both for and against this group having different travel behaviour than the other two groups. Based on previous work such as that of Frändberg and Vilhelmson (2011) that analysed mobility trends in Sweden, one might argue that frequent online shoppers make more trips and more trips by car because there is a higher share of men and a higher share of people aged 36–55 in this group. On the other hand, one might also argue that frequent online shoppers make fewer trips and fewer trips by car because there is a larger share of individuals living centrally with a lower share of driver's licenses and access to a car and living in families without children. Thus, there is no clear indication that a difference in travel behaviour between the studied consumer groups depends on differences in the background characteristics.

Table 1. Background data for the different categories of online shoppers

Typology	Frequent	Regular	Not or non-regular	All
Number of respondents	321	1,400	2,427	4,148
Share of total sample	9%	34%	57%	100%
Gender				
Female	44 %	48 %	52 %	50 %
Male	56 %	52 %	48 %	50 %
Age				
15–22	13 %	15 %	13 %	13 %
23–35	26 %	27 %	18 %	22 %
36–55	38 %	35 %	32 %	34 %
56–80	24 %	23 %	37 %	31 %
Family type				
Family with children under 10 years of age	22 %	24 %	18 %	21 %
Family with teenage children	15 %	16 %	14 %	15 %
Adults without children	50 %	45 %	45 %	46 %
(At least one) pensioner	13 %	15 %	22 %	19 %
Place of residence				
Centrally in main town	44 %	41 %	34 %	37 %
Suburbs of main town	35 %	35 %	37 %	36 %
In village	15 %	12 %	15 %	14 %
In the countryside	6 %	12 %	14 %	13 %

Table 1. (continued) Background data for the different categories of online shoppers

Typology	Frequent	Regular	Not or non-regular	All
Homogeneous regions				
Stockholm	31 %	23 %	19 %	22 %
Gothenburg	12 %	10 %	9 %	10 %
Malmö	5 %	6 %	7 %	7 %
Dense areas	36 %	36 %	38 %	37 %
Semi-dense areas	11 %	15 %	17 %	16 %
Semi-rural areas	4 %	5 %	5 %	5 %
Rural areas	2 %	4 %	4 %	4 %
Driver's license				
No	17 %	13 %	12 %	13 %
Yes	83 %	87 %	88 %	87 %
Access to a car				
Always	48 %	54 %	59 %	56 %
Most of the time	24 %	21 %	19 %	20 %
Sometimes	10 %	10 %	8 %	9 %
Rarely	9 %	7 %	7 %	8 %
Never	9 %	8 %	6 %	7 %

In Table 2 the total number of trips (unweighted) is presented for the defined groups of online shopping habits and by car and other transport modes. The data are further separated into various errands and trip purposes. The errands considered are shopping trips (shopping trips for groceries, shopping trips for purchases other than groceries, and pick-up of goods purchased on the Internet) and other purposes. In total, the dataset contained information on almost 15,600 trips. However, as shown in Table 2, the number of trips for frequent online shoppers when divided into various types of trips is limited and will affect the statistical analysis of the data. The number of observations when studying all modes exceeds the sum of trips by car and other modes than car because these figures include those respondents who did not indicate the type of transport mode in their questionnaire.

Table 2. Total number of trips in the dataset (unweighted) for online shopping habits and transport mode

	Number of trips in the dataset …								
	…by car for those who shop online…			…by another mode than car for those who shop online…			…by all modes for those who shop online…		
	Frequently	Regularly	Never or seldom	Frequently	Regularly	Never or seldom	Frequently	Regularly	Never or seldom
Shopping trips (total)	153	588	856	96	216	264	274	881	1 234
Groceries	86	353	516	41	113	125	152	542	752
Other purchases	56	209	315	33	80	121	89	290	439
Collecting online purchases	11	26	25	22	23	18	33	49	43
Other purposes	726	3,018	4,101	639	2,220	2,514	1,355	5,240	6,606
Total trips	879	3,606	4,957	735	2,436	2,778	1,629	6,121	7,840

3.2 Travel for shopping

The travel behaviour for the different groups of online shopping habits was analysed by taking all shopping trips and errands into consideration and then separating for trips made by car and other transport modes. The results are presented both by daily distances and number of trips per day. Differences between shopping groups were tested using Tamhane's test for multiple datasets assuming different variances.

Number of shopping trips per person per day

The number of shopping trips per person per day is presented in Table 3. The results do not indicate any statistically significant differences between the studied shopping groups. This result can be interpreted to mean that there are no major differences in number of visits to the shops whether one shops online or not. There is a tendency for frequent online shoppers to use other travel modes than a car when collecting goods purchased online, but this difference is not significant. Not surprisingly, frequent online shoppers make significantly more trips than the other groups for the main purpose of picking up goods purchased online.

Table 3. Number of shopping trips per person per day for online shopping habits and transport mode

	Trips by all modes for those who shop online…			Trips by car for those who shop online…			Trips by another mode than car for those who shop online…		
	Frequently	Regularly	Never or seldom	Frequently	Regularly	Never or Seldom	Frequently	Regularly	Never or Seldom
Shopping trips (total)	0.63	0.60	0.62	0.40	0.39	0.40	0.18	0.14	0.13
By shopping errand:									
Groceries	0.35	0.37	0.39	0.21	0.24	0.26	0.08	0.08	0.07
Other purchases	0.22	0.19	0.20	0.15	0.14	0.14	0.06	0.05	0.06
Collecting online purchases	0.07*	0.03	0.02	0.03*	0.01	0.01	0.04*	0.01	0.01

* Significant difference between frequent online shoppers and the other two groups at the 5% level.

Distances travelled per day for shopping trips

Based on the travel diaries, the total distance travelled per person per day was calculated and analysed (Table 4). For the total number of shopping trips and regarding all transport modes, there is a significant difference between frequent and regular online shoppers and those who never or seldom shop online. Separating this result for transport mode and shopping errand, the result indicates that this difference stems from longer travel distances by car (almost twice as long as frequent online shoppers) for those who never or seldom shop online and mainly for other purchases than groceries. The travel distance by other transport modes than a car for shopping trips is the same. Regarding trips for pick-up of goods purchased online, there are longer trips made by car than by other transport modes.

Table 4. Travel distance for shopping trips in kilometre per person per day for online shopping habits and transport mode

	Trips by all modes for those who shop online…			Trips by car for those who shop online…			Trips by another mode than car for those who shop online…		
	Frequently	Regularly	Never or seldom	Frequently	Regularly	Never or Seldom	Frequently	Regularly	Never or Seldom
Shopping trips (total)	4.9 F,N	4.6 R,N	8.4	3.0 F,N	2.9 R,N	5.5	0.4	0.4	0.5
By shopping errand:									
Groceries	2.4	2.0 R,N	3.4	1.4	1.3 R,N	2.2	0.2	0.2	0.2
Other purchases	1.7 F,N	2.2 R,N	4.5	1.2 F,N	1.5 R,N	3.0	0.2	0.2	0.2
Collecting online purchases	0.5	0.1	0.1	0.3	0.0	0.1	0.0	0.0	0.1

F-Frequent, R-Regular, N-Never or seldom. Significant difference between groups at the 5% level.

3.3 Total travel including other purposes than shopping

The analysis was also carried out for all trips made in order to study whether similar results regarding shopping trips are also seen for other trip purposes in terms of the number of trips, trip distances, and transport modes. The results are presented for total travel as well as for shopping trips and for other purposes and errands separately.

Total number of trips

The results for all transport modes and total travel suggest that the frequency of online purchases is positively correlated with the number of trips made per person per day (Table 5). People who frequently and regularly shop online make significantly more trips per person per day when all transport modes are studied in terms of the number of trips made for other purposes than shopping. This pattern is also seen when analysing total travel by other modes than a car. Frequent and regular online shoppers thus make significantly more trips by bicycle, by foot, and by public transport than those who never or seldom shop online. The number of trips made by car is almost the same regardless of online shopping habits.

Table 5. Total number of trips per person per day for online shopping habits and transport mode

	Trips by all modes for those who shop online…			Trips by car for those who shop online…			Trips by another mode than car for those who shop online…		
	Frequently	Regularly	Never or seldom	Frequently	Regularly	Never or seldom	Frequently	Regularly	Never or Seldom
Total travel	$2.63^{F,N}$	$2.60^{R,N}$	2.47	1.48	1.51	1.50	$1.12^{F,N}$	$1.05^{R,N}$	0.93
By trip purpose									
Shopping (total)	0.63	0.60	0.62	0.40	0.39	0.40	0.18	0.14	0.13
Other	$1.98^{F,N}$	$1.97^{R,N}$	1.83	1.07	1.09	1.07	$0.88^{F,N}$	$0.83^{R,N}$	0.71

F-Frequent, R-Regular, N-Never or seldom. Significant difference between groups at the 5% level.

Total travel distance

The results for total travel by all modes mirror the results for shopping trips in that people who shop online frequently and regularly travel shorter distances than those who never or seldom shop online (Table 6). The difference in distance between frequent online shoppers and those who never or seldom shop online is significant for trips made by car. The pattern is the same when looking at other trip purposes than shopping for all transport modes and trips made by car, but for other modes than a car the travel distance is longer for frequent online shoppers than the other categories.

Table 6. Travel distance in kilometre per person per day for online shopping habits and transport mode

	Trips by all modes for those who shop online…			Trips by car for those who shop online…			Trips by another mode than car for those who shop online…		
	Frequently	Regularly	Never or seldom	Frequently	Regularly	Never or seldom	Frequently	Regularly	Never or Seldom
Total travel	52.7	57.3	62.7	$24.1^{F,N}$	28.5	33.1	27.0	26.6	26.9
By trip purpose									
Shopping (total)	$4.9^{F,N}$	$4.6^{R,N}$	8.4	$3.0^{F,N}$	$2.9^{R,N}$	5.5	0.4	0.4	0.5
Other	47.0	52.0	53.0	20.9	25.3	27.1	17.1	14.4	14.2

F-Frequent, R-Regular, N-Never or seldom. Significant difference between groups at the 5% level.

4. Conclusions

The continuing growth of online shopping has the potential to lead to changes in mobility patterns. In theory, physical shopping trips could be more or less replaced by goods delivery systems and thus lead to a considerable reduction in travel mileage. The majority of online shoppers are younger, and as this generation grows older they will bring these habits with them. Furthermore, frequent online shoppers had less access to a car and they also were more likely not to have a driver's license, both of which are factors that have proven to be important for reductions in vehicle mileage.

In order to discuss the sustainability implications of online shopping, it is important to analyse mobility in terms of travel frequency, travel length, and modal split. When analysing shopping trips, the result of this study indicates no major differences between the groups of online shopping habits in terms of the total number of physical shopping trips made and irrespective of the type of shopping trip being studied. There is a tendency, however, that frequent online shoppers make more trips by other travel modes than car, including public transport, bicycle, or walking, when picking up goods purchased online.

As opposed to many other studies, the travel distance is also included in the analysis presented here. Our results indicate that frequent online shoppers tend to travel significantly shorter distances for shopping per day by car (almost half the distance of those who never or seldom shop online), but the travel distance by other modes than a car is almost the same as the other customer groups.

To broaden the picture, other types of trips than shopping were also studied. Here the travel pattern is somewhat different. Our results indicate that the number of trips for purposes other than shopping is significantly higher for frequent and regular online shoppers compared to those who never or seldom shop online. The number of car trips is the same irrespective of the category being studied, and it is the number of trips with other transport modes than a car that differ between the studied categories of shopping habits.

One could argue that when looking at factors related to sustainability the pattern is strengthened when considering the travel distance. If looking at car travel, those with frequent online shopping habits use the car as often as others but for shorter total distances. When it comes to travelling by other modes than car, those with frequent online shopping habits make more trips by bicycle, walking, and public transport than those with less frequent online shopping habits.

The differences in travel behaviour between consumer groups identified here might result from differences between individual characteristics and their potential for various travel behaviours. Among frequent online shoppers, there is a larger share of people living in central areas, with less access to a car, and who are younger than average. However, when analysing subsamples of the dataset (not presented in this article) with, for example, similar distances to various locations and public transport, there is still a persistent trend of differences between customer groups depending on online shopping behaviour – though insignificant.

When looking at all shopping trips and all transport modes together, there are only small differences between the categories in the number of physical shopping trips made. This indicates that there are no major differences in the number of visits to the shops and that online shopping does not reduce the demand for travel to any significant degree. Instead, our results indicate a complementarity effect for both shopping trips and other errands in that the time saved by purchasing items online is used for making additional physical shopping trips as well as trips for other purposes. This is also in line with the result from other empirical studies, e.g. Casas el al (2001) and Cao et al (2010), that have indicated generally high levels of mobility and consumerism among individuals exhibiting frequent online shopping behaviour.

When looking at the individual characteristics and mobility patterns of people frequently and regularly shopping online, the results of this study indicate a potential for reducing car mileage. There is, however, nothing to suggest that this potential can be realized solely through the growth of online shopping in the population, and online shoppers currently show few significant differences in travel behaviour in terms of the total number of trips and the total daily distances travelled. There is a strong concern that travel savings for one purpose, in this case shopping, are used for other purposes instead.

Although we doubt that online commerce can act as a stand-alone measure for vehicle mileage reduction, online shopping might increase the use of more sustainable modes for shopping trips as well as other trip purposes – even on a short-term basis. Online shopping could, therefore, act as a facilitator for a less car-dependent lifestyle. The results presented here are based on current societal structures, land uses, and travel patterns. Even now, those frequently using online shopping are not a homogenous group and this will become even more obvious when online shopping becomes more common and used, more or less, by everyone. This stresses the importance of supporting more sustainable transport modes through infrastructure as well as the planning of shopping locations. We also argue that research and analyses should focus on how the sustainability potential of online shopping can be supported. For instance, because frequent online shoppers use other modes than a car for shopping for groceries, this indicates that urban planning should focus on ensuring safe and accessible routes for walking, biking, and public transport for these types of purchases.

The dataset has also revealed interesting information with implications for the retail sector in that frequent online shoppers have almost the same number of physical visits to shops as those not shopping online. The fear of having less people in the stores due to the growth of e-commerce seems to be ill founded. However, in this study we have not been investigating whether the amount of purchase in the shops differs between the consumer groups. Thus it could very well be the case that frequent online shoppers go to the physical store only for the purpose of gathering information. On the other hand, and as expected, the data show that frequent online shoppers make more trips than the other groups with the purpose of picking up goods purchased online.

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ANALYSIS OF COMMON GOVERNANCE TRANSPORT SYSTEM DEVELOPMENT POSSIBILITIES IN THE EAST-WEST TRANSPORT CORRIDOR

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Equitable access to efficient economic infrastructure and effective public services is essential to achieving the future economic growth. Insufficient transport infrastructure and long border crossing procedures limiting international accessibility for goods and passengers are the biggest present problems in the East–West transport corridor. The joint action plan must highlight the areas and components of the transport system, which are important for the effective interconnectivity of the individual networks, and/or for absorbing the steadily increasing intraregional and transcontinental freight flows. The successful East–West transport corridor activities' governance first of all needs to identify the corridor's administrative structure, non-governmental organizations' (NGO) place in the management structure, partnerships between the transport hubs in the EWTC mechanism and the possibility of cooperation between private and public sectors.

The latest events and constantly changing environment show that the impact of political solutions on business is prevalent in the CIS and the EU countries. Thus, the analysis of economic, political, managerial, legal, even moral aspects that affect the interests of the stakeholders remain significant.

Keywords: transport corridors, management, governance, planning, infrastructure

1. Introduction

The majority of the surveys presented in this article were organized and executed by the international project "BSR TransGovernance" activities. This project was financed by the European Union's Baltic Sea Region Programme 2007–2013. The project objective is to demonstrate how multi-level governance models, tools and approaches can contribute to a better alignment of transport policies in the BSR at various administrative levels and better incorporation of the business perspective. This is expected to increase commitment of public and private stakeholders to achieving greener and more efficient transport in the Baltic Sea Region, in line with Priority Area Transport of the EU Baltic Sea Strategy.

The project will place particular focus on developing and testing joint planning and implementation frameworks for transport policies at reference scales, that have witnessed a long process of cooperation across the national borders with involvement of public/private stakeholders, and/or which have gathered a vast evidence for Multi-level governance (MLG) actions. These are: MACRO (overall BSR area), MESO (cross-border integration areas), CORRIDOR (transnational multimodal transport corridors) and MICRO (intermodal terminals).

In specific real conditions at those reference scales the project will employ several demonstration showcases. Through the so called 'stakeholder management process' the project will encourage relevant public and private actors to jointly develop:

– sustainable implementation and management frameworks for macro regional and cross-border strategies, programmes and action plans; that will be tested on the cases of streamlining the results of the BTO and TransBaltic, by using them in the national and regional transport planning processes (MACRO);

– MLG models for the planning and operation stages of intermodal terminals – and testing them on five different cases in the BSR (MICRO);

– operational MLG model for better freight management in a transnational transport connecting EU with non-EU countries – and testing it on the East West Transport Corridor (CORRIDOR);

– operational MLG model supporting the transformation of a multimodal transport corridor into a regional development axis.

The project has a strong triple-helix partnership from all BSR EU Member States and Norway representing all vertical governance levels. It is supported by PA Transport Coordinators, national transport ministries and several other actors, which will be engaged as reference partners. (*http://www.transgovernance.eu/*)

There are notable differences that exist between EU countries (Lithuania, Sweden, Denmark, Germany) and other countries located to the East of EU (Belarus, Ukraine, Russia, Kazakhstan, China). The disparity in quality and availability of infrastructure in particular is seen in the East–West connections (backlog of transport infrastructure investments in the East) (*Discussion paper "Promoting sustainable…"* 2013).

The keynote of the development is effective integration of the EU countries and Eastern countries transport sectors into East–West transport corridor service system and transport services market complying with the common criteria for transport development in the corridor (*European Union Strategy for the Baltic Sea region* 2010).

The government authorities of all countries which are crossed by the EW transport corridor must consolidate the results of complex joint international efforts directed towards specifying the long-term plans for further East–West transport corridor development perspectives (Šakalys 2011). The EW transport corridor's international importance and the priority status must be given at the highest governmental level in all 8–10 countries whose territories it crosses. The decisions must focus on the better use of the existing infrastructure, "intelligent" management of traffic, networks and systems (Palšaitis, Zvirblis 2010).

Due to the specific nature and needs of the East–West transport corridor countries the region is covered by its own transport network. One of the biggest present problems is insufficient transport infrastructure and long border crossing procedures limiting international accessibility for goods and passengers (Bazaras *et al.* 2013).

In order to define a mission of the public authorities in the field of transport system development, it is essential to analyse two most important segments of this broad system: the infrastructure and its users (carriers, operators) that have different specific features of functioning and activity development. Transport networks in EW corridor countries are a driving force of common market competitiveness or even markets themselves. (*European Union Strategy for the Baltic Sea region.* 2010) Therefore, the development and modernization of transport infrastructure and removing the bottlenecks are the essential measures that ensure economic progress in working out national economy development strategies and programmes of both the EU, CIS and other East countries (*International project "BSR TransGovernance"* 2014).

2. Transport system development situation in the East–West transport corridor countries

Three integrated environments can be distinguished when describing the current transport system development situation in the East–West transport corridor countries. Analyses of these environments, that directly affect transportation efficiency and safety (Bazaras, Palšaitis 2011), describe main problems of transportation in each East–West transport corridor country and in the region. The existing transportation management and development organization model of separate East–West transport corridor country is presented in Figure 1. Relations between the elements are shown in Figure 2.

In Figure 2 arrows indicate the links between cells, which show that these environments are interrelated and cannot be distinguished. The largest influence on other elements of the environment has EU, CIS and other East countries and transport system development policy.

Common to all three environmental elements, is the cost of transportation and investment in to the transport system infrastructure development, as well as efficiency and quality of services for customers. The important aspects are the interconnection of individual transport networks of the EU, CIS and other Eastern countries, reduction of infrastructural drawbacks and harmonization of the various transport development priorities.

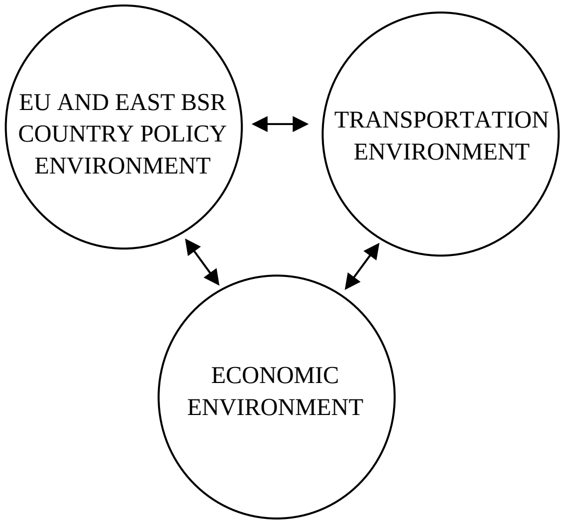

Figure 1. Existing EU, CIS and other East countries transport system organization and development model

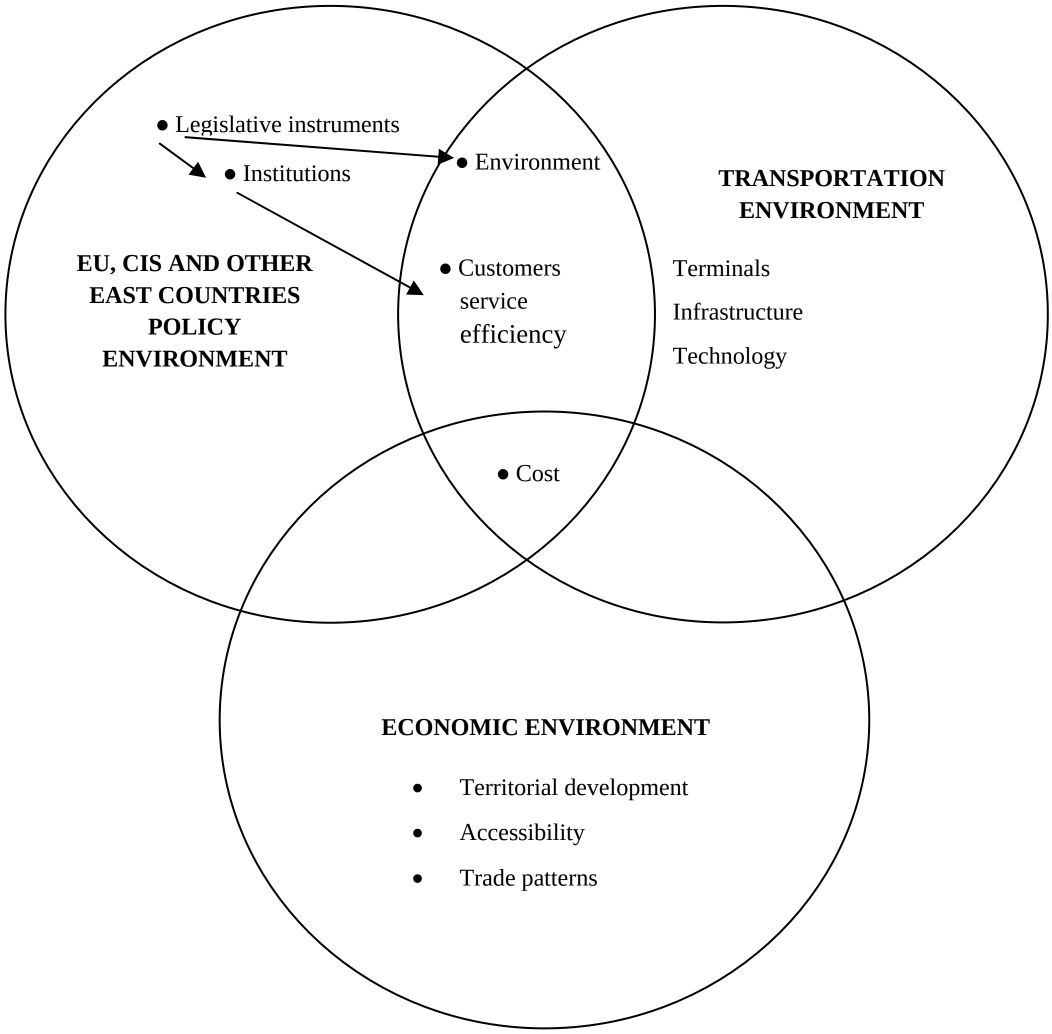

Figure 2. Links between East–West transport corridor countries' transport systems organization and constituent elements of development model

Supply chains are becoming more and more global and further integration of EU companies with these global value chains can enhance more and more trade gains with third countries that have different specialisation. This can be done by further opening the EU economy to the rest of the world. Bilateral and multilateral free trade agreements (FTAs) would be the best way to reducing trade barriers. They should not only remove international trade tariffs, but also lower barriers beyond the borders (*OECD (2014), OECD Surveys: European Union 2014, OECD Publishing. http://dx.doi.org/10.1787/eco_surveys-eur-2014-en*). The EU already concluded FTAs with some Eastern countries including Georgia and Moldova (as well as Ukraine but with suspension till 2016). On-going FTA negotiations with dynamic Asian economies can yield substantial economic gains and increase trade flows. This requires actions to overcome the impact of administrative borders on efficiency of transport flows within EU, CIS and other Eastern countries and to reduce the remoteness of this area to the main economic centers of Europe and other parts of the world (Sydorowski, Talberg 2013). This also requires better connections between the EU member states and Eastern Partnership countries, Russia, the Black Sea and the Mediterranean regions as well as Far East countries. The joint action plan must highlight the areas and components of the transport system that are important for the effective interconnectivity of the individual networks, and/or for absorbing the steadily increasing intraregional and transcontinental freight flows. A joint strategic transport planning process must support sustainable growth in the EU, CIS and other East countries and requires close cooperation between the European, national, regional authorities, concerned professional associations and involvement of the public and private market stakeholders.

3. Benefits of EU, CIS, eastern partnership and other eastern countries common transport system development for all stakeholders

Transport is an integral part of most economic activities. Therefore, adequate transport services provision is a pre-requisite for sound economic development. When traffic volumes are increasing to the point that congestion arises, it is of greatest importance to ensure the accessibility of the major economic centers. This is possible only when there is joint strategic transport planning process and close cooperation between the national authorities and involvement of the market stakeholders. More efficient transport services facilitate trade and widen the geographical space for competition by reducing the cost of delivery, thereby boosting economic growth. This is particulary true in transport corridors and hubs areas of transport system development.

Table 1 contains the expected benefits for the different stakeholders, upon common transport system development.

Table 1. Benefits of East–West transport corridors countries common transport system development

STAKEHOLDER	EXPECTED BENEFITS
(Inland) shipping companies	Higher quality of service and entering of new markets
Existing shippers	Lower transport costs, more transport opportunities/alternatives, greater reliability and safety.
Potential (new) shippers	Better access to market, opening up of new markets, more transport opportunities/ alternatives, lower transport costs.
Railways	Higher quality of service and possibility to compete with the separate market segments.
Road haulage industry	Higher quality of service, greater flexibility and reliability.
Forwarding industry	Greater range of transport opportunities/alternatives, lower costs.
Intermodal transport operators (MTO's)	Better coordination of activities, higher quality of service, more transport alternatives, lower costs.
Authorities, policy makers and the society at large.	Efficient interfaces between transport networks, need – based approach to infrastructure investments, additional transport opportunities/alternatives, enabling limitation/ control of traffic congestion, greening transport corridors. Increased competition, offering cost-effectiveness (and accelerated introduction of market principles).

All stakeholders involved in transportation processes can expect to benefit from the common EU, Eastern Partnership, CIS and other Eastern countries transport systems development. It will contribute to a sustainable growth of transport capacity alongside the lesser energy consumption and emissions.

Common transport system development must be strongly supported by each countrie's national government policy makers especially because of its socio-economic benefits for business and society as a whole. Currently, users of transport systems base their choice of preferred mode or transport on the direct costs only. Common East–West transport corridor transport system development will stimulate intermodal transport development which will be cheaper than the alternatives and will offer better quality of services. Planning and funding of intermodal mobility must be addressed jointly for all transport modes according their respective contribution to ensuring better access.

Therefore it is of crucial importance to interconnect individual transport networks of the East–West transport corridor countries, diminish infrastructural drawbacks and harmonize various transport modes development priorities. Activities related to planning and developing of the transport networks should be aligned with the regional development perspective. For this matter, the establishment of formalized coordinating bodies (e.g. EGTC or other structures) for the regional transport systems and nodes/hubs connecting East–West transport corridor is essential. Those coordinating bodies should negotiate and identify most prominent bottlenecks and obstacles in transport connections to major European and transnational corridors and aim at identificating the most important investment needs for transport corridors that cross various East–West transport corridor countries (Fastén 2012).

This would allow to bring together a variety of stakeholders at all levels of administration, business and civil society along the corridor and to address specific issues of green corridor development as well as to attract funds for the corridor development and to ensure further East–West corridor planning.

Furthermore, better integration of relevant country's transport markets into the socio-economic development processes of the region is required. Bridging EU, Eastern Partnership, CIS and other Eastern countries transport networks could increase the entire region's accessibility.

4. Methodology of the survey

To investigate East West transport corridors strengths and weaknesses with respect to better alignment of transport policies within the EWTC is possible /by using of the Delphi Technique method (Hsu & Sandford 2007). During the survey the expectations and future visions of different kinds of institutions and companies were determined. The first step of the survey was to choose a heterogeneous target group, in order to guarantee an analysis from as many perspectives as possible. In each country that is crossed by EWTC, from five to ten interview partners were selected, representing different institution or company groups. Another aspect in selecting the companies or institutions was the possibility to contact potential interview partners on a higher management level. The private sector was represented by transport and logistics service providers. The public sector was mainly represented by the administrators responsible for state and regional development. Support initiatives may either belong to the private or the public sector or are public-private-partnership. Both institutional groups have experience in initiating, financing and executing regional development activities. Last, representatives from research institutions completed the target group by an independent and research-oriented perspective.

For the identification directions of multi-level governance to better align transport policies in the East–West transport corridor two round surveys were organized.

The first round survey was performed during the October of 2013. The first distributed questionnaire's task was to find out how joint governance of East–West transport corridor must highlight the areas and components of the BSR transport system that are important for the effective interconnectivity of the individual networks, and/or for absorbing the steadily increasing intraregional and transcontinental freight flows. 50 questionnaires were distributed and 18 questionnaires were received back filled (Germany – 2, Sweden – 5, Lithuania – 2, Ukraine – 1, Russia – 1, China – 1, other countries – 6.)

The second round survey was conducted by web-basis survey system during 18-04-2014–15-05-2014 time period. Questionnaire was sent to EWTCA members and relevant authorities directly involved in the transport corridor management activities. Number of the respondents was 21. Countries respondents were: Denmark, Germany, Sweden, Norway, Russia, Lithuania. 13 respondents were representing EWTCA members.

5. Transport corridors management sensitive points

The survey identified that transport infrastructure in the EWTC is extremely important for effective development of transport services quality, reliability and attractiveness. Greater attention must be paid to the corridor's infrastructure in Eastern Partnership and CIS countries (Table 2). However the EWTC transport infrastructure development in EU countries must also be in the centre of all activities.

Table 2. Infrastructure "bottlenecks" in the EU and CIS countries

Bottlenecks	EU	EPC/CIS
Infrastructure	6,78	7,61
Equipment	6,22	7,33
Services provided using international intermodal transport	7,61	7,67
Conditions for the effectiveness of international intermodal transport services in the corridor	7,94	7,89

It is extremely important to create cooperation system along transport corridor between governmental institutions and private companies (Table 3). The differences in terms of the equipment, legal regulation, information and communication technologies (ICT) and transport and logistics business model usage must be eliminated.

Table 3. Sensitive points in the management of the transport corridors

Sensitive point	Rate
Can be a single moderator for management process organization?	5,35
Differences in the equipment using.	6,06
Differences in the transport and logistics business model using.	6,56
Differences in the legal regulation.	7,11
Differences in the ICT usage.	7,29
Cooperation along transport corridor from private companies' point of view.	7,50
Cooperation along transport corridor from governmental (municipality) institutions point of view.	7,78

It is crucial to identify the corridor's administrative structure, EWTC association place in the management structure, partnerships between the transport hubs in the EWTC mechanism, as well as cooperation strengthening possibilities between private and public sector for effective the East–West transport corridor activities governance.

As it was previously noticed – research methodology is broad and comprises diverse aspects related to transport corridor management possibilities. However, this article intends to highlight the most problematic points – bottleneck effect and sensitive points in weak management aspects. Additional research results are still processed and will be presented in other publications.

Research results indicated that bottleneck effect is unambiguously evaluated as more problematic phenomenon in the CIS and Eastern Partnership countries than in the EU member states. Virtually all problematic scores in the evaluation were assigned to the CIS and Eastern Partnership countries. This shows that the functioning of infrastructure and related equipment as well as quality of services provided are assessed as more complex and problematic in comparison with the EU member states. The present evaluation indicates that the establishment of general methodology and possible management institutions requires inevitable confrontation with specific problematic points at the particular environment. Therefore, different economic-political circumstances in the CIS/Eastern Partnership countries and the EU area are substantially relevant and theoretically possible equalization of these areas is the matter of the separate scientific discussions.

The other aspects of research were sensitive points in management. This term was coined and provided for the respondents as the prerequisite for the evaluation of possible challenges within unified management of transport corridor. The results were astonishing – the idea of single moderator was evaluated in the frames of the lowest relevance score by the respondents. The explanation of this evaluation may be twofold: 1) respondents did not pay enough attention to establishment of a unified management framework institution; 2) Experts consider the establishment of this single moderator is hardly implementable. However, the following evaluation criteria remain significant due to practical implementation issues – legal regulation; application of ICTs; co-operation between private and public sectors. All of the aforementioned criteria are directly linked with management processes and authors assume that they should be coordinated by a unified management framework/institution alongside newly established management technologies which would be admissible to all stakeholders.

Single EU and CIS/ Eastern Partnership countries administrative structure (directorate) has many advantages for transport policy in the development of EWTC. It could:

- Improve and develop regional and local transport infrastructure;
- Promote multimodal transport and intermodality within the EWTC;
- Provide high value added logistics services;
- Ensure sustainability of transport system through energy efficiency and improve mobility demand management;
- Improve traffic safety and security.

In accordance with the conducted research and assessing the problematic transport corridor management aspects it is therefore possible to formulate the following questions linked to the establishment of potential unified management framework/institution. It would be possible to create Single EU and CIS/Eastern Partnership countries administrative structure (directorate) upon finding solutions to these issues:

- Who can be a constitutor?
- What could be the scale of powers allocated?
- What would be the finance source?
- What would be the nature of cooperation with the transport administrations of particular countries?

However, more realistic would be to create the binary EU and CIS/Eastern Partnership and other Eastern countries (including China) administrative structures (directorates) responsible for:

- Transport activities coordination alongside EWTC;
- Improvement and development of the regional and local transport infrastructures;
- Promotion of multimodal transport and intermodality within the EWTC;
- Increasingly make use of ICTs via delivering relevant services on-line;
- Provision with high value added logistics services;
- Ensuring sustainability of transport system through energy efficiency and better mobility demand management;
- Improvement of traffic safety and security.

The binary administrative structure can be created answering the following questions:

- Who can be a constitutor?
- What could be the scale of powers shared?
- What would be the finance sources?
- What could be the nature of cooperation with the transport institutions of particular countries/

The main motivation for establishing a management structure for the development EWTC is the possibility to combine the short term perspective that prevails among the business community with medium and the long term perspective that EWTC Association could add to the corridor in terms of improving its functions and capacity, when needed.

This includes the necessary dialogue with regional, national or the EU important institutions – a dialogue that could not be successfully handled by individual companies.

6. Critical implementation issues

During the survey the following elements were considered as being critical implementation issues that would need to be addressed at the next stage of the East–West transport corridor development strategy and programme:

- ***Organizational structure, governance arrangements and reporting structures.*** The East–West transport corridor Steering Committee nominates and establishes the East–West Transport Corridor steering group and East–West Transport Corridor programme organization teams, as well as the two independent review groups.
- ***Financing options.*** Integrated programme organisation teams develops the financing and funding scheme and presents it to the East–West Transport Corridor steering group and the East–West transport corridor States and other countries administrative units for the confirmation.

– ***Implementation of programme risk management strategy.*** The East–West Transport Corridor programme organization team develops the Risk Management Plan and presents it to the East–West Transport Corridor steering group and EWTC countries administrative units for approval.

– ***Resource planning with particular reference to the early identification of long lead items.*** The East–West Transport Corridor programme organization team develops a resource based critical path implementation programme for review and acceptance by the PSG and follows with a staffing plan for internal resources and external consultancies.

– ***Implementation of robust and effective stakeholder consultation programmes at all stages of the process.*** The East–West Transport Corridor programme organization and East–West Transport Corridor steering groups approve the involvement of a public-relations consultant to assist in establishing the necessary public relations campaign for the programme.

– ***Integration strategies with existing rail systems throughout the EWTC***. The East–West Transport Corridor programme organization team performs a system-wide audit of all existing systems and planned improvements that is considered as a country input into the Options Assessment plan.

– ***Impact assessment of programme on regional transport market provision and competing modes;*** The East–West Transport Corridor programme organization team conducts, in cooperation with external consultants, a detailed transport market analysis to further justify the transportation models developed during the feasibility study.

– ***Identification and consultation on programme phasing requirements noting commercial, social and political imperatives.*** The East–West Transport Corridor programme organization team shall enhance the critical path implementation programme with required interfaces at the national, regional and municipal levels to streamline the planning, land expropriation and design approvals processes.

7. Summary

The joint action plan must highlight the areas and components of the transport system which are important for the effective interconnectivity of the individual networks, and/or for absorbing the steadily increasing intraregional and transcontinental freight flows. The following elements are considered as critical implementation issues and would need to be addressed at the next stage of the East–West transport corridor development programme:

– output definition (organizational structure, potential financing scheme, risk management overview, pre-planning budget, pre-planning time-line, etc.);

– organisational structure, governance arrangements and reporting structures;

– financing options and resource planning;

– implementation of programme risk management strategies;

– integration strategies with existing rail systems throughout the EWTC system;

– impact assessment of programme on regional transport market provision and competing modes;

– identification and consultation on programme phasing requirements noting commercial, social and political imperatives.

In general, it is notable, that transport corridor management mechanism still remains problematic, firstly due to economic and political environment that influences business organization and regulatory models. The latest events and constantly changing environment show that the impact of political solutions on business is prevalent in the CIS/Eastern Partnership countries and the EU countries. Thus, the analysis of the following aspects remains significant: economic, political, managerial, legal, even moral affecting the interests of the stakeholders.

The unified administrative structure of the East–West transport corridor has a great number of advantages; however, experts consider that it is hardly implementable.

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FORMATION OF FAILURE MODELS FOR THE EVALUATION OF THE RELIABILITY OF SUPPLY CHAINS

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Logistics and supply chain management is a comparatively new scientific field which has been rapidly developing.

Apart from the criterion of total logistics costs, that is used to evaluate the efficiency of supply chains, another criterion - total satisfaction of consumer needs - is being increasingly used for the same purpose. It can be explained by the transition to such new logistics concept as the sustainability of supply chains, which is characterized not only by flexibility, rate of response, strength, adaptability, but mostly by the reliability of functioning of the logistics system's elements.

The paper presents critical analysis of the existing approaches to the formation of failure models in supply chains, the methodical approach and classification of failures for the key logistics functions (purchasing, order processing, transportation, storage, warehousing and materials handling) as well as some developed and improved failure models for a number of logistics functions and operations; there have been also given some examples of calculating the reliability indices for the elements of the supply chain.

Keywords: supply chains, reliability, failures, calculation models

1. Introduction

The modern period of logistics development is characterized by a heightened interest in the reliability of supply chains. The aim of researches in this direction is creation of a complex of models and methods by means of which it would be possible to optimize the supply chains with the account of the reliability indices.

But the peculiarity of the situation is the fact that this stage of development of the theory of logistics and supply chain management is associated with the emergence of new concepts such as "sustainability", "durability", "«robustness", "flexibility", "adaptability", "response time" and, of course, "reliability". Thus, in the paper (Sergeev, 2013), on the basis of the shift of logistical paradigms, the authors conclude that "durability has become one of the most important parameters of the supply chain operation along with the level of service and costs", "and, namely, durability serves as the criterion of the efficiency of the whole supply chain". However, we think that the cited paper involves some uncertainty in the interpretation of the concepts of "durability" and "reliability". For example, in the section, which is concerned with "the durability and reliability of technical systems", both concepts are based on the same principles and the difference between them is the following:

- reliability is a property of the system to maintain its characteristics of the key performance indicators (KPI) within the established values;
- durability is a property of the system to restore itself that means that "the system is able to restore the values of the KPI in the specified tolerances".

Provided that the objects of the theory of reliability are restorable objects, for which the recovery of a serviceable state is stipulated in the relevant documentation, it appears that the distinction between the two terms is virtually blurred. However, in the course of developing of the table of distinctive characteristics, "sustainability" and "durability" were attributed by the authors to higher levels - to the zero and the first level correspondingly, whereas "reliability" was attributed to the lower third level.

For almost all the above-mentioned concepts, there are no indicators (except the KPI system in the SCOR-model) and methods for their evaluation. Therefore, we believe that the reliability theory of technical systems, as well as its accumulated analytical and application developments, with the account of the specific character of the supply chain functioning, can be chosen as a real platform for their formation.

The performed analysis of a number of sources has shown that, despite the existence of separate decisions, the bulk of the problems of assessing the reliability of supply chains are far from the final decision for the following reasons:

1. Supply chains are considered as systems that are operating to the first failure, while the probability of no-failure operation is accepted as the main indicator of the reliability of supply chains (Blanchard, 2004; Zaitzev and Uvarov, 2012).
2. The calculations on the proposed models and methods are being made on the basis of the original data, while collection, analysis and systematization are reduced to simple statistical dependencies (Sergeev, 2013); for example, “the perfect order” is defined as the ratio of “the number of precisely executed orders” to “the total number of orders”.
3. The number of variations of simple failure models is limited and reduced to three types:
   - The model of the “perfect” or the “ideal” order (Ballou, 1999; Christopher, 2004);
   - The model of “supply and demand” (Wolfgang and Thorsten, 2006), which is formed by the analogy to the “load-strength” technical systems (Gertsbakh and Kordonsky, 1966);
   - The «just-in-time» model (Lukinskiy et.al. 2012).
4. The description of complicated failure models, involving multiple logistic operations, has not been possible to find in the sources available to the reviewers.
5. The main tool for improving the reliability of supply chains is considered external (or excess) redundancy, while internal sources, in particular, insurance reserves, are not given the necessary attention (Lukinskiy et.al., 2014).

2. Classification of the features of failure models in supply chains

For the development of a methodological approach to the classification of failure models, it is reasonable to clarify the basic concepts and definitions that form the conceptual framework of the reliability of supply chains.

The analysis of a number of sources has shown that the concept of “failure” has a fairly wide range. Therefore, in this paper we choose a synthesized version of “failure” as “the loss of the ability of the whole supply chain, as well as of the links in the chain, to perform its functions in accordance with the agreements between the members of the chain”.

It should be emphasized that in the works on reliability, except the notion of “failure”, one can find such terms as “defect”, “damage”, “problem” and “malfunction” which sometimes are used interchangeably that, in our opinion, is incorrect. The most important of these terms is “malfunction”, which can be characterized as a transient failure leading to a short-term partial loss of functioning that can be corrected by the operator without significant time and cost.

For the specification of the general approach, we will consider the kinds of failures concerning the main and the related logistics flows.

Material flow includes components related to the physical parameters of the order (for example, the number, nomenclature, weight and others). Examples of failures related to material flow are damage of packages, deficiency in quantity, re-sorting, insufficient amount dispatched, etc.

Information flow includes document flow and information sharing occurring within the supply chain during its operation. Failures may be associated with the execution or handling of documents in the supply chain or in the process of information exchange between supply chain members.

Financial flow is characterized by monetary costs for the organization of delivery orders in the supply chain. Occurring failures are associated with additional costs for the organization of cargo delivery. These costs may occur in the process of recovery after a failure or as a consequence of any failure (for example, penalties for exceeding the allowable cargo weight or penalties for lateness).

Intellectual flow reflects the influence of the human factor. Despite the controversial nature of this concept, we believe that consideration of the impact of staff is relevant, but so far researchers have not paid enough attention to this factor, despite the fact that it is involved in the performance of all types of logistics operations and functions in the supply chain.

In addition to the mentioned failures, in all flows various kinds of extreme emergency situations, which are advisable to segregate to a separate category, can occur. It refers to situations caused by natural disasters, force majeure and other reasons which cannot be influenced by the supply chain participants.

Thus, the supply chain is a complex system which has independent functionality and consists of many interacting components (subsystems), thereby acquiring new properties that cannot be reduced to the properties of the subsystem level.

The supply chain is a system of «man-machine-environment», where the environment means the totality of social and economic environments. Obviously, in the supply chain one should allocate units (members of the supply chain) and elements (executable operations). Such decomposition, which separates companies and the operations they perform within a specific supply chain, allows evaluating any supply chains.

We should also note such property as self-organization (and self-training) of a supply chain, which is goal-directed behavior in complex environments through adequate changes in both internal and external conditions for the recovery of the operation.

Table 1. Classification of criteria of failure models in supply chains

Criterion	**Classification**
Type of logistics flow	Material, information, financial, service, intellectual (human factor), etc.
Consideration of failure occurrence	Without considering time (statistical) Taking into account time (dynamical)
Character of variables (arguments)	Stochastic events, stochastic variables Stochastic processes (flows)
Relationship between the variables	Independent Dependent (functional, stochastical)
The relationship between operations	Simple (one-parameter) Complicated (multi-parameter) Combined

Generalization of different sources, dedicated to researches of the reliability of logistics systems, allows us to classify the main criteria of failure models in the supply chain (see table 1). Obviously, the criteria listed in the table do not represent all the possible options, but at the same time they make it possible to characterize a large number of them, which is particularly important for the complicated and combined models involving different types of processes, the types of relationship between the variables, their character and others.

3. Failure models of the main logistics functions and operations

Table 2 shows the basic failure model for a number of logistic functions and operations. The presented models are based on the general theory of reliability of complex systems (Gertsbakh and Kordonsky, 1966; Lukinskiy et.al., 2012) and the disciplines that are included in the operations research (probability theory, the theory of stochastic processes, queuing theory, the theory of recovery, etc.), in particular, on the theorem on numerical characteristics, repeated experiments, the compositions of distributions, the transformation of random variables, etc. (Wentzel, 1969).

Table 2. Failure models in supply chains

Logistical function	**Logistical operation**	**Model for calculation of reliability indices (similar model)**
1. Procurement, orders management	Forecasting of supply and demand volumes	The task of «demand – offer» (similar to task of «load – strength»)
	Determination of order quantity	Static problem - one-time purchase (analogous to «economic risk»)
	The choice of the intermediary (suppliers, carriers, etc.)	Reliability of redundant systems (similar to «hot», «cold» and «easier» redundancy and etc.)
2. Warehousing, materials handling	Formation of the perfect (ideal) order	Simple probabilistic models for separate indicators. Combined models
	Order picking	A probabilistic model that is based on the composition of stochastic variables (analogous to «just in time» model)
3. Transportation	Transportation (multimodal, unimodal and etc.), delivery	The «just-in-time» model. Reliability of redundant systems
4. Inventory management	Determination of inventory parameters	Probabilistic estimates of values of safety stock and deficit
	Selection of inventory management strategy	Models based on the achievement the limiting values of implementations of inventory consumption (similar to «calculations for wear»)
5.Supply Chain Management	Estimation of influence of reliability indices of individual operations on the efficiency of the supply chains (simple, multi-level, etc.)	Discrete-continuous models for restorable logistics systems

Let us consider failure models (see table 2), focusing attention on their clarification and correction.

Model of «supply and demand». The density of distribution of the sum of two random variables $z = x + y$, when the random variables are independent, is expressed by one of the formulas (Wentzel, 1969).

$$f(z) = \int_{-\infty}^{\infty} f_1(x) f_2(z - x) dx \tag{1}$$

or

$$f(z) = \int_{-\infty}^{\infty} f_1(z - y) f_2(y) dy . \tag{2}$$

The density of distribution $f(z)$ is called the composition of distribution laws of summands $f_1(x)$ and $f_2(y)$.

In describing the logistics processes of procurement and the management of orders with stochastic values of demand y (consumer) and supply x (supplier), it is necessary to consider the difference between the random variables x and y, i.e. z = x - y = x + (- y). In this case, the formula (1) and (2) are written in the form:

$$f(z) = \int_{-\infty}^{\infty} f_1(x) f_2(x - z) dx = \int_{-\infty}^{\infty} f_1(y - z) f_2(y) dy . \tag{3}$$

The corresponding probability of customer satisfaction (the lack of deficit) is defined by the dependence:

$$F(z) = \int_{0}^{z} f(z) dz . \tag{4}$$

The numerical method of calculation of $f(z)$ and $F(z)$ is the most common, but for some distribution functions there can be obtained analytical solutions (see table 3).

Table 3. Formulas for calculating the probability of the demand satisfaction (the model of «supply and demand»)

Distribution laws; the parameters of the law		Calculating formula
demand	**supply**	
Normal; average value M_y; Root-mean-square deviation σ_y	Normal; average value M_X; Root-mean-square deviation σ_X	$P = 1 - F\left(-\frac{M_x - M_y}{\sqrt{\sigma_x^2 + \sigma_y^2}}\right)$
Exponential; parameter λ_y	Exponential (with the shift parameter x_C); parameter - λ_x	$P = 1 - \frac{\lambda_x}{\lambda_x + \lambda_y} \exp(-\lambda_x x_C)$
Poisson; b	Poisson; a	$P(z = k) = \sum_{m=0}^{\infty} \frac{b^m}{m!} \cdot \frac{a^{m+k}}{(m+k)!} e^{-(a+b)}$ for positive values $k > 0$

The model of "determination of order quantity" is based on the well-known static (or one-periodic) inventory management task. The most common version of the model can be written as

$$C_{\Sigma} = C(s - z) + h\int_{0}^{S} (s - x) f(x) dx + p\int_{S}^{\infty} (x - s) f(x) dx \ , \tag{5}$$

where c - the purchase price (or production) per unit of output;

s - size of the order;

z - initial stock (before ordering);

h - specific costs associated with the storage of surplus;

x - random variable of demand for the product with the distribution density;

p - specific losses from missed demand.

From the condition $\left(dC_{\Sigma} / ds\right) = 0$ after transformations we find the so-called "critical ratio"

$$F(s) = \frac{p-c}{p+h}, \tag{6}$$

where F (s) - cumulative distribution function of demand.

From the point of view of estimating the reliability of the supply chain, this model allows us to calculate the probability of the non-selling production batch or deficit probability P (s) = 1 - F (s).

It should be emphasized that the "critical ratio" depends only on the cost parameters. Thus, the size of the order S will be determined by the distribution function F (s) chosen to approximate the demand.

Table 4 shows the formulas for determining S and the results of comparative calculations for some distribution laws. As the input data, the following parameters were taken: p = 10; c = 6; h = 1; the average value of demand $\bar{x} = 10$; root-mean-square deviation $\sigma_x = 4$.

Table 4. The optimum size of the order at a one-time purchase

The distribution law	The parameters of the law	The optimum size of the order S	The results of calculation
Normal	$\bar{x} = 10$; $\sigma_x = 4$	$F\left(\frac{s-\bar{x}}{\sigma}\right) = \frac{p-c}{p+h}$	S=8,6
Exponential	$\lambda = \frac{1}{\bar{x}}$	$S = \frac{1}{\lambda}\ln\frac{p+h}{c+h}$	S=4,5
Weibull	$m = f(\upsilon);\ x_0 = \frac{\bar{x}}{b_m}$	$S = x_0 \sqrt[m]{\ln\frac{p+h}{c+h}}$	S=8,4
Rayleigh	$M = \frac{\bar{x}}{\sqrt{0{,}5\pi}}$	$S = M\sqrt{2\ln\frac{p+h}{c+h}}$	S=7,6
Uniform	$a = \bar{x}$; $b = \sigma\sqrt{3}$	$S = \frac{p-c}{p+h}(b-a)+a$	S=8,9
For the Weibull distribution the parameters m and b_m are determined by a gamma-function or a special table (Lukinskiy et.al., 2012) based on the coefficient of variation υ			

Model of «selection of intermediary». The model is based on classic dependencies of the so-called circuit reliability when the redundant elements are included in the system «in parallel» to those elements, which reliability is insufficient. For example, to assess the reliability of the supply chain link, which includes one main and «n» redundant suppliers, the probability of no-failure operation is calculated by the formula

$$P = 1 - (1 - P_0)(1 - \prod\nolimits_{i=1}^{R}(1 - P_i)), \tag{7}$$

where P_o, P_i – the probabilities of no-failure operation of one main and «n» redundant suppliers, respectively.

As a rule, this kind of models is complemented by the condition, associated with limiting the costs for the system operation.

Model of «perfect (ideal) order». This model is most common in the works related to the reliability of supply chains. Usually, the calculated dependence includes three criteria of failure: fulfillment of an order out-of-time (P1), number of orders that are fulfilled not to the fullest extent (P2) and the number of improperly executed documents (P3).

The calculation formula of the probability of failure of formation of a perfect order has the form

$$P_0 = \prod\nolimits_{i=1}^{n} P_i = P_1 P_2 P_3 . \tag{8}$$

The number of elements in the calculation formula varies within wide limits, for example, in (Ballou, 2004) n=5. Also, when forming a multiproduct order, it is recommended to use the formula for WAFR (weighted average fill rate)

$$P_0 = \sum \omega_i P_i \ , \tag{9}$$

where w_i – frequency (weighting coefficient) for i^{th} nomenclature;

P_i – the probability of failure-free formation of the i^{th} nomenclature of an order.

However, the validity of using (9) requires further proof, since the method for determining weighting coefficients w_i is subjective.

Possible approach for the assessment of perfect order can be formed on the basis of the theorem on repeated experiments (Wentzel, 1969). According to this theorem

$$\prod_{i=1}^{n}(q_i + p_i z) = \sum_{m=0}^{n} P_{m,n} z^m \ , \tag{10}$$

where p_i - the probability of occurrence of event A in the i^{th} experiment;

$P_{m,n}$ - the probability of occurrence of event A in the n experiments precisely m times;

z - arbitrary parameter.

After expanding the left-hand side of the equation (10) and the reduction of similar terms for different z^m, it becomes possible to find the probability $P_{0,n}$, $P_{1,n}$,..., $P_{m,n}$, i.e. the probability of formation of a perfect order with a different number of simultaneously observed features of failure, m

The next step is the approximation of the obtained dependence $P_{m,n}$ by one of the discrete distributions, such as a binomial one:

$$P^*_{m,n} = C_n^m p^m q^{n-m} = \frac{n!}{m!(n-m)!} p^m q^{n-m} \ , \tag{11}$$

where p - the average value of probability of faultless formation of a perfect order; $q = 1 - p$. For the calculation p we can use formula $p = \sum_{i=1}^{m} p_i / m$.

Example. According to the results of the observations, the following features of failures have been identified: non-compliance with the application in time (probability of no-failure perform the operation $p_1 = 0{,}9$); the number of orders is not in full ($p_2 = 0{,}8$); the number of misfiled documents, $p_3 = 0{,}5$. The average value for the binomial distribution will be $p = 0{,}733$. Assume that n – the total number of the features of imperfect order; m - the simultaneous appearance of 0,1, ... n features.

Table 5 shows the results of calculating the probabilities of formation of a perfect order by the formula (10) and (11). From the analysis of the table we can say that between the distributions there is considered a good consensus.

Table 5. The results of calculation of probabilities $P_{m,n}$ and $P^*_{m,n}$

Number of features of failure, m	**The results of calculation of probabilities based on**	
	theorem on repeated experiments	binomial distribution
0	0,360	0,393
1	0,490	0,430
2	0,140	0,157
3	0,010	0,020

The «just-in-time» (JIT) model.

Transportation is a key logistical operation, a description of which is characterized by a large number of indicators and factors. As mentioned previously, the most complex in the preparation and decision-making in the supply chain management are transportation operations. This is due to the fact that the external environment of these operations is characterized by the uncertainty, which in turn is associated with a variety of risks that differ in frequency and in nature. The main classification criteria of transportation include modes of transport (road, sea, etc.) and the type of transportation (direct, combined, unimodal, multimodal, etc.).

Time characteristic of overcoming complicated circumstances and observing the requirements of international road transport (IRT) are random and should be taken into account while designing delivery of cargo, planning and arranging freight transportation just in time.

Taking the above mentioned features into account, the total time of transportation can be determined by means of formula:

$$T_o = \sum_{i=1}^{A} t_{i,i+1} + \sum_{j=1}^{B} \tau_j + \sum_{k=1}^{C} \Theta_k , \tag{12}$$

where $t_{i,i+1}$ – travelling time between i and $(i+1)$ points; τ_j – time of preparation of customs documents in j- point (in the country and at the borders); Θ_k – time for loading, unloading and warehousing in k-point; A,B,C – the number of sections of the roads a car moves, customhouses and loading/unloading points.

Then, with the account of the peculiarities of the international transportation, the formula of calculation of the total time spent on the route should be adjusted and presented as follows:

$$T_o = \sum_{i=1}^{A} t_{i,i+1} + \sum_{j=1}^{B} \tau_j + \sum_{k=1}^{C} \Theta_k + \sum_{l=1}^{D} \varphi_l + \sum_{m=1}^{E} \psi_m + \sum_{n=1}^{F} \eta_n , \tag{13}$$

where φ_l – random component, showing the increase of the trip time for repair and maintenance activities and other reasons; ψ_m – random component reflecting constraints connected with AETR; η_n – random component reflecting bans on the use of heavy-load vehicles; D, E, F – the number of cases of standing idle (considering the mentioned reasons).

JIT is one of the concepts of logistics, which, according to SCOR, is a model corresponding to the indicator «duration cycle of order fulfillment». In the paper (Lukinskiy et al, 2012), the JIT model is formed on the basis of the composition of distribution laws of stochastic variables T_i, which are the time of execution of i^{th} operation. The probability P of the just-in-time logistic cycle execution can be calculated with the formula

$$P = \Phi\left(\frac{T_o - T_c}{\sigma_T}\right), \tag{14}$$

where T_0 – «just-in-time» delivery time with probability P_0;

T_c, σ_T – the mean and the root-mean-square deviation of the delivery time accordingly.

In the case of constraints, instead of dependence (6), one should use the simulation modeling.

Models of inventory management. The main difference of this group of models from the rest is that the calculated dependencies are based on stochastic stock consumption processes and their reaching of one (or two) limits states.

In table 3, there are presented systematically calculated failure models (models of probability of deficit) for the main inventory management strategies and different options of description of the stock consumption processes.

Table 6. Failure models for different inventory management strategies

Strategy	**Options**	**Options of description of stock consumption processes**
With a fixed level (with re-order point ROP)	1.Order quantity S_3=const 2.Order quantity $S_3\neq$const (mini max)	1. Deterministic: - linear, nonlinear; - initial state («focus» or «stochastic variable »). 2. Stochastic processes: - stable, unstable; - with vigorous or gentle stirring; - initial state (see item 1). 3. Flows of «rare events» 4. The above-mentioned processes with «pulse» or «extreme» emissions.
Periodic (T, S)	1. Periodic delivery: values of T_0 and S_3 are constant. 2. T_0=const S_3= var (up to S_{max})	
Combined	1. Order is placed when inventory level is less than ROP or at T_0 moment of time 2. Order is placed at T_0 moment of time if inventory level is less than ROP	

Calculation dependencies to estimate the probability of occurrence of deficit are given in the papers (Ballou, 1999; Gertsbakh and Kordonsky, 1966; Lukinskiy et.al., 2012).

The presented failure models allow evaluating the probability of failure-free performance when executing a number of logistics operations and functions. At the same time, a number of problems require further development associated with diversification of supplies, the relationship between events and running processes, their sequence and others.

4. Approbation

Approbation of the developed methodical approach has been carried out with the use of the data published in various sources and of the collected information on the indicators of reliability of logistics enterprises (transport companies, warehouses, etc.).

The most developed of all failure models to assess the reliability are those related to inventory management in warehouses in multilevel supply chains. On the one hand, this is due to the importance of the solution of the problem connected with deficit and excess inventories for enterprises; on the other hand, it can be explained by a deep theoretical study of inventory management tasks and cumulated experience of their practical solving. In addition, by its nature, the inventory management models are identical to the classical failure models in technical systems.

With regard to models of perfect order, the practice of calculations of key performance indicators (KPI), which became widespread because of the implementation of the balanced scorecard system in some enterprises, played a positive role in their development. In general, we can say that these models are efficient, and their further development requires changes and updates to data collection and analysis of primary data.

The model of selection of intermediaries and the JIT model also can be referred to quite successfully developed models. But they did not receive wide distribution because of the lack of relevant sections in the textbooks on logistics and supply chain management. For this reason, the probabilistic model of «supply and demand» is almost never used in the process of procurement and management of orders.

5. Conclusion

The complex of failure models to assess the reliability covers the major functional areas of logistics and includes key logistics functions and operations: procurement, orders management, transportation, inventory management, warehousing and materials handling. Revised and improved models allow calculation of the necessary reliability indices for the elements of supply chains, in other words, they allow actual assessment of the level of customer satisfaction.

Further development of the developed complex is connected with the identification of causes that are giving rise to failures during the execution of logistics operations that are related to the change in the parameters of material, information, financial, and particularly intellectual (human factor) flows. In this case, the opportunity to assess the reliability of supply chains, not only during re-engineering but also during the design of logistic systems, becomes real.

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APPLICATION OF EPC STANDARDS AND MOBILE NETWORKS SERVICES TO ENHANCE THE QUALITY OF POSTAL SERVICE

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This article deals with new technologies and methods to optimize the transport and delivery of postal mails. Introduction of this article defines the technologies and procedures that postal operators have started to use. The main part of the article describes specific implemented solutions of several postal operators and their benefits. The last part shows using of EPC standards in a processes chain. The conclusion of the article is devoted to the evaluation of these technologies and their potential in the area of postal sector.

Keywords: delivery mails, mobile technology, post, RFID technology, EPC standards

1. Introduction

Information, currently, is still the best competitive tool and those who get control of it first, gain a big advantage. Using automatic identification technology can extract information from manufacturing, logistics and business areas in near real time. These technologies are indispensable aid in identifying, tracing and tracking of any object. Recent advances in RFID will enable us to allow, in the future years, to obtain any object in heterogeneous environments as a small RFID device. This device will be able to monitor, control and ultimately may have an important role in a number of key decision-making processes. Therefore, RFID technology can be described as very beneficial, as it is currently implemented in more areas than it might initially seem. But there are other technologies that have experienced tumultuous development besides RFID technology, namely the mobile telecommunications. This technology has been gradual convergence of telecommunications with information technology and new media course (together mobile telecommunications) and contributed to a massive change in orientation, not only in industry but also in one's daily life (Fuchikova, Kebo 2012).

Mobile telecommunications technology has played an important role in accelerating and moving into the areas of communication and processes, which are important in the terms of time. It is these two contactless technologies that we are currently considering as the key ones, since they have made the greatest enrich and simplify the existing processes in all areas of human activities. It can be said that both are beneficial only in specific industrial areas, which means that one technology brings benefits to those processes and areas where it would be unrealistic to use the other and vice versa. It is natural to assume that reaching the desired track record (enrichment) could be achieved just by integrating these technologies mentioned above, and this would also eliminate the unreality of the use of technology in inappropriate areas. The combination of advantages of both technologies could of course not only reach new markets, but also improve processes in the existing industrial sectors.

2. Mobile telecommunication in postal sector

One of the areas, where mobile telecommunications have found their place is just the postal sector. This technology makes it possible to move the communication to the end customer. It may be important especially in the delivery of postal mails, because mail recipient is not usually aware of the arrival of mail to his address. Precisely in this area, there is the possibility of streamlining this process through mobile telecommunications, because it allows communication with the end customer (recipient of postal mail) (Bolarin 2011). No less important is the communication with the sender of postal mail that could be informed of the delivery of mail through mobile telecommunications.

3. Analysis of the use of mobile communication postal operators to streamline postal delivery process

At present, a large number of postal operators are using mobile telecommunication to streamline delivery processes. There are many solutions how to use this technology to improve the above-mentioned processes, but all they have common ideas. These ideas are:

- provide information about delivery status of mail to the recipient postal mail,
- provide information about delivery status of mail to the sender postal mail,
- arrange a day, time and place of delivery postal mail to the recipient.

Research has found that most postal operators use mobile services for the following activities (services): telephone conversation with the recipient of postal mail, for sending an SMS message to the recipient of postal mail, for sending an SMS message to the sender of postal mail, for sending an interactive SMS message to the recipient of postal mail or for sending an SMS message to the recipient of postal mail, after delivery of postal mail into postal box; with the standard forms of communication:

- **Telephone conversation (notice)** – It's a service for communication with the recipient of postal mail. This communication provides information on status mail or place and time of delivery of postal mail.
- **SMS message to recipient** – It's a service that provides information about status and the planned delivery of postal mail via SMS message to mobile telephone recipient of postal mail
- **SMS message to sender –** It's a service that provides information about the delivery status of postal mail to the sender of the postal mail. SMS message usually sent after the delivery of postal mail.
- **Interactive SMS to recipient –** This is a special type of service that is based on two-way communication. There is mean SMS communication between postal operator and recipient of postal mail. The recipient will receive SMS message, and the first part of message content preliminary information on delivery of postal mail to the recipient address. This part is the same as in the two previous cases. The second part of SMS message contains information about the possibility of changing the date of delivery.

In the second part of SMS message there are predefined alternate days for delivery. Each day is represented by a numerical choice. If the recipient of postal mail wants to deliver the postal mail on a different day, he sends an SMS with an appropriate answer with a numeric choice, which is predefined in the incoming SMS message.

SMS message to recipient after delivery – This is again a specific type of services. In this case, the SMS is sent to the recipient after delivery of postal mail into postal box.

A very specific and new way to use the SMS service in postal sector is through automated postal dispensaries (the so-called Pack Boxes or Pack Station). After every transport and storage of postal mail there is generated and sent an SMS to the recipient with information on storage mail. The SMS message contains info about location and designation of pack station and access cote to open the compartment. The use service of mobile network can result in:

- attractiveness of postal services,
- reduction or elimination of the cost of the failed delivery of postal mail,
- replacement of paper notification of delivery failure postal mail,
- possibility for the recipients to participate in the final phase of the process of mail delivery,
- streamline access of mail recipients.

4. Other possibilities of mobile telecommunications to improve the process of delivery postal mail

4.1. Sending SMS confirmation of receipt mail to the sender and monitoring postman

The principle of this solution lies in the arrival of the postman to the address of the addressee and probing barcode Smartphone. The value of this code would be read out and recorded in the database. On the basis of this initiative there would be generated and sent SMS messages to the sender mail. The process of the solution would be undertaken in real time. The content of the report will inform the delivery of the parcel in time and space.

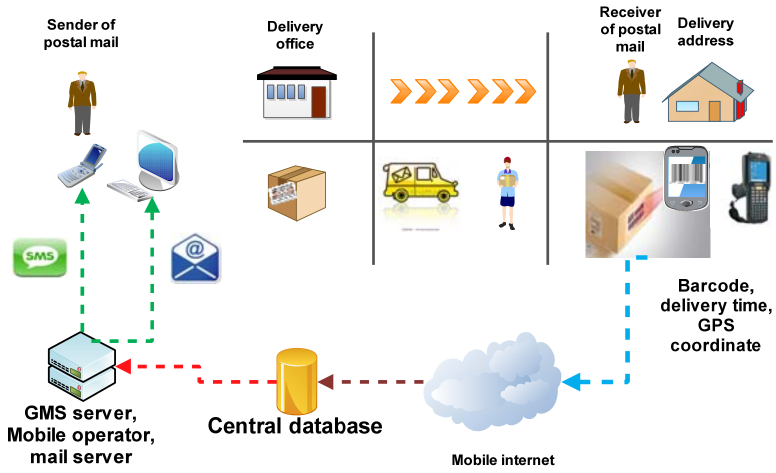

Figure 1. Principle of this solution 1

4.2. Delivery of postal mail to the selected GPS

The principle of this solution lies in the additional delivery of mail to the GPS coordinates, the recipient who sent the mail through SMS. GPS address by means of a smart phone. Based on this GPS coordinates, postal operator delivers, for a fee, mail to the place designated addressee mailings. All communication take place by means of the SMS messages sent.

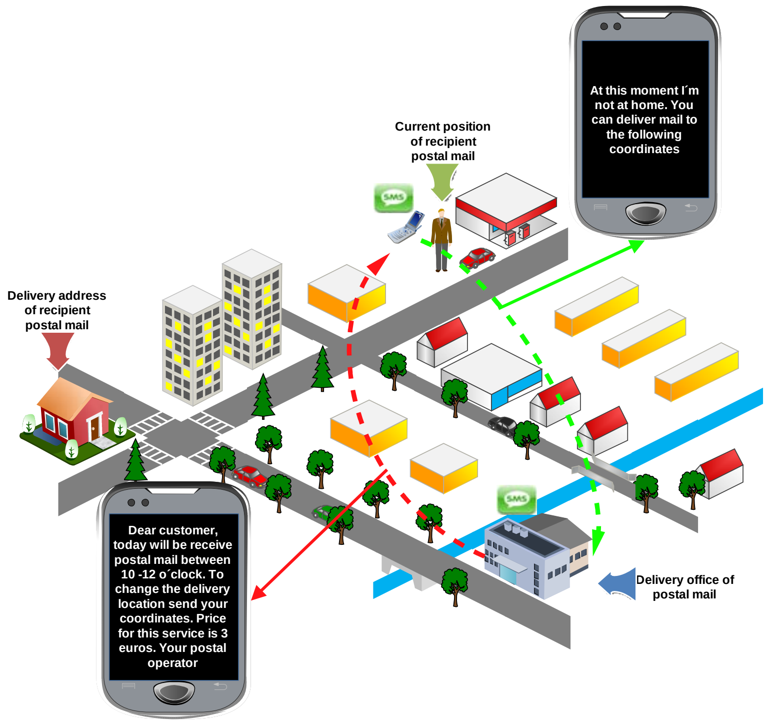

Figure 2. Principle of this solution 1

4.3. Draft model to improve the process of mail delivery

Given the nature and scope of these two technologies, it is evident that each provides a positive effect in different planes within the shipping process. Let us then outline what the main effects of these technologies bring in terms of the process of monitoring the transport and delivery (delivery) of mail.

RFID technology is a complex, combining a number of different computing and communications technologies to achieve the desired objectives. (Kolarovszki, Dúbravka 2010) RFID technology enables real-time consignments bearing RFID identifier uniquely specify the exact time and location specific mailings at various stages of the production process, that enables to provide valuable information about the input or output of the consignment under such processing centres. Generally, it is an element of automation, which provides information without human intervention.

Mobile services in turn allow for certain conditions to facilitate communication between the postal operator and customer, using their services similarly, as mentioned in assessment using the services of mobile networks in the postal sector. The whole essence of the proposal is based on simplicity and eliminates the need of human labour to optimize mail supply (delivery).

Before starting the planning and designing the process model we define some basic principles that should be met in the development of the proposed model:

- eliminate the need of human intervention (necessary labour) under the proposed model,
- the lowest level necessary hardware and software,
- automate the entire process of the proposed model,
- allow the sender to change the mail delivery available,
- simplicity and complexity of the system,
- possibility to use additional hardware and software,
- applicability of primarily recommended insured letters and parcels.

Therefore, the way to integrate these technologies within the proposed model has been more noticeable, trying to describe the scope of each of these technologies on a general model of the transport and delivery of postal items. Out of the above, the two technologies have been used in the design as well as some other additional technologies, which to a certain extent, within the model, eliminates the need of a higher number of necessary hardware. This additional element is just bar code technology.

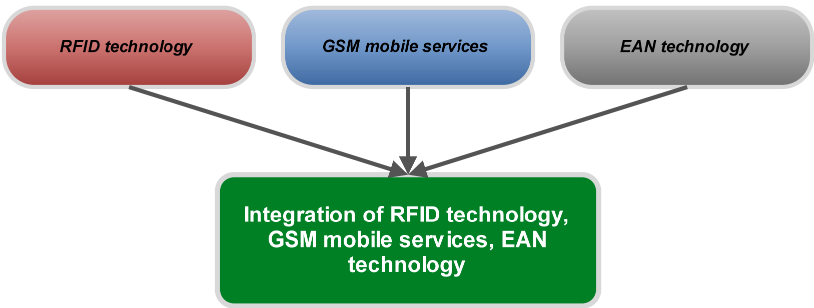

Figure 3. Integration technologies

Before we begin to define the areas of use of these technologies in the postal sector, it is necessary to outline a simplified general model of transport and delivery of postal items. In view of the relatively high cost of design and, generally large volumes of mail distributed to the light of the principles, we deal only with recommended, insured letter-post and parcel shipments.

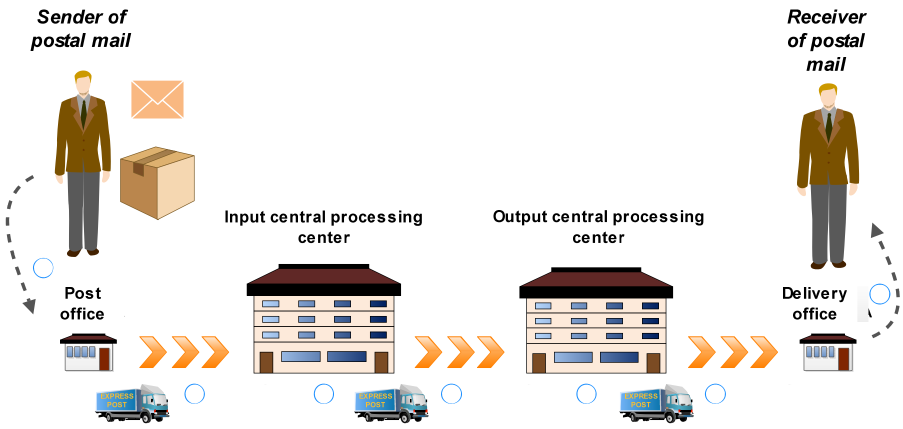

Figure 4. Principle transport in postal transport network (Vaculik, Zelik 2010)

Simplified principle of transport and delivery of postal items is implemented in the following points:

1) The consignor comes to posting place and makes recommendations, insured letter or parcel,
2) The consignments are transported to the input of the central processing centre
3) are processed and categorized according to the address of lines of output to the central processing centres,
4) The consignments are transported from the central processing centre input to output processing centre
5) again leads to sorting of mail by individual delivery points,
6) as follows, categorized shipments are transported to various delivery points,
7) Then, shipments are delivered to the addressees.

We can now consider the applicability of technologies due to the simplified general model of transport and delivery of postal items by the principles set out in the design of the model. The proposal is to construct a model that would allow monitoring the consignment in the postal mail transmission network operator, and arranged at certain points of communication with the addressee of the handling and disposition of the consignment. As for the nature of the design model, we can conclude that the function will perform at two levels, namely in:

- identification part and
- communication part.

By the identification of the shipmen, it will be tracked from submission to delivery through passive identification technology to posting and delivery locations, and also through active identification technology in the processing centres. By passive identification technology we mean the aforementioned barcode technology and by active identification technology – the RFID technology.

Names of passive and active identification technologies have been chosen because of the need of separation technology, which is needed to identify mail within individual branches i.e. postal operator places human involvement, and those without the human factor bypass. The essence of communication is the ability to convey one-sided or two-way communication between the operator and the addressee of the postal mail.

When selecting appropriate options for the proposed model, they can be derived from the length information stored in the RFID identifier, i.e. the number of characters that are stored in memory. This value is usually quite high and if it's printed in bar code would thus long value obstructing the possibility of manual data entry, assuming no bar code reading device for storage in the database. This is one of the reasons why we decided for the second option, there will be a relationship between the information stored in the barcode and the information stored in the RFID identifier in the smart label. So there will be pre-defined table relationships between the data from the barcode and the data from RFID identifiers. When you enter barcode into the database of the deposit site is still attaches the data from RFID identifier stored in the predefined table sessions. The principle is shown in the following figure (Tengler, 2013).

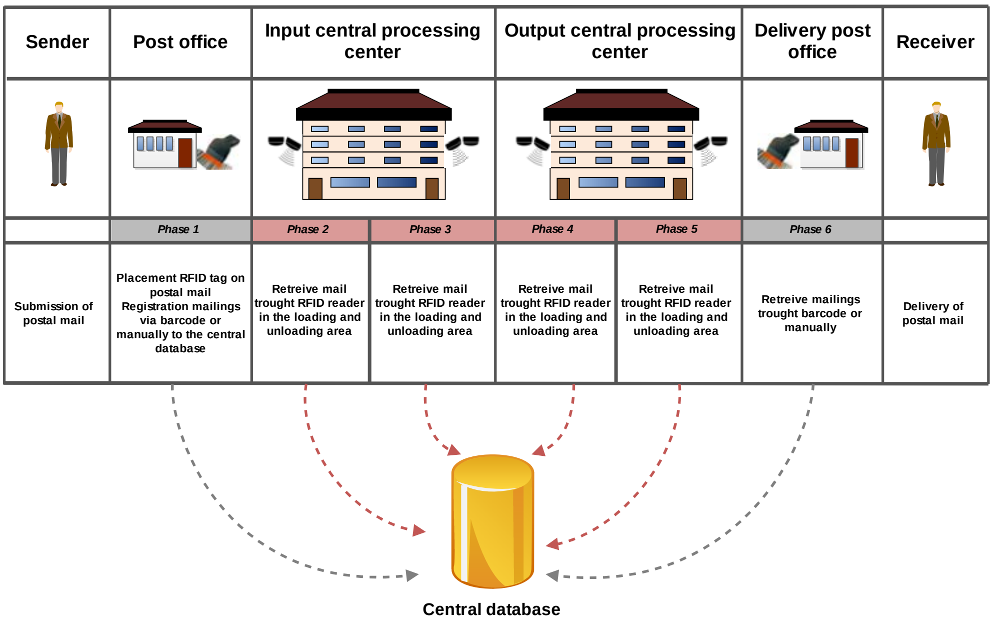

Figure 5. Principle of this model (Tengler 2013)

Anticipated benefits of the proposed system

As for the based on the model design system, we can say what benefits might accrue to all participants in the process of administration, transport and delivery of postal items, the sender, addressee and postal operator. Taking benefits for postal operator may be primary or secondary.

Benefits for the customer (shipper)

- detect the condition, respectively, delivery of mail via SMS or e-mail,
- increase comfort services for the sender's mail.

Benefits for the customer (the addressee)

- increase comfort services for the addressee,
- improved accessibility to postal consignment to the consignee,
- obtain information about the planned delivery of mailings, before the completion of the transport of the consignment to the place of the delivery postal operator,
- option available to change the shipment, i.e. to change the date of delivery of the consignment, respectively the shipment to the delivery location postal operator via SMS or email.

Benefits for the postal operator

The primary benefits

- The flow of mail,
- monitoring compliance with quality requirements for the provision of postal services,
- the possibility of reducing costs in relation to the identification and elimination of bottlenecks in the distribution network,
- the possibility of cost reduction due to the reduction or elimination of unsuccessful delivery attempt and also in connection with the issuance of the consignment at the place of delivery postal operator in an unsuccessful delivery attempt,
- Possibility to reduce the percentage of non-delivery of mail at the first attempt.

Secondary benefits

- Using subsequently implemented infrastructure for monitoring transport units (postal cages, containers, crates, bags and other) under their postal operator of the transmission network (Tengler, 2013).

5. Creation of real models

A custom application was created in an environment middleware OnId/AMP, database system based on MySQL and Ozeki SMS Server. Functional diagram consists of two main interlinked parts. The first part (Fig. 11) consisting of processors ***FilterEqualTo***, ***EarlyDecoupler***, ***InsertProcesor*** and ***Inline-SelectProcessor*** provide input of relevant information during the process of each processing centre.

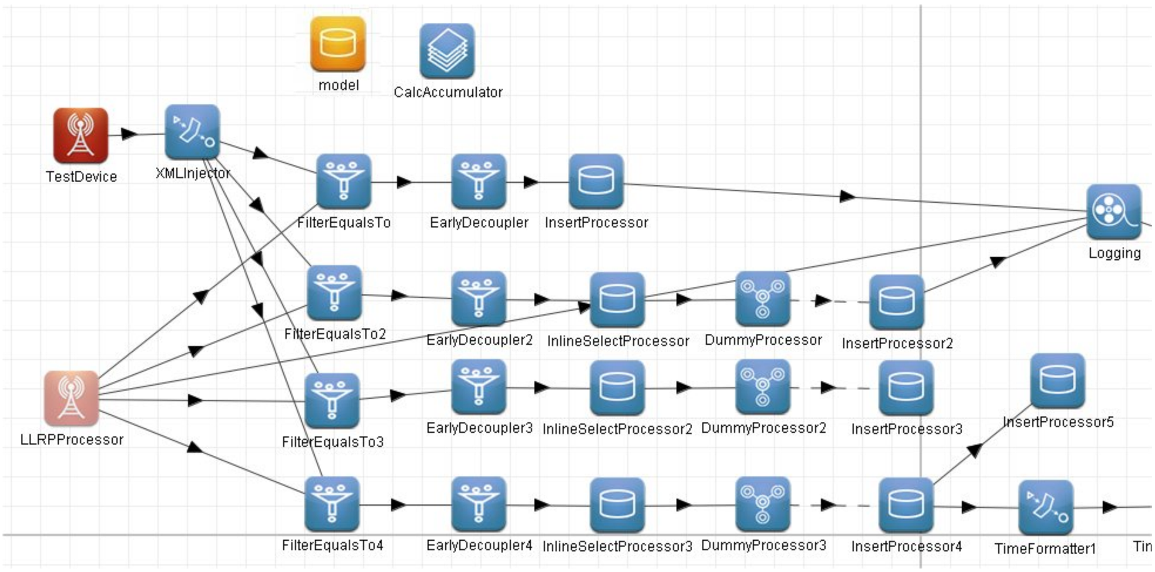

Figure 6. First part of real model

The system contains several mutually cooperating tables in the database "Model", in which the individual has entered manually input, during processing chains and processing SMS and its notification.

The last part of the model (fig. 7) consists of processors for the preparation of a short message (***TimeFormater***, ***QueryExecutor***, ***MessageTransformer***) and its transfer to Ozeki SMS Server to manage its transmission through the mobile network operator and processing feedback notification (***InlineSelectProcessor*** and ***SMSSender***).

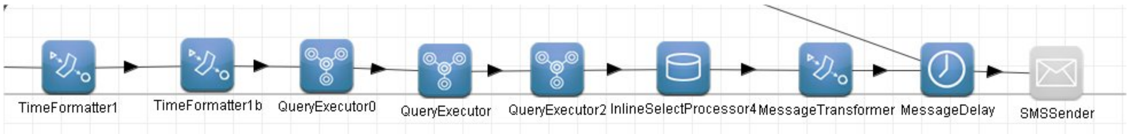

Figure 7. Second part of real model

6. Use of EPC codes, created by the existing EPC standards in mail and logistics

As it has been shown in Fig. 8, throughout the processing chain is involved in three basic parts - RFID, GSM mobile technology and EAN respective EPC standards. In the previous sections we have considered the particular technology of RFID and mobile technology. But to the entire communication chain must be able to work some elements of standardization. Therefore, the final parts look more like the EPC standards and their application in the processing chain.

Implementation of RFID - EPC tag second generation (EPC GEN2 tag) to the postal service would be an increase in efficiency and productivity of the sector. Price tags are steadily declining and, therefore, the postal sector should pay more attention to the integration of this technology into their business processes, thereby ensuring not only increases of efficiency and productivity, but also increase of the visibility and accuracy of postal operations.

Standards represent the cumulative inter-conditional actions and measures that lead to efficient unification recurring solutions or can be seen as determining the performance requirements of raw materials and products, the manufacturing processes, to achieve uniform quality and functional use.

EPC codes, created on the basis of the existing standards may be used throughout the supply-demand chain, from producer to consumer. Mail can also be used with such EPC codes in their activity. The proposal to use the developed EPC code, based on the existing standards, is described in the following example (see Figure 8).

Imagine postal processes such as Supply Chain. The automatic data collection throughout the chain will serve data carrier, in which the memory will be stored the stored PC code itself, in this case, the EPC Gen2 RFID tags. We have to identify Gen2 EPC RFID tags

EPC scheme used in this case:

- SGLN to uniquely identify physical locations, specific place,
- SGTIN to uniquely identify a specific type of product,
- SSCC to uniquely identify logistic units.

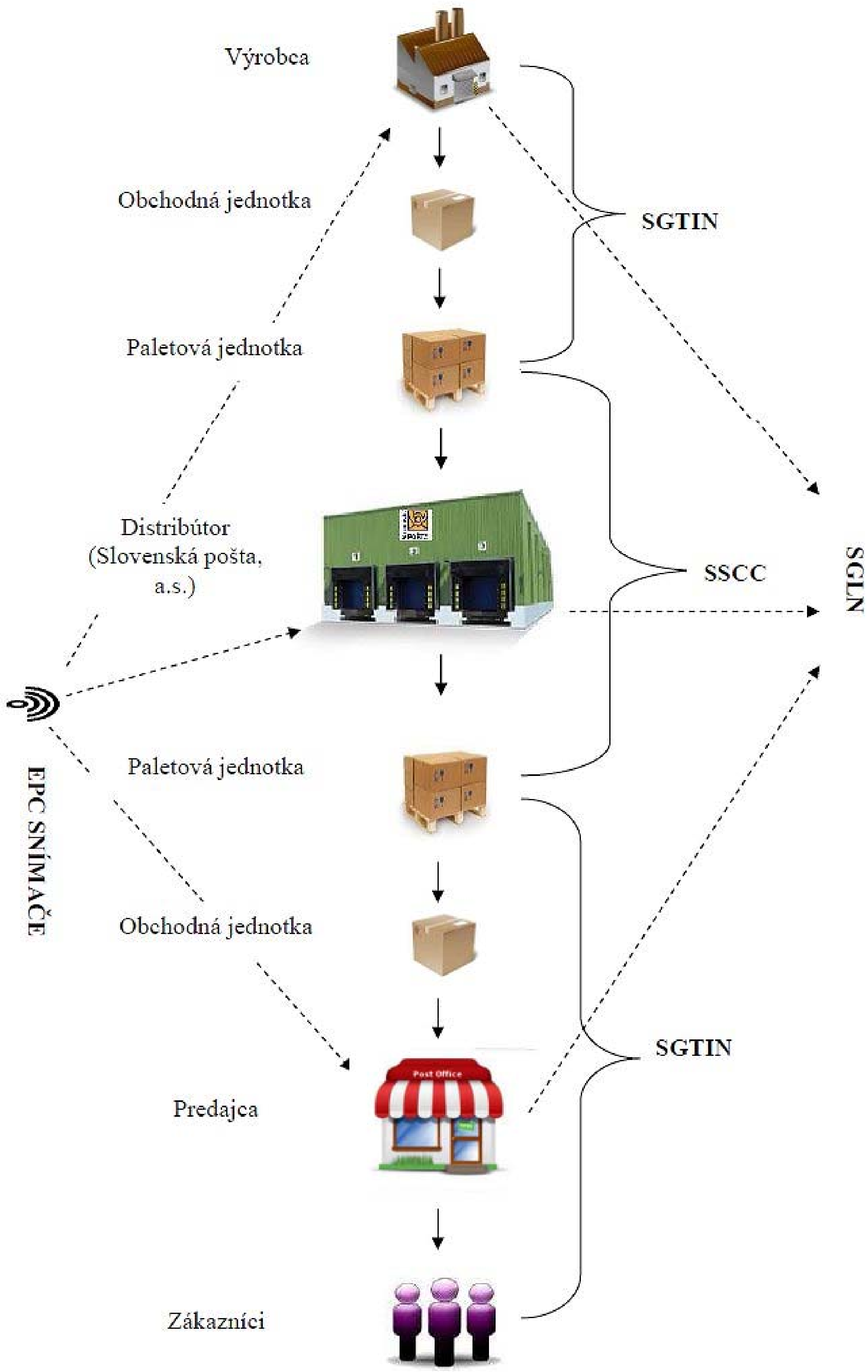

Figure 8. Use of EPC codes in mail and logistics

The data encoded in the tag memory will be scanned EPC sensors. EPC sensor will be placed at strategic points in the supply chains in order to track the movement of goods in the chain. Sensor data then executes software EPC middleware, which sends the data to the EPC IS or other existing enterprise information systems. Sharing data provide EPC IS, from which the distributor can (eg Slovak Post) require specific information about the product. Search Services (Discovery Services) allow users to access data related to a specific EPC code, and also allow users to request access to this data.

Therefore it has been necessary to add to the whole processing chain use the EPC standards. An essential part of their use is to understand the transformation of information between the imposition of the carrier identifier (RFID tag) and useable information hierarchically higher system (ERP).

6.1. Forms of EPC codes

EPC URI (uniform resource identifier) is the preferred way to uniquely identify specific physical object within information systems. EPC URI is a string that shall take the following form:

urn: epc: id: scheme: component1.component2. ...

Where the scheme is an EPC scheme and component1 and the following sections represent the elements used by GS1 key corresponding to the EPC code. Example for SGTIN:

urn: epc: id: SGTIN: GS1firm_prefix.kind_of_goods,serial_number ->

urn: epc: id: SGTIN: 0614141.112345.487 [13]

The structure of the EPC URI guarantees the uniqueness of all physical objects and applications around the world. EPC codes may take three forms. In computer systems, including electronic documents, databases and electronic messages shall have EPC code form. Another form, which may EPC codes acquire, is the form of the so-called EPC tag URI. Binary data structures defined in the Tag Data Standard are intended for use in RFID Tags, particularly in UHF Class 1 Gen 2 Tags. Specifically, it specifies that memory in these tags consists of four separately addressable banks, numbered 00, 01, 10, and 11. Bank 00 consists of access and kill password, bank 01 contains its own EPC, bank 10 is defined by the manufacturer and finally bank 11 is available to the user.

Memory bank code EPC RFID tag second generation also includes EPC code and "control" information (filter), which is used to guide the process of collecting data from RFID tags. This information can be used to filter tags, or to improve their reading efficiency. EPC tag URI is a URI string that represents a specific EPC code with specific settings for the "control" information stored in the memory bank EPC code. In other words it is a text equivalent of the entire contents of the EPC memory bank. This form is often used by the data collection, when reading RFID tag of "control" information interest application that provides data collection.

The EPC global Architecture Framework is used in the form of "events at the application level." Examples EPC tag URI when used SGTIN key:

urn: epc: tag: SGTIN-96: Filter.GS1_firm_prefix.kinf_og_itens.serial_number ->

urn: epc: tag: SGTIN-96: 3.0614141.112345.487

Another form, which can acquire EPC codes, is a form of binary encoding. Memory bank code EPC RFID tag contains the second generation compressed encoding EPC code and "control" information in a compact binary form. Converting between EPC Tag URI and binary form in the second generation RFID tag is 1:1. Binary form is used for low level software or hardware and usually converted into the EPC Tag URI or URI clear identity before being presented to form EPC code application logic. While pure identity URI is independent of RFID, EPC Tag URI and binary encoding are specific to the second generation of RFID tags (RFID EPC Gen2), because they contain a unique EPC identifier in addition to the "control" information. The EPCglobal Architecture Framework, this form uses the "Protocol for Sensor low level" and the "Air Interface Class 1 Gen2 and High Frequency".

The best way to show the transformation of information illustrates using the Smart Label, which is a combination of RFID technology and standard bar code in a single carrier (Fig. 9)

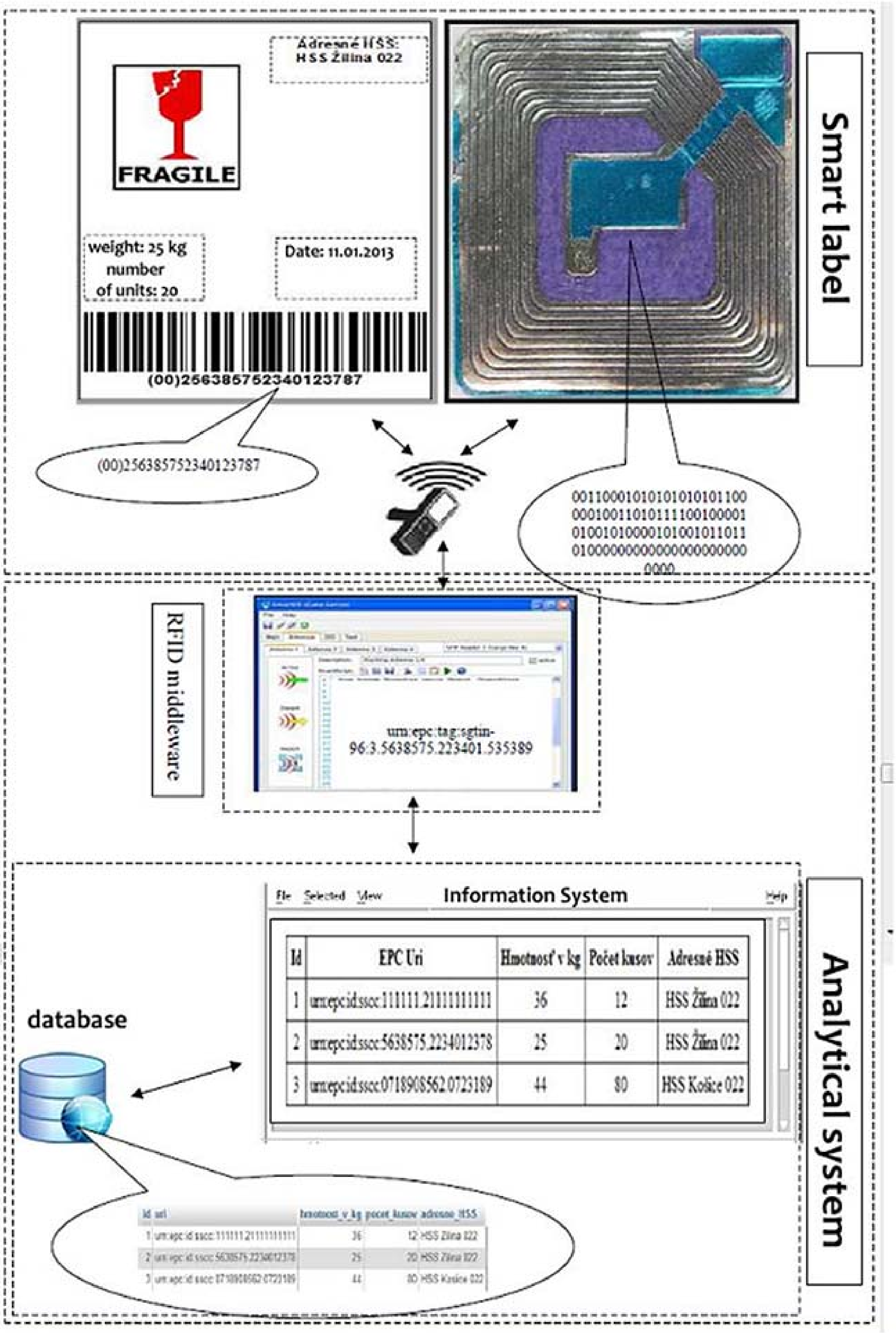

Figure 9. Use of EPC codes in the mail and logistics

Since we use middleware which does not directly support the EPC standards, it was necessary to provide management of their own means. As we can see in figure 10 for the decoding verification there was created a simple application in OnID/AMP middleware environment too.

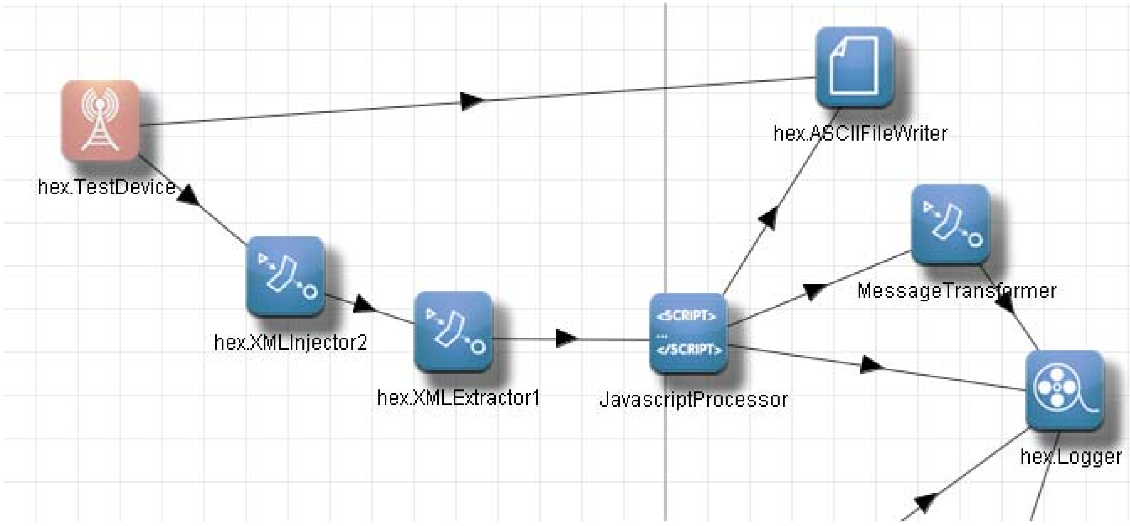

Figure 10. Procedure for decoding the content of identifier

At the entrance gate (***hex.TestDevice*** in fig. 10) the identifier is read. Standard representation is in the hexadecimal form in the xpathe /reading/tagId. For example:

3140 677A F407 1C2B 6700 0000

The next step is to adjust this form by ***hex.XMLInjector*** processor and ***XML.extractor*** processor. The adjusted form will be suitable for custom processing in a JavaScript - processor ***JavascriptProcessor*** in the scheme above. The first task of the processor is to save incoming massage to the variable content that is executed by this code:

```
var content = new XML(message.content);

 var answer = new XML();
```

Next task is transformation of hexadecimal format to binary format for example by H2B (Hex to Bin) function, which may look like this:

```
function H2B (prem) {
 var i;
 b ="";
 for (i=0; i < 90; i++) {
   a = prem.charAt(i);
   if (a == "0") { b += "0000";}
   else if (a == "1") { b += "0001";}
    ...
   else if (a == "F") or (a == "f") { b += "1111";}
   else if (a =="") break;
  }
 return b;
}
```

Result of function is in binary form:

```
<msg>
  0011000101000000001100111011110101111010000000111
  00011100000101011011001110000000000000000000000000
</msg>
```

In further processing, the binary code is transformed according to the EPC specification (partition, filter) for each header and we can get individual parts of EPC structure in the XML report:

```
answer = "<msg> prefix:" + H2B(content).substr(0,8) + "\n "
 + "filter: " + H2B(content).substr(8,3) + "\n "
 + "partitions: " + H2B(content).substr(11,3) + "\n "
 + "company prefix: " + BinToDec(H2B(content).substr(14,40)) + "\n "
 + "element serial: " + BinToDec(H2B(content).substr(54,18)) + "\n "
 + "serial number: " + BinToDec(H2B(content).substr(62,24)) + "\n "
 + "</msg>";
context.sendMessage(answer);
```

By using the ***sendMessage*** method there is generated an output message in the form:

```
<msg>
  prefix:00110001
  filter: 010
  partition: 000
  company prefix: 111111111111
  element serial: 11111
  serial number: 14270464
 </msg>
```

Next, the final format of EPC standard is created. This format is suitable for entry into the EPCIS system and by methods of ***sendMessage*** requested information is sent for further processing and by using the method ***outLine*** we can send information to the log system.

```
answer = "<msg> urn:epc:tag:sscc-96: "
+ BinToDec(H2B(content).substr(8,3)) + "."
+ BinToDec(H2B(content).substr(14,40)) + "."
+ BinToDec(H2B(content).substr(54,18)) + "."
+ BinToDec(H2B(content).substr(62,24)) + "\n "
+ "</msg>";
context.sendMessage(answer);
context.outLine("message to Logger...");
```

The resulting report is in the XML format:

```
<msg> urn:epc:tag:sscc-96: 2.111111111111.11111.14270464 </msg>
```

The description is used to decode the identifier for containers: SSCC-96 bits length. In a similar way, it is possible to create a number of processors to decode any input data according to the standard of an identifier of the EPC and its transformation from binary format into a form accepted in the further processing in the form of ***urn***, ***uri*** or ***pure identity*** regardless of encoding of the identifier and the bit size of the stored information (8-bit, 6-bit, etc.).

In the same way, for example, there can be decoded manufacturing information of any tag (TID Transponder Identification), where we can know by the encoded data about the used chip, memory size, type and serial number or user memory. By using Application Identifier (AI) we can store in the user memory further information: the length of goods, expiration date, and many others according to specifications and standards of GS1.

This makes it possible to link any postal, transport or logistics chain system working under EPC standards and RFID technology. We can label not only the shipments themselves within delivery chain, but also the transport of containers, pallets, vehicles and processing centres including end-Post offices buildings.

Manufacturer (postal operator) produces a business unit (letter, parcel). To indicate the business unit, we use EPC code developed on the basis of standard SGTIN. Growing of the business units will be stacked so that to be together created with a variety of pallet units (container), which will be labelled by EPC code, created under SSCC standard. Strategic locations where the production takes place (income items), loading / unloading, selling (supply items) goods, or the place where the goods are stored shall be labelled the EPC code generated by standards-based SGLN. Marked points help to locate the exact location of goods in the warehouse or goods traced anywhere in the supply chains.

7. Conclusion

In this article, we have portrayed the main areas of using services of mobile network and especially the SMS service. This service is in conjunction with the process of delivery postal items, it allows creating a fast and effective bridge between the postal operator and the recipient for providing information on the status of delivery mail. Therefore, it allows one-way but also two-way communication in order to improve the process of delivering mail and also increase comfort services in a competitive environment. And that's why we can say that use of mobile networks can be described as a key to obtaining meanings competitive advantage in postal market. At the same time, there have been described necessary standards that are used for marking the various elements in the processing chain.

Use of EPC codes in the postal service can be a variety. In combination with RFID identifiers, as the medium of the EPC code, it can be used for the marking of the transport unit. Transport units can be marked with smart labels. The added value is based on itself RFID, that allows you to capture transport units without direct optical visibility, allows you to read more labels in a short time and at greater distances, as many of the radio technologies at an operating permit busy transmitting and receiving signals more efficiently than optical scanners.

The problem with the use of EPC codes in the mail may be in the absence of headers for operators at present, because there is no header and encoding scheme for the postal sector. Post Office would have to ask for header by GS1. A preferable option now appears to be using the already existing EPC standards (header) and adding the data according to their own needs; the data must remain for the structure, which binds to the selected header. ***It is for consideration of weather***, like the CPID automotive or aerospace industry for ADI, it is worthwhile to create a coding scheme for the postal sector of some sort (PPID Postal part identification) that would more clearly reflect the needs of the sector (shipment, related services, locating and other elements). It has been a bit difficult process for approving and setting standards for operators, but the outcome could be more effective than the application of the existing standards.

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DEVELOPMENT OF THE MODEL OF DECISION SUPPORT FOR ALTERNATIVE CHOICE IN THE TRANSPORTATION TRANSIT SYSTEM

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The decision support system is one of the instruments for choosing the most effective decision for cargo owner in constant fluctuated business environment. The objective of this Paper is to suggest the multiple-criteria approach for evaluation and choice the alternatives of cargo transportation in the large scale transportation transit system for the decision makers - cargo owners. The large scale transportation transit system is presented by directed finite graph. Each of 57 alternatives is represented by the set of key performance indicators Kvi and set of parameters Paj. There has been developed a two-level hierarchy system of criteria with ranging expert evaluations based on Analytic Hierarchy Process Method. The best alternatives were suggested according to this method.

Keywords: Transport model, transit, decision support, Baltic Sea Region

1. Global logistics trends and freight transport development

International business has been undergoing a period of rapid transformation. Researchers at the McKinsey Global Institute (McKinsey Global Institute, 2012) calculated the economic centre of gravity of the world by using Gross National Product (GDP) as a measure of the mass or weight of a country and using the world map as a physical object (Figure 1).

Based on the calculations, the centre of gravity in 1950 was in the Atlantic Ocean. Today the centre of gravity is over southern Russia and moving eastward, as shown in the map at figure 1. As a result of shift of economic mass, supply chain configurations are becoming increasingly volatile and the shift in the global economic centre of gravity to emerging regions may see reduced growth on traditional trade routes. Such restructuring is contributing to economic growth, better allocation of resources and more freedom of choice for consumers, as well as increased competition. In order to be internationally competitive, businesses are organising strategic worldwide networks that can deliver an efficient and high-quality response to demand from any segment of the world market. The efficient and integrated organisation of such activities is often referred to as global logistics and it has become the core of global competitive power. Business will need extensive market intelligence for using the opportunities that arise from this change of economic centre of gravity.

Global logistics networks serve as a circulatory system for the corresponding global value-adding chain where various components in the logistics network serve different functions in an organisationally unified manner. Therefore, in order to establish a region as a key component in global logistics networks, it is necessary to create a vision of how to position the region strategically within the context of the overall global logistics networks.

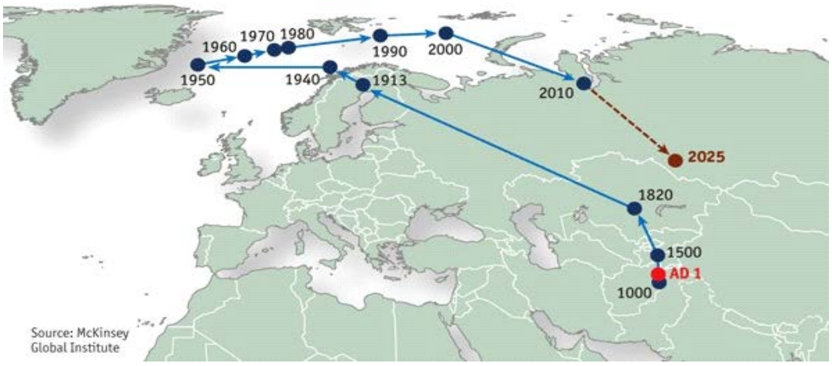

Figure 1. Evaluation of the earth's economic centre of gravity

Development pattern of the particular sectors within the EU transport system is quite unbalanced which is preconditioned by the following factors: first of all, the extent of the particular countries involvement into the work of the transport industry varies from country to country; secondly, it is influenced substantially by the pattern of the EU financial packages allocation. Nowadays one of the top priorities of the EU transport policy is the expansion of the Trans-European networks (the possibility is envisaged even to stretch them outside the EU borders), as well as building up the global transport corridors in cooperation with other countries.

Any strategy adopted for the purposes of the transport system development marking worth since it contains two split-level components. One of these components is of a global character: today the appropriate infrastructure including transport must be ensured to guarantee a successful development of a given region. This assumption quite logically leads us to the next level – the EU specifically formulated practical proposals and problem-solving strategies. The same two-level approach can be used to describe the EU transport policy. However, when stipulating the EU transport policy, one has to take into account a major impact it confronts due to the influence of political and economic factors.

The Baltic region is remarkable for its economically advantageous geographical position within the Eurasian transport system, connecting Russia with the biggest world markets of the Central and Eastern Europe as well as with the Baltic States and the CIS States and China. In the situation where a large increase in trade and freight transport volumes in the Baltic Sea Region (BSR) is expected and in which the BSR is facing a major economic restructuring, efforts to additional study of more integrated and sustainable transport and communication links within the BSR are needed.

The volatility and uncertainties of today's economic environment and expanding global supply chains require coordinated efforts to optimise network configurations and inventories to synchronise global supply and demand. At the same time, new business models are emerging with shift to customer-driven supply chains. Reconfiguring supply chains around customers has led to the necessity for more flexible and adaptive formation system of transport and logistics links. In this situation decision support system (DSS) is one of the instruments for choosing the most effective decision for a customer in constant fluctuated business environment.

There are seven typical steps in the process of multi-criteria decision making (Sinha, 2007):

- to identify transportation alternatives;
- to establish performance criteria;
- to establish relative importance of performance criteria;
- to establish commensurate scale for measuring levels of each criteria;
- Using the established scale, quantify level (impact) of each criterion for each alternative action;
- to establish the combined impact of the different criteria for each alternative;
- to determine the most satisfying alternative.

The first two tasks mentioned above are the subject of the current investigation.

2. Identification of transportation alternative. Case study for the route "China – Russia"

Containerization greatly reduced the expense of international trade and increased its speed, especially of consumer goods and commodities. Today approximately 90% of non-bulk cargo worldwide is moved by containers stacked on transport ships (Mikulko, 2013).

The increasing use of containers in transport has increased the share of intermodal transport chains, which contain several modes of transport. Cost-efficient railway or sea transport is used on the main routes of intermodal transport, while flexible road transport is used in collection and distribution activities.

Therefore the main transport corridors connecting China and Russia for containerised cargoes are:

1. Southeast China -all-water route via Suez Canal to Baltic Sea;
2. Southeast China -all-water route via Suez Canal to Black Sea;
3. International Transport Corridor "Trans-Siberian" (or "East-West", the backbone of which is Trans-Siberian Railway) with different connections to rail/sea/road and delivery network at both ends;
4. West Europe-West China (through Kazakhstan territory) – rail and road connections.

The main competition is taking place between the two all-water routes and "Trans-Siberian" transport corridor. The ocean route through the Suez Canal is the most important trade route between the Far East, Southeast Asia and Europe and Russia. Large and global companies have developed an efficient logistics system which consists of a collection and delivery network at ends, terminals and large vessels for which some type of vessels can transport till 18000 TEU at a time.

Containerized cargoes are transported via shipping lines and operated on a regular basis. There are three main shipping companies (and brand leaders) in the container industry that provide services worldwide in the industry. They have about 39.65% market share together. These are APM-Maersk, Mediterranean Shipping Company and CMA-CGM Group. These three shipping lines are the main service providers for cargoes transhipped through the Baltic ports (Midoro, 2005). Short sea connections are based on these three main service providers:

1. Loading place in China-Main China port-Hamburg-Riga-Custom clearance place-Unloading place
2. Loading place in China-Main China port-Hamburg-Klaipeda-Custom clearance place-Unloading place
3. Loading place in China-Main China port-Hamburg-Tallinn-Custom clearance place-Unloading place
4. Loading place in China-Main China port-Hamburg-HaminaKotka-Custom clearance place-Unloading place
5. Loading place in China-Main China port-Bremerhaven-St. Petersburg-Unloading place
6. Loading place in China-Main China port-Gdansk-Riga-Custom clearance place-Unloading place
7. Loading place in China-Main China port-Gdansk-Klaipeda-Custom clearance place-Unloading place
8. Loading place in China-Main China port-Gdansk-Tallinn-Custom clearance place-Unloading place
9. Loading place in China-Main China port-Gdansk-HaminaKotka-Custom clearance place-Unloading place
10. Loading place in China-Main China port-Gdansk-Ust Luga-Unloading place
11. Loading place in China-Main China port-Zeebrugge-Ust Luga- Unloading place
12. Loading place in China-Main China port-Rotterdam- St. Petersburg-Unloading place
13. Loading place in China-Main China port-Antwerp-Riga Custom clearance place-Unloading place
14. Loading place in China-Main China port-Antwerp-Klaipeda Custom clearance place-Unloading place

15. Loading place in China-Main China port-Antwerp-Tallinn Custom clearance place-Unloading place
16. Loading place in China-Main China port-Antwerp-HaminaKotka-Custom clearance place-Unloading place
17. Loading place in China-Main China port-Antwerp-St. Petersburg-Unloading place
18. Loading place in China-Main China port-Novorossiysk-Railway station in Russia-Unloading place
19. Loading place in China-Main China port-Novorossiysk-Unloading place
20. Loading place in China-Main China port-Odessa-Custom clearance place-Unloading place
21. Loading place in China-Main China port-Odessa-Railway station in Russia-Unloading place
22. Loading place in China-Main China port- Vladivostok/Nahodka/Vostochny-Railway station in Russia-Unloading place
23. Loading place in China-Main China port-Railway station for train departure in China- Suhe-Bator (MN) - Naushki (RU) border-Railway station in Russia-Unloading place
24. Loading place in China-Main China port-Railway station for train departure in China-Manzhouli (CN) - Zabaikalsk (RU) border-Railway station in Russia-Unloading place
25. Loading place in China-Main China port-Railway station for train departure in China-Alashankou (CN) - Dostyk (KZ) border-Railway station in Russia-Unloading place
26. All mentioned possibilities could be started by rail or road transportation of cargo to the China main port (50 above mentioned transportation chains).
27. Loading place in China- Railway station for train departure in China- Suhe-Bator (MN) - Naushki (RU) border-Railway station in Russia-Unloading place
28. Loading place in China-Railway station for train departure in China- Manzhouli (CN) - Zabaikalsk (RU) border-Railway station in Russia-Unloading place
29. Loading place in China-Railway station for train departure in China- Alashankou (CN) - Dostyk (KZ) border-Railway station in Russia-Unloading place
30. Three mentioned possibilities could be started by rail or road transportation of cargo to the Railway station for train departure in China (6 above mentioned transportation chains).
31. Loading place in China – Horgos (CN) - Korgas (KZ) border-Custom clearance place in Russia-Unloading place (by road)

There could be several alternatives found for cargo delivery, determined by different routes and modes which form the vector space of a family of alternative transit vector routes. There are 57 alternatives of cargo transportation in the large scale transportation transit system in total which can be presented by graph shown at figure 2. All 57 routes and divided into seven clusters:

1. (1-3)+(6-8)+(13-15) – 1st cluster. Transportation through Baltic ports (Riga, Klaipeda, Tallinn);
2. (4+9+16) - 2nd cluster. Transportation through Finland (HaminaKotka port);
3. (5+12+17+18+19) – 3rd cluster. Transportation through St. Petersburg port, Ust Luga port;
4. (18-21) – 4th cluster. Transportation through Novorossiysk, Odessa ports;
5. 22 – 5th cluster. Transportation through Vladivostok/Nahodka/Vostochny ports;
6. (23-28) – 6th cluster. Direct railway solutions (Trans-Siberian Railway and West Europe-West China corridor);
7. 29 – 7th cluster. Transportation by truck (West Europe-West China corridor).

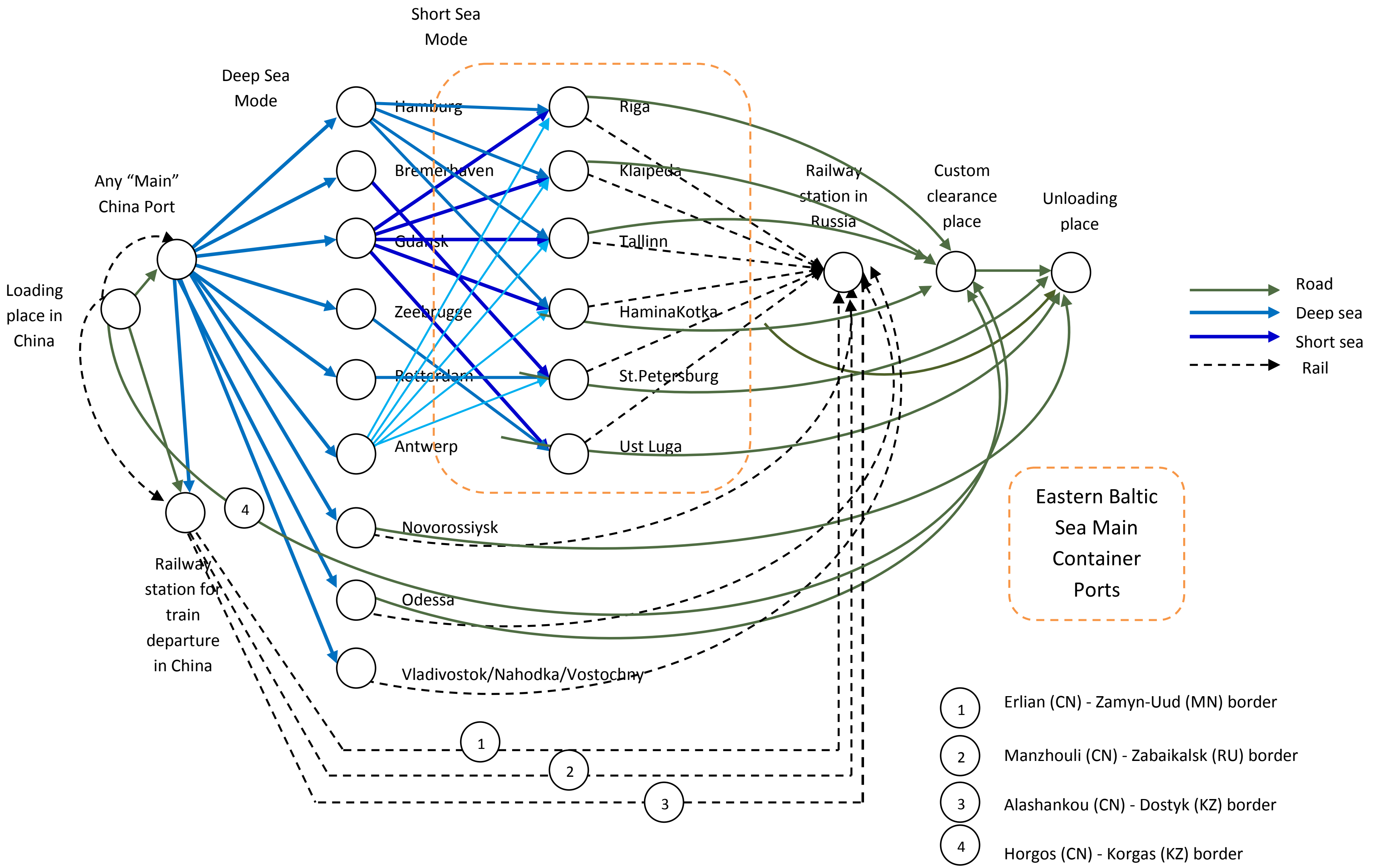

Figure 2. The alternatives of cargo transportation in the large scale transportation transit system

The large scale transportation transit system is presented by directed finite graph which is an ordered pair D = (V, A) where V is set of finite vertices (railway stations, ports, border points and logistics centres) and A is set of finite arcs (transport lines between ports and/or logistics centres). The vertices are grouped in clusters. In each cluster only one vertex can be used as alternative for transit routes. Each vertex v_i ($V=\{v_i\}$, $i=1,\ldots n$) is characterized by an individual set of key performance indicators K_{vi} and each arc a_j ($A=\{a_j\}$, $j=1,\ldots m$) is characterized by an individual set of parameters P_{aj}. The set of key performance indicators K_{vi} and set of parameters P_{aj} are described further.

If all characteristics of the graph were known the research would come down to the standard task solving.

The standard System of KPI (Key Performance Indicators) of ports and other Logistics objects currently used in the Baltic States came down to the very simple provide an incomplete picture of competitiveness. These KPIs are primarily describing the gross level of logistic object activity (e.g. total TEU or total tonnage). But traffic volumes often present a distorted picture: they are not always accurate (e.g., transhipment ports double count containers, once when unloaded and then when reloaded), container volumes give equal weight to empty and loaded boxes, cargo tonnages often include container tare weight, they do not distinguish between low-value/high-volume bulk cargoes and high-value unitized cargoes, and they are affected by a number of exogenous factors which makes it difficult to establish solid correlations with a logistic object's competitiveness (The World Bank, 2013). It is often sought to make transportation decision on the basis of wider range of performance criteria that reflect the concerns of all key stakeholders, i.e. agency goals, perspectives of facility users, concerns of society as a whole, environmental impact from transportation and others (Maciulis, 2009; Kopytov, 2010). But in reality such criteria are not decisive for the cargo owners.

That's why the set of key performance indicators K_{vi} and set of parameters P_{aj} should be determined to suggest further the multiple-criteria approach for evaluation and choice the alternatives of cargo transportation in the large scale transportation transit system with special attention to Baltic Sea Region.

3. Performance criteria for transportation decision making

There are a lot of major issues in business decision making in the international container transportation industry and cargo owners determine the mode by which they will have their freight transported, considering mainly their corporate, personal priorities. One of the general approaches for taxonomy of cargo owner's preferences was proposed in (Kabashkin, 2003). The framework D for decision making sets out the factors influencing the transit sector from users' point of view in the order of their priority:

$$D = \cap_{k=1}^{5} A_k \, , A_k = \{a_{ki}\}, \; i = \overline{1, m_k} \, , \tag{1}$$

where A_k – factor of influence with m_k parameters:

A_1 – geographical plane,

A_2 – economical plane,

A_3 – institutional/political plane,

A_4 – infrastructure plane,

A_5 – technology plane.

The choice of parameters at higher levels A_{k+1}, $k = \overline{1,4}$ become feasible when lower level A_k is achieved.

But $A_3 = \begin{cases} 1 \\ 0 \end{cases}$, "1" – if institutional and political situation in transit area is acceptable for users, "0" – otherwise.

In this case the analyse could be minimized by making decision support system taking into account the infrastructural, technological, economical, geographical factors and excepting the political.

Taxonomy of KPI K_{vi} for this model can be described by set of parameters shown at the figure 3 with suggested quantitative metrics for both - quantitative and qualitative KPIs.

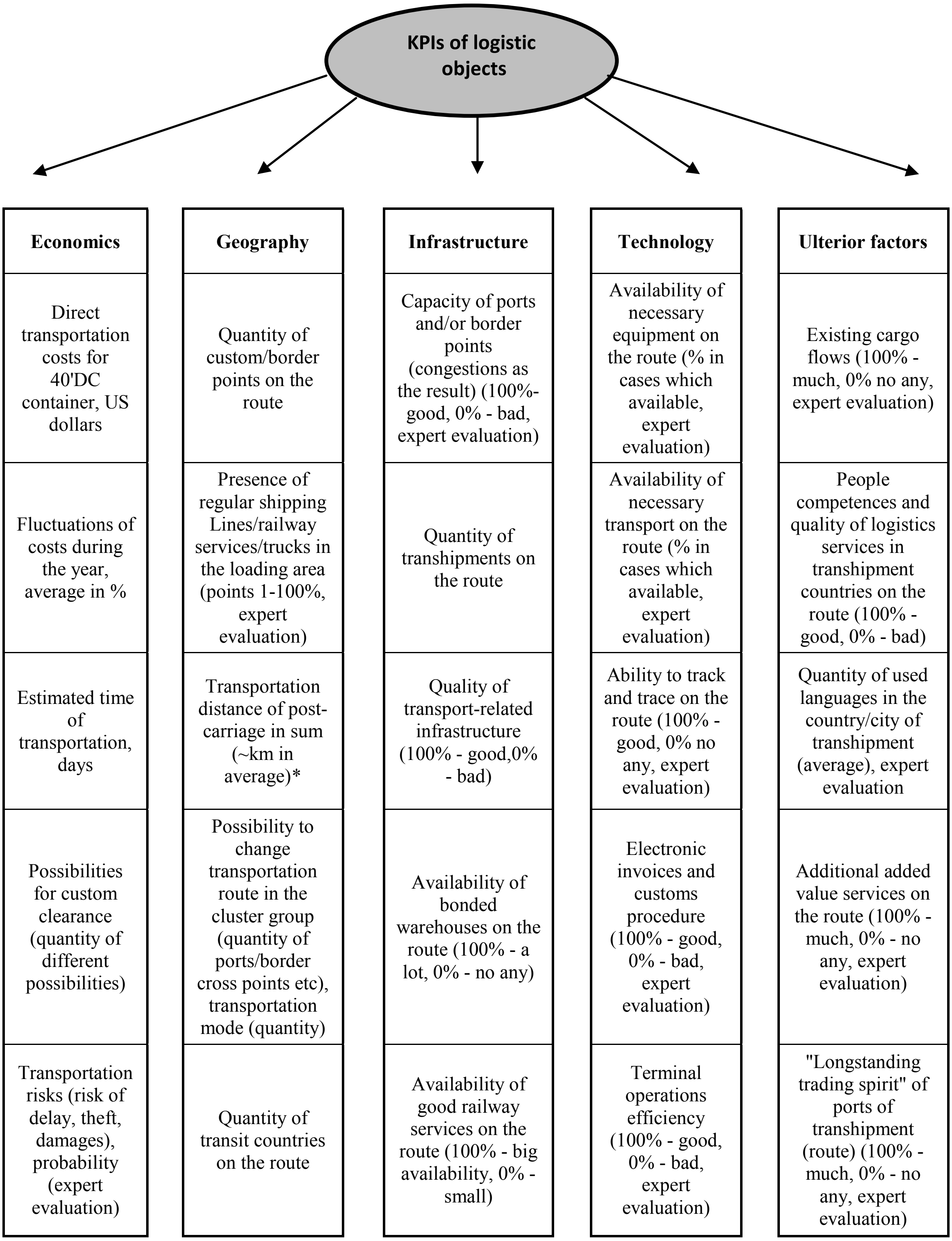

Figure 3. The Taxonomy of the set of key performance indicators K_{vi} and their quantitative metrics

After the initial steps of the decision making process (defining the alternative transportation actions and establishing the appropriate performance criteria) are realized the relative weight to each performance criterion to reflect its importance compared to other criteria may be defined. The known methods can be used to establish such weights: equal weighting, direct weighting, regression-based observer-derived weighting, the Delphi approach, the gamble method, pair wise comparison by the analytical hierarchy process and value swinging (Sinha, 2007).

The Authors chose the pair wise comparison by the analytical hierarchy process because this is method based on qualitative measurements and we have a lot of such measurements in the Research. Therefore the results are translated into numerical form which is very essential in terms of this Research.

4. Establishment of relative importance of performance criteria

The relative importance of performance criteria based on Experts Decisions was established accordingly to AHP (Analytic Hierarchy Process) method (Saaty, 2001). The companies and the real cargos' owners (located in Russia) that trade with China on a regular basis were put in the role of experts:

1. Equipment and machinery Trader;
2. Textile Trader;
3. Metal Company;
4. Chemical Trader;
5. Conserved Food Importer;
6. Shoes Manufactory;
7. Cars Importer.

This choice of Decision Makers was performed accordingly to the Statistics of Import from China to Russia for year 2012 and main "groups" of cargo:

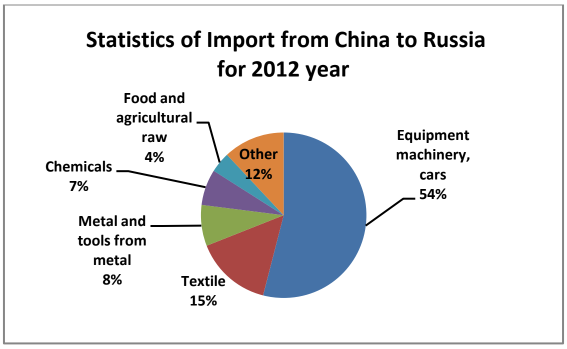

Figure 4. Statistics of Import from China to Russia

The AHP (Analytic Hierarchy Process) is based on paired comparison and seems to be the best choice in this context since it allows structuring the choice procedure as a hierarchy of several levels (Saaty, 2001). This method allows to evaluate the significance of each factor and to find the best alternative according to experts' decisions at the first stage of evaluation.

Table 1. Paired comparisons matrix for criteria (first hierarchy level)

Criteria	Economics	Geography	Infrastructure	Technology	Ulterior factors	Priority vector
Economics	1	**1**	**5**	**7**	**7**	0.4116
Geography	1	1	**3**	**5**	**7**	0.3474
Infrastructure	1/5	1/3	1	**3**	**5**	0.1369
Technology	1/7	1/5	1/3	1	**3**	0.0672
Ulterior factors	1/7	1/7	1/5	1/3	1	0.0365

Conformity Relation =	**3.78%**

The relative importance of KPIs based on Experts Decisions was established accordingly to AHP (Analytic Hierarchy Process) method and the most decisive KPI is "Economics" with the priority vector 0.4116.

5. Establishment of commensurate scale for measuring importance levels of each criteria

Each of the five key performance indicators K_{vi} has five set of parameters P_{aj}. The relative importance of parameters was determined at the 2nd stage. There are five calculations in total. The paired comparison matrix for criteria "Economics" and its parameters is presented in the Table 2.

Table 2. Paired comparison matrix for criteria (2nd hierarchy level)

Criteria	Direct transportation costs for 40'DC container, US dollars	Fluctuations of costs during the year, average in %	Estimated time of transportation, days	Possibilities for custom clearance (quantity of different possibilities)	Transportation risks (risk of delay, theft, damages), probability (expert evaluation)	Priority vector
Direct transportation costs for 40'DC container, US dollars	1	**7**	**2**	**3**	**6**	0.4460
Fluctuations of costs during the year, average in %	1/7	1	**1/5**	**1/7**	**1/2**	0.0428
Estimated time of transportation, days	1/2	5	1	**2**	**3**	0.2537
Possibilities for custom clearance (quantity of different possibilities)	1/3	7	1/2	1	**2**	0.1748
Transportation risks (risk of delay, theft, damages), probability (expert evaluation)	1/6	2	1/3	1/2	1	0.0828

Conformity Relation =	**2.58%**

The relative importance of parameters based on Experts Decisions was established accordingly to AHP (Analytic Hierarchy Process) method and the most decisive parameter in the group of "Economics" is "Direct transportation costs for 40'DC container, US dollars" with the priority vector 0.4460.

6. Quantifying the impact of each parameter for each alternative

Using the expert evaluation process the impact of each of twenty-five parameters was determined for each alternative. In the example below the previous most decisive parameter in the group of Economics is illustrated.

Table 3. Priority vector determination of the parameter "Direct transportation costs for 40'DC container, US dollars"

	Cluster 1	**Cluster 2**	**Cluster 3**	**Cluster 4**	**Cluster 5**	**Cluster 6**	**Cluster 7**	**Priority vector**	**Priority vector (normalized)**
Cluster 1	**1**	1	1/3	2	7	6	8	2.1665	0.2038
Cluster 2	1	**1**	1/3	2	7	6	8	2.1665	0.2038
Cluster 3	3	3	**1**	3	7	6	9	3.7385	0.3517
Cluster 4	1/2	1/2	1/3	**1**	5	4	7	1.4204	0.1336
Cluster 5	1/7	1/7	1/7	1/5	**1**	1/2	6	0.4038	0.0380
Cluster 6	1/6	1/6	1/6	1/4	2	**1**	7	0.5549	0.0522
Cluster 7	1/8	1/8	1/9	1/7	1/6	1/7	**1**	0.1791	0.0168
SUM	**5.9345**	**5.9345**	**2.4206**	**8.5929**	**29.1667**	**23.6429**	**46.0000**	**10.6296**	**1.0000**

Conformity relation	**6.77%**

Quantifying the impact of each parameter for each alternative we could compare the normalized priority vectors and conclude that the higher vector of importance belongs to the alternative number 3 (Cluster 3). This is “Transportation through St. Petersburg port, Ust Luga port”.

7. Establishment of the combined impact of the different criteria for each alternative

Using previous information we find the priorities in the group of KPI (economics, infrastructural, technologic, geographical and ulterior factors). The priorities in the group “Economics” are presenter in the Table 4.

Table 4. The combined impact of the different criteria (in the group “Economics”) for each alternative

Alternatives	Criteria (ECONOMICS)					Priorities in the group
	Direct transportation costs for 40'DC container, US dollars	Fluctuations of costs during the year, average in %	Estimated time of transportation, days	Possibilities for custom clearance (quantity of different possibilities)	Transportation risks (risk of delay, theft, damages), probability (expert evaluation)	
	Priority vector					
	0.445970	0.042755	0.253655	0.174832	0.082789	
Cluster 1	0.203814	0.020835	0.032985	0.053502	0.051612	0.1137
Cluster 2	0.203814	0.032638	0.032985	0.053502	0.051612	0.1142
Cluster 3	0.351705	0.052171	0.041896	0.259115	0.051612	0.2192
Cluster 4	0.133630	0.072491	0.064346	0.071764	0.126793	0.1020
Cluster 5	0.037985	0.159713	0.283719	0.259115	0.204555	0.1579
Cluster 6	0.052205	0.285831	0.345484	0.259115	0.275310	0.0560
Cluster 7	0.016847	0.376321	0.198586	0.043889	0.238505	0.0369

The combined impact of the different criteria for each alternative was established.

8. Determination of the most satisfying alternative

Using previous information the most satisfying alternatives between seven clusters was determined. Matrix of evaluations of the vector of the criteria priorities is shows in the Table 5.

Table 5. Determination of the most satisfying alternative

Alternatives	Criteria					Priorities in the group
	Economics	Geography	Infrastructure	Technology	Ulterior factors	
	Priority vector					
	0.411650	0.347482	0.136992	0.067279	0.036596	
Cluster 1	0.113779	0.065736	0.197719	0.202189	0.231672	0.1188
Cluster 2	0.114284	0.057042	0.192963	0.228496	0.197814	0.1159
Cluster 3	0.219282	0.190588	0.148336	0.208958	0.116202	0.1951
Cluster 4	0.102060	0.148337	0.103029	0.169197	0.137684	0.1240
Cluster 5	0.157971	0.180409	0.132036	0.101610	0.204844	0.1601
Cluster 6	0.056064	0.145958	0.112073	0.070190	0.109594	0.0777
Cluster 7	0.036924	0.040032	0.057079	0.058955	0.034289	0.0377

The most satisfying alternatives between seven clusters are:

1. Cluster 3 - Transportation through St. Petersburg port, Ust Luga port (priority - 0.1951);
2. Cluster 5 - Transportation through Vladivostok, Nahodka, Vostochny ports - Russian East ports (priority - 0.1601);
3. Cluster 4 - Transportation through Novorossiysk, Odessa ports (priority - 0.1240).

Resume

A shift of economic mass to emerging economies has been seen in recent years. As a result, supply chain configurations are becoming increasingly volatile and the shift in the global economic centre of gravity to emerging regions may see reduced growth on traditional trade routes. According to the (McKinsey Global Institute, 2012) the economic centre of gravity has been shifting east for the past decade at the rate of 140 km. Reconfiguring supply chains around customers has led to the necessity for more flexible and adaptive formation system of transport and logistics links. In this situation decision support system (DSS) is one of the instruments for choosing the most effective decision for customer in constant fluctuated business environment.

Global container cargo flows strongly depend on large commercial markets like Asia and Europe. Meanwhile China currently is one of key exporters of containerized cargoes in the world. The flows of containerized cargoes in the Easter Baltic ports region are determined by the neighbourhood of consumer markets with Russia being the key destination point of such cargoes.

The multi-criteria decision making process of route choice for containerized cargo flows coming from China with destination points in Russia via Baltic Sea Region is a/the case study of DSS development for the large scale transportation transit system.

There are a lot of major issues in business decision making in the international container transportation industry and cargo owners determine the mode by which they will have their freight transported, considering mainly their corporate, personal priorities. Firstly - the lack of systemized information with respect to the criteria for decision making.

From another side the standard System of KPI of ports and other Logistics objects currently used in the Baltic States came down to the very simple providing an incomplete picture of competitiveness.

That's why the set of key performance indicators K_{vi} and set of parameters P_{aj} of should be determined to suggest further the multiple-criteria approach for evaluation and the alternatives of cargo transportation in the large scale transportation transit system with special attention to the Baltic Sea Region.

Therefore the multiple-criteria approach for the evaluation and choosing the alternatives of cargo transportation in the large scale transportation transit system with special attention to the Baltic Sea Region was suggested. The multimodal transportation system with finite number of known alternatives defined by the routes and modes of transportation was considered. Each alternative was represented by its performance in multiple criteria.

The large scale transportation transit system was presented by directed finite graph which is an ordered pair $D = (V, A)$ where V is a set of finite vertices (railway stations, ports, border points and logistics centres) and A is set of finite arcs (transport lines between ports and/or logistics centres).

Each vertex v_i ($V=\{v_i\}$, $i=1,\ldots n$) was characterized by an individual set of key performance indicators K_{vi} and each arc a_j ($A=\{a_j\}$, $j=1,\ldots m$) was characterized by an individual set of parameters P_{aj}.

There could be found several alternatives for cargo delivery determined by different routes and modes which form the vector space of a family of alternative transit vector routes. The 57 alternatives for cargo delivery based on case study were described. All 57 alternatives were classified to 7 clusters. The multiple-criteria approach was suggested. A two-level hierarchy system of criteria with ranging expert evaluations based on Analytic Hierarchy Process Method was developed. The best alternatives were suggested according to this method.

The multiple-criteria approach for evaluation and choice the alternatives of cargo transportation in the large scale transportation transit system for the decision makers - cargo owners was suggested in this Paper. In further researches more complete model for decision of the route choice will be described, with special emphasis on BSR; the criteria of optimization will be formulated.

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MODELING OF COMPLEX STRUCTURES FOR THE SHIP'S POWER COMPLEX USING XILINX SYSTEM

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One of the most essential tasks for a number of systems of the automatic controls in the autonomous electric power systems of the water transport is accurate calculation of variable harmonic components in the non-sinusoidal signal. In the autonomous electric power systems operating with full semiconductor capacity, the forms of line currents and voltages are greatly distorted, and generator devices generate voltage with inconsistent frequency, phase and amplitude. It makes calculation of harmonic composition of the distorted signals be a non-trivial task. The present paper provides a mathematical set for solution of the outlined problem including the realization in the discrete form. The simplicity and efficiency of the system proposed make possible to perform its practical realization with the help of cheap FPGA. The test of the developed system has been performed in the medium Matlab.

Keywords: power systems, intellectual systems, harmonic components, ship

1. Introduction

The modern ship's electric power systems (SEPS) are characterized by the presence in its composition of a great number of the conversion load, including frequency transformer, un-interruptive power supply, inverters, rectifiers and other consuming devices varying in their non-linear volt-ampere features.

Similar load has a negative impact on the supplying network of the alternating current, generating into it highest harmonic components of currents and voltages.

At the same time, a great deal of the ship's automation systems apply the line currents and voltages to form the reference signal. Thus, for example, an automatic voltage regulator (AVR) of the ship's synchronous generators (SG) performs regulation by an average value of voltages and currents in the circuit. However, with the distorted form of the variable signals (that is caused by the presence of a wide range of highest harmonics) their average value increases and an automatic voltage regulator (AVR), correcting the error, decreases the exciting current of the synchronous generator that results in loss of voltage in the ship's electric power systems (SEPS). Consequently, decrease in relative value and increase in highest harmonics take place, and, thus, the electromagnetic moment of the non-synchronous motors decreases, the level of interferences influencing the systems of the ship's automatic controls becomes higher, and the losses in the power supply lines enlarge. Practically, such an error is corrected by the adjustment of the voltage corrector (VC). However, as the harmonic composition periodically varies depending on the mode of operation and the composition of the load of the electric power station, the setting of the voltage corrector should be changed constantly. This problem should be solved by measuring the level of the basic harmonics of the current and voltages of the ship's circuit.

On the other side, it is known that filter-compensating devices (FCD) are the most efficient means to increase the quality of electric energy in the ship's power supply systems at the moment. Their efficiency in higher harmonic suppression and compensation of their volt-ampere reactive may be provided only by the high accuracy of the calculation of parameters in the target harmonics of the line currents and voltages.

2. Settlement of the problem

Thus, the required functional set of the systems taken as an example determining their efficiency, in particular, and their operational performance in general, is a set for identification of external parameters of the control system. The major function of the block is extraction of harmonic components required for their analysis, calculation of their parameters from the distorted signal and application of the results of that analysis in the control of the means of the increasing values for quality of the electric energy in the ship's electric power systems. With this, such parameters as levels of target harmonics of currents and voltages, values of summary harmonic distortions, values of distortion capacity, volt-ampere reactive, etc. are regulated.

If sources of energy for a ship's electric power station may be represented as a generator of the sinusoidal signal

$$x(t) = a_1(t)\sin\left(\omega_1(t)t + \varphi_1(t)\right) \quad (1)$$

where $a_1(t)$ – amplitude, $\omega_1(t)$ – rate of phase change and $\varphi_1(t)$ – phase – non-stationary parameters of the generator; the scheme under research may be represented by the structural sketch in Figure 1.

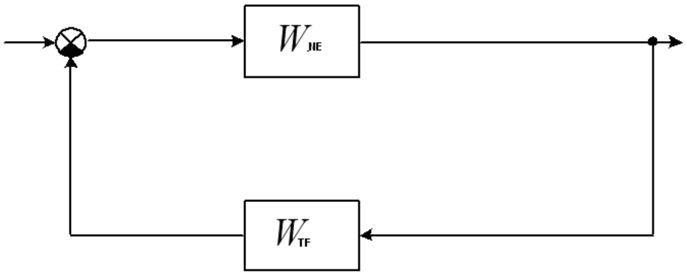

Figure 1. Simplified schematic diagram of the system under research:
W_{TF} – non-linear element, W_{NE} – transfer function of the generator set in the ship's electric power system, generating periodically non-stationary signal x(t)

As it would seem, this standard for the theory of the automatic control of the form structural scheme cannot be analyzed by the tools of the classical frequency criteria as the sense itself for the frequency characteristics of a non-stationary element is lost. With this, the non-linear element WНЭ itself is, generally, non-stationary as the main semi-conductor load of the ship's electric power system is a set of a closed system (for example, autonomous inverters and converters) described by commutation functions and consequently containing periodically varying coefficients.

In the view of the problem being solved, it is required to determine the harmonic composition of the non-stationary signal in order to use it as a set of reference signals in the system of the quality management for the electric energy in the ship's electric power system. The present paper proposes to use a certain function approximating the target harmonics of the distorted signal. The structural sketch of such a system is given in Figure 2.

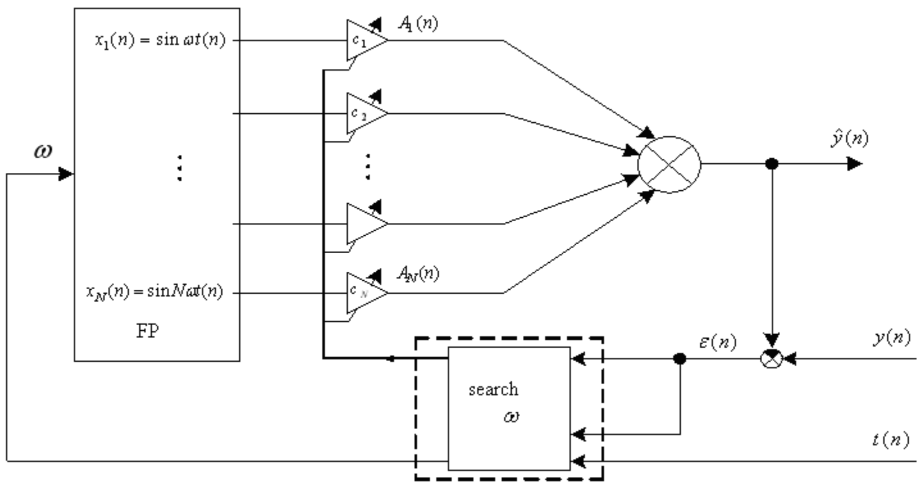

Figure 2. The structural sketch of the approximator, performing monitoring of the frequency ω and the components of the harmonics of the signal y

Identification of the target non-stationary harmonics of the distorted signal is made by adjustment of the parameters of the relevant function-prototype (FP). In its general form, the input signal y(t) of the identification system, being a signal proportional to the circuit current or voltage in the ship's electric power system, may be described by Fourier's series:

$$y(t) = \sum_{k=1}^{N} a_k(t)\sin\left(k\omega_k(t)t + \varphi_k(t)\right) = x(t) + \xi(t),$$

where $a_k(t)$ is amplitude, $\omega_k(t)$ is a rate of phase change and $\varphi_k(t)$ is a phase angle of k-harmonics, N is a number of harmonics (in general $N = \infty$), $\xi(t) = \sum_{k=2}^{N} a_k(t)\sin\left(k\omega_k(t)t + \varphi_k(t)\right)$ is a set of non-approximated (i.e. non-recoverable by the device being designed) harmonics.

Let's introduce the vector for the parameters $\phi(t) = \left[a(t), \omega(t), \varphi(t)\right]^T$, which belong to the space of parameters $\Phi(t) = \left\{\left[a, \omega, \varphi\right]^T\right\}$.

The approximation error is exhibited by the expression

$$\varepsilon = y - \hat{x}, \tag{2}$$

where $\hat{x}(t) = \hat{a}_1(t)\sin\left(\hat{\omega}_1(t)t + \hat{\varphi}_1(t)\right)$ is a recovered harmonic component. Moreover, it is evident that the more components ξ(t) of the function will be recovered by the relevant generators of the approximating functions the less the error (2) will be.

And also let the energetic function of the error be exhibited by the mean square error

$$E = \frac{1}{2}\varepsilon^2. \tag{3}$$

The function (3) is the function of three variables, that is E(A, ω, φ) or E(ф). The task of the approximation is to seek such an algorithm of variation of elements of vector ф, with which minimization of the function (3) takes place, i.e. the search of such a value $\overline{\phi}$ of the vector ф, to which the extreme value of the function E (minimum), where the following condition would be realized:

$$E(\phi) \geq E(\hat{\phi}), \quad \forall E \in \Phi, \tag{4}$$

where Φ is a permitted area or an area of the possible values for the vector ф, determined by the limitations

$a \in \left[a_{\min}, a_{\max}\right]$, $\omega \in \left[\omega_{\min}, \omega_{\max}\right]$ and $\varphi \in \left[\varphi_{\min}, \varphi_{\max}\right]$.

At this stage we have approached the task of seeking the extreme (4) (minimum) of the energetic function (3). The function is differentiable by all the elements; however the expression (2) assumes non-linear conversion of the elements for the input vector ф. The latter circumstance challenges the possibility to apply gradient algorithms mostly recommended by themselves in the extreme systems.

Let's consider mathematical aspects of the possibility to apply gradient methods in the task outlined for the case of recovery of one target harmonics. Let's write down the gradients for the recovered parameters in the vector ф:

$$\begin{aligned}
\frac{d\hat{a}(t)}{dt} &= -\mu_A \frac{\partial\left[E(t,\phi(t))\right]}{\partial\hat{a}(t)} \\
\frac{d\hat{\omega}(t)}{dt} &= -\mu_\omega \frac{\partial\left[E(t,\phi(t))\right]}{\partial\hat{\omega}(t)} \\
\frac{d\hat{\varphi}(t)}{dt} &= -\mu_\varphi \frac{\partial\left[E(t,\phi(t))\right]}{\partial\hat{\varphi}(t)}
\end{aligned} \tag{5}$$

The energetic function may be represented as follows

$$E(t,\phi(t)) = \frac{1}{2}\varepsilon(t,\phi(t))^2 = \frac{1}{2}\left[y(t) - \hat{a}(t)\sin\left(\hat{\omega}(t)t + \hat{\varphi}(t)\right)\right]^2.$$

Substituting it into (5) and differentiating the right-hand part, we will have

$$\begin{aligned}
\frac{d\hat{a}(t)}{dt} &= -\mu_A \varepsilon(t)\sin\left(\hat{\omega}(t)t + \hat{\varphi}(t)\right) \\
\frac{d\hat{\omega}(t)}{dt} &= -\mu_\omega \varepsilon(t)\hat{a}(t)t\cos\left(\hat{\omega}(t)t + \hat{\varphi}(t)\right) \\
\frac{d\hat{\varphi}(t)}{dt} &= -\mu_\varphi \varepsilon(t)\hat{a}(t)\sin\left(\hat{\omega}(t)t + \hat{\varphi}(t)\right)
\end{aligned} \tag{6}$$

As it is clear, the time parameter outside the cosine mark appears in the second equation of the system (6). Thus, for this energetic function the expression of the gradient for the angle velocity contains a combined, i.e. secular (age) and, simultaneously, a non-linear term. When applying Newton-Raphson's method (or similar ones), using a hessian, several of such terms will appear. So, whatever small the function of the error ε(t) would be, in the course of time the secular term will be increasing without limits.

This fact explains the failures in realization of the numerical techniques on the basis of similar algorithms created by using common approaches of adaptive systems and gradient methods in particular, practical realization of which in the described cases of application faces with the divergence of the process when monitoring the changes in signal phase and frequency.

Consequently, it is necessary to develop such an algorithm for identification of the harmonic composition of signals proportional to currents and voltages in the circuit which makes possible to provide the convergence of the process with the existing non-linear features and the non-stationary character of the system under review and, at the same time, to support the implementation of the up-to-date digital systems especially under the necessity to identify a set of harmonic components of the signal that requires parallel and pseudo-parallel operation of a number of copies or nuclei of the algorithm sought.

3. The solution of the task outlined

The core of the proposed principle of the approximation of every harmonics of the measured signal is in the formation of the periodical function basing on the function-prototype Rk(ωk(t),φk(t),t), where k is a number of the approximated harmonics (or simply Rk(k,t)); so changing its parameters we will strive to approach the minimum of the error between the input signal and periodical function. Proceeding from the physical sense of the processes under the review, as it was stated above, it is reasonable for FP to use the function Rk(t)=sin(ωk(t)t+φk(t)). Thus, every harmonics will be approximated by the weight function (Dirac response) $\hat{x}_k(t) = \hat{a}_k(t)R(k,t)$.

Thus, the frequency ω(t) and phase function φ(t) of the target function are variable, so let's go to the notion of the complete phase ψ(t)=ω(t)t+φ(t), taking into account all the variations of the function phase. The system (6) will be expressed as

$$\frac{d\hat{a}(t)}{dt} = -\mu_A \varepsilon(t)\sin\hat{\psi}(t) \tag{7.1}$$

$$\frac{d\hat{\omega}(t)}{dt} = -\mu_\omega \varepsilon(t)\hat{a}(t)t\cos\hat{\psi}(t) \tag{7.2}$$

$$\frac{d\hat{\psi}(t)}{dt} = \hat{\omega}(t) + \mu_\psi \frac{d\hat{\omega}(t)}{dt} \tag{7.3}$$

The energetic function would be expressed in the form of the following expression: $E(t) = \frac{1}{2}\left[y(t) - \hat{a}(t)\sin\hat{\psi}(t)\right]^2$, i.e. for the error of the approximation we will have $\varepsilon(t) = y(t) - \hat{a}(t)\sin\hat{\psi}(t) = y(t) - \hat{x}(t)$.

It should be noted that the change in the phase of the input signal may be compensated by the similar change in the initial phase of the approximating function (that will exactly correspond to the behaviour of the signal being approximated), short-time change in the frequency of the same function or by the combination of these processes.

Let's pass on the integral of the function (7.2) and the final interval [ti – T/2, ti + T/2] of T duration, where one more interval of FP is determined. As one can see, FP used by us is 2π-periodical (i.e. T=2π/ω) and odd-symmetrical in respect to the middle of the interval where it was determined and integrated. Let's assume that the amplitude of the approximated harmonics for the time of the FP period does not change (or changes slowly). So, for the basic harmonics we will have

$$\hat{\omega}_1(t) = -\mu_{\omega 1} \int_{t_i - \frac{T}{2}}^{t_i + \frac{T}{2}} \varepsilon(t)\hat{a}_1 t \cos\hat{\psi}(t)dt \tag{8}$$

Considering (1)-(2) and taking into account that according to the experimental research [1-4] odd harmonics are predominant in the ship's circuit в, express (8) in the following form

$$\hat{\omega}_1(t) = -\mu_{\omega 1} \int_{t_i - \frac{T}{2}}^{t_i + \frac{T}{2}} [a_1(t)\sin\psi_1(t) + a3(t)\sin\psi_3(t) + \\ a_5(t)\sin\psi_5(t) + ...]\hat{a}_1(t)t\cos\hat{\psi}_1(t)dt \tag{9}$$

If the frequency of the period for the Function-Prototype coincides with the period of the approximated harmonic, i.e. $\hat{\omega}_1(t) = \omega_1$ so (9) will transformed into:

$$-\mu_{\omega 1} \int_{t_i - \frac{T}{2}}^{t_i + \frac{T}{2}} t\left[\frac{a_1\hat{a}_1}{2}\sin[2\omega_1(t)t + \varphi_1(t) + \hat{\varphi}_1(t)] + \frac{\hat{a}_1 a_3}{2}\left[\sin[4\omega_1(t)t + \hat{\varphi}_1(t) + \varphi_3(t)] + \right.\right.$$
$$\left.\left. + \sin[2\omega_1(t)t + \hat{\varphi}_1(t) - \varphi_3(t)] + ...\right] - \frac{\hat{a}_1 a_1}{2}\sin[2\omega_1(t)t + \varphi_1(t) + \hat{\varphi}_1(t)]\right] = \tag{10}$$
$$= -\mu_{\omega 1} \int_{t_i - \frac{T}{2}}^{t_i + \frac{T}{2}} t\frac{\hat{a}_1 a_3}{2}[\sin[4\omega_1(t)t + \hat{\varphi}_1(t) + \varphi_3(t)] + \sin[2\omega_1(t)t + \hat{\varphi}_1(t) - \varphi_3(t)] + ...]$$

In the connection with that only odd harmonics will take place in the input signal, so under the mark of the integral vice versa only even harmonics with frequencies $2\omega_1$, $4\omega_1$, $6\omega_1$ etc. will remain, and the integral of their sum in the interval T will be equal to 0 due to the even non-symmetry of the sine components.

With appearing the error δ between the real and recovered frequencies of the main harmonics under-integral expression in (9) will also contain the given even harmonics.

In fact, the calculated integral conversion in a general form will represent the resultant of the function of the approximator error ε(t) by means of the window (or using the terms of scanning systems, weight) function $\hat{x}_k(t)$. Thus, the result of integrating the expression (9) is the value of correlation FP and ε(t). If δ tends to zero, (9) will also tend to zero irrespective of he phase shift between FP and every harmonics of the input signal or their amplitudes. The latter feature of the expression enables to simplify it to the form

$$\hat{\omega}_1(t) = -\beta_{\omega 1} \int_{t_i - \frac{T}{2}}^{t_i + \frac{T}{2}} \varepsilon(t)r(t)dt\,,$$

where r(t) – even- or odd-symmetric in respect to the interval of integration of FP (derivative of R(t)). The form of this function determines the dynamic qualities of the tracking system for the frequency of the basic harmonic. It should be noted that T is a variable value. It is this circumstance that enables to synchronize the FP with the period of the target harmonic and reject the standard measure of time (frequency), having the long-term stability with due necessity.

Taking the above-mentioned into account, the function will be expressed as follows:

$$\hat{\omega}_1(t) = -\beta_{\omega 1} \int\limits_{t_i - \frac{\pi}{\hat{\omega}_1}}^{t_i + \frac{\pi}{\hat{\omega}_1}} \varepsilon(t) r(t) dt \; .$$

For the numerical system this function may be expressed in the following discrete form:

$$\omega_{i+1} = \omega_i + \tau\beta_{\omega 1}\varepsilon_i r_i \, ,$$

where τ is the time for the integration step.

Within every cycle corresponding to the period of FP, the FP has a number of certain arms and spots. As for the latter, one may say about the initial point of the period, about the final one as well as about zeroes and extreme values of the FP. It is reasonable as an increment of the target parameter to use distance (time) between certain points. Thus, as the expression (9) will represent the sum of the harmonic components with the lowest frequency (the first resonance frequency) equal to 2ω1, and consequently the correlation function will tend to zero already in the period corresponding to the half of the period of the main harmonic, so the sufficient interval of the integration may be considered the half of the period of the main harmonics or intervals divided by it. In other words, the increment of the frequency (period) change in the FP will be equal to the integral (9) at the half-period of the frequency of the main harmonic. In the discrete form:

$$\omega_{i+1} = \omega_i + \frac{2\beta_{\omega 1}\tau}{T}\varepsilon_i r_i \, .$$

Otherwise, expressing the period by means of frequency FP we will have

$$\omega_{i+1} = \omega_i + \frac{\beta_{\omega 1}\tau\omega_i}{\pi}\varepsilon_i r_i \, .$$

Substituting αω= τ βω1/π, we will have

$$\omega_{i+1} = \omega_i + \alpha_\omega \omega_i \varepsilon_i r_i \, . \tag{11}$$

Coefficient αω also determines the dynamic features of the frequency tracking system and depends on the form of the FP. Product αωωi in the expression (11) enables to preserve these specific features with changing the frequency of the input signal, i.e. in fact it describes the reconfigurable filter as it determines constant value of the time of the integrator adapting to the non-stationary frequency of the restorable harmonic.

In the same way we express in the discrete form the expression (7.3), describing the complete phase of the FP

$$\psi_{i+1} = \psi_i + \tau\omega_i + \tau\alpha_\psi \alpha_\omega \omega_i \varepsilon_i r_i \, . \tag{12}$$

The complete description of the approximator calculated on the basis of the expressions (11) and (12), in the discrete form will be represented by the system

$$\begin{aligned} \omega_{i+1} &= \omega_i + \alpha_\omega \omega_i \varepsilon_i \cos(\psi_i) \\ \psi_{i+1} &= \psi_i + \tau\omega_i + \tau\alpha_\psi \alpha_\omega \omega_i \varepsilon_i \cos(\psi_i) \\ a_{i+1} &= a_i + \tau\alpha_a \varepsilon_i \sin(\psi_i) \\ \varepsilon_i &= y_i - R_i \\ R_i &= a_i \sin(\psi_i) \end{aligned} \tag{13}$$

In case of realization of the numerical methods of the solution for the given system by means of the digital calculating devices arrangement of the FP in the discrete form starts influencing the dynamic functions of the system. In other words, a number of steps in discretization of the FP gains significance in this case. On the other hand, one may not proceed from the continuous function striving for the desired features and, on the contrary, taking dynamic characteristics it is possible to produce a discrete function-prototype (DFP) satisfying them.

The key role in the solution of the implementation of the solution (13) is given to the coefficients α, the selection of which is the compromise between the velocity of the approximator adjustment in accordance with the changes of an input signal and the accuracy of approximation. Virtually, large values of coefficients make possible to lessen the time of transition processes, however at the same time non-linear distortions start prevailing in the approximating signal. Therefore, in order to improve the values it is possible to apply additional filters for FP parameters or adaptive readjustment of coefficients. The hybrid variant of the tracking system in which internal DFP with high velocity of approximation is used for tracking and output signal of the approximator is taken from the additional external DFP, arguments of which are renewed only in the characteristic points mentioned above. Renewal takes place only by current (or filtered) parameters of the internal DFP.

4. Results of the modeling

Modelling according to the proposed algorithm has demonstrated the convergence of the solution without any limitations in the interval of modelling. The results of modelling are given in Fig. 3 and Fig.4.

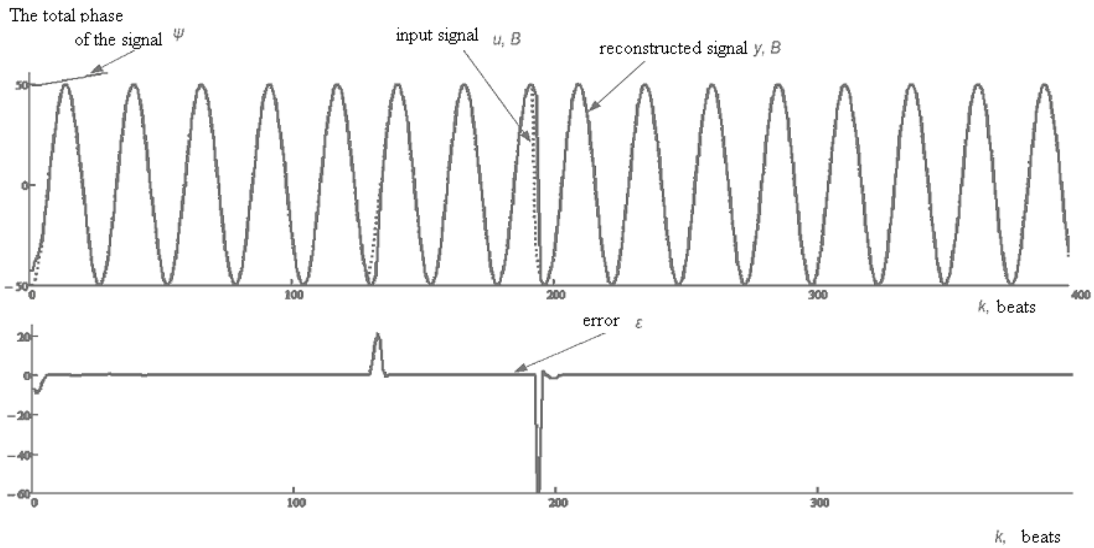

Figure 3. Tracking of the main harmonic y(k) of the distorted signal v(k) with variable frequency ω(k) and error of tracking ε(k) according to the proposed algorithm

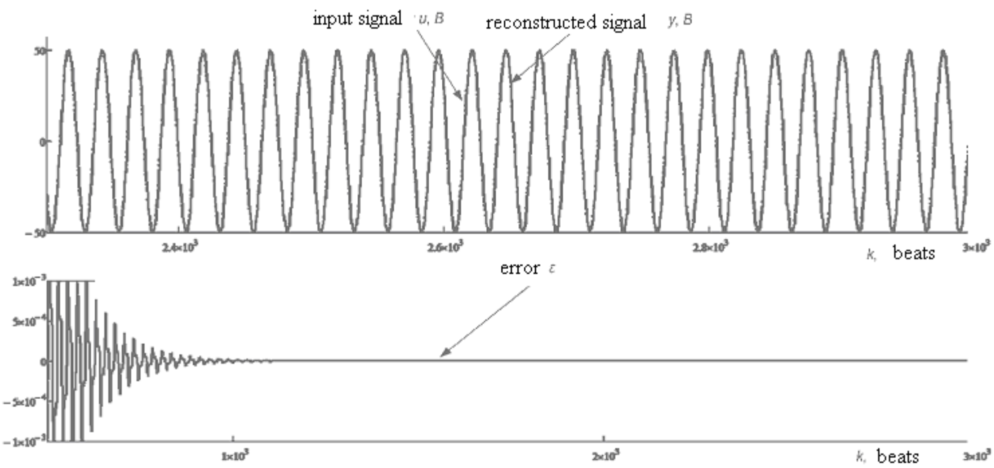

Figure 4. The process of tracking of the main harmonic y(k) of the distorted signal v(k) in the large time interval

Fig.5 shows the results of modelling the process of tracking over the main harmonic of the signal v(t), if the 5th and the 7th harmonics are available with the levels 10% and 5% respectively.

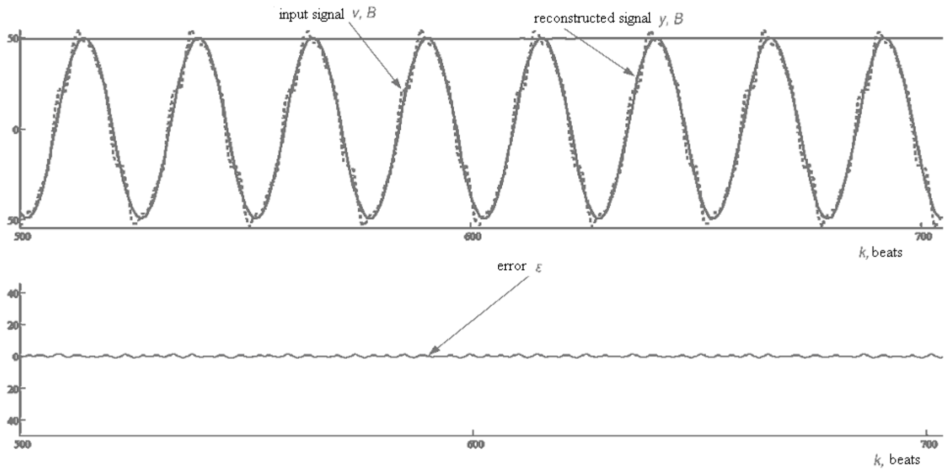

Figure 5. Approximation of the main harmonic y(k) of the distorted signal v(k) if the 5th and the 7th harmonics are available

Fig. 6 provides the result of modelling of the transition process of the approximator. The frequency of the input signal changes with the leap from 50 down to 46.5 Hz without any additional filtration of the restored signals.

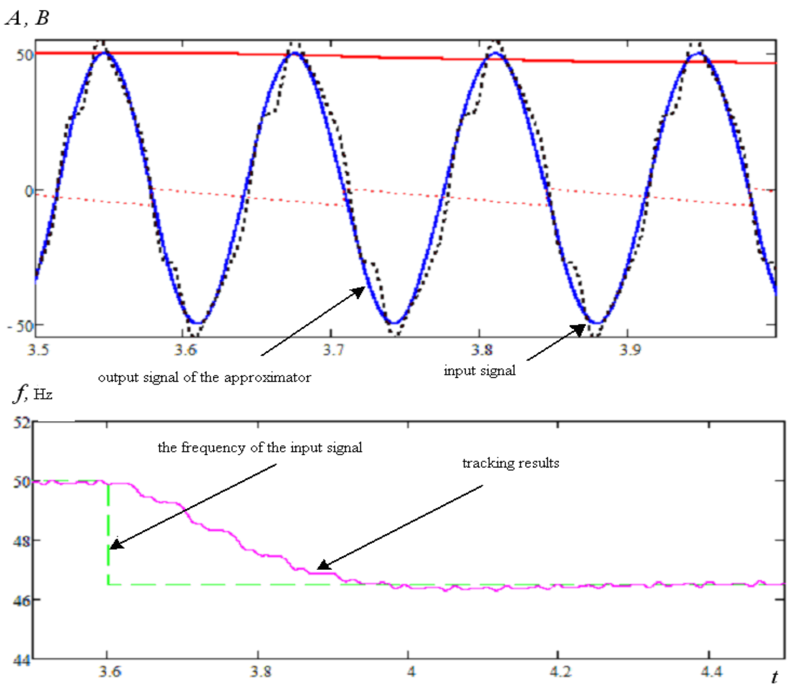

Figure 6. Response of the approximator to the leap-ahead change in frequency of the input signal

5. Comparison with the existing solutions

The proposed method of tracking over the parameters of the main (and, in general, of any) harmonic of the distorted signal, makes possible to provide unique, stable and convergent solution of the non-linear dynamic system. The obtained algorithm provides the unique asymptotic trajectory, being periodical and lying in the vicinity of the approximated function – target harmonic of the signal.

This method may be successfully applied in design of the multivariable systems for identification of external parameters in the water transport and in other autonomous electric power systems.

A number of existing solutions with which the proposed system may be compared is rather limited. For example, such distributed methods as fast or discrete Fourier transform are beyond the comparison in connection with the fact that with the frequency shift the component of the input signal is expressed itself as the so-called effect of leakage as a result of which the frequency deviation for 5 Hz causes the appearance of errors in the evaluation of amplitude more than 10%.

The comparative analysis of the operation of the designed system and the extended Kalman filter produces the following results of modelling. Application of the extended Kalman filter with the availability of the 5th and 7th harmonics besides the main harmonic with amplitudes 10% and 5% respectively, does not allow having an error less than 4%. At the same time, the system proposed by the author, under the same conditions has an error not exceeding 0.2% by the frequency. And if we use a filter of low frequencies by the signal of the restored frequency, the error reduces to the level less than 0.04%.

6. Practical implementation

The simplicity of the proposed algorithm allows implementing multivariable approximator with minimum requirements to the computational hardware of the device. The simplest and the most effective algorithm with computational function or a FP tabular model may be implemented in the FPGA. FPGA architecture, its flexibility and possibility to implement parallel computational processes makes them the most promising platform for the practical implementation of the reviewed tracking system.

Modelling of the scheme operation (Fig.7), realizing the system (13) by means of FPGA, and generation of the firmware code have been made by means of software Xilinx System Generator in Matlab 14. Spartan 6 in Xilinx has been chosen as FPGA. Fig.8 provides the report about the number of FPGA resources required while creating the tracking system for the parameters of one harmonic of the input signal, produced by means of block Xilinx Resource Estimator. This realization of the described algorithm is used for acquisition of the main harmonic of the circuit voltage in order to provide correct operation of automatic voltage regulators of the ship's synchronous generators (AVR for the SG) under the conditions of high distortion of voltages and currents in the ship's circuit.

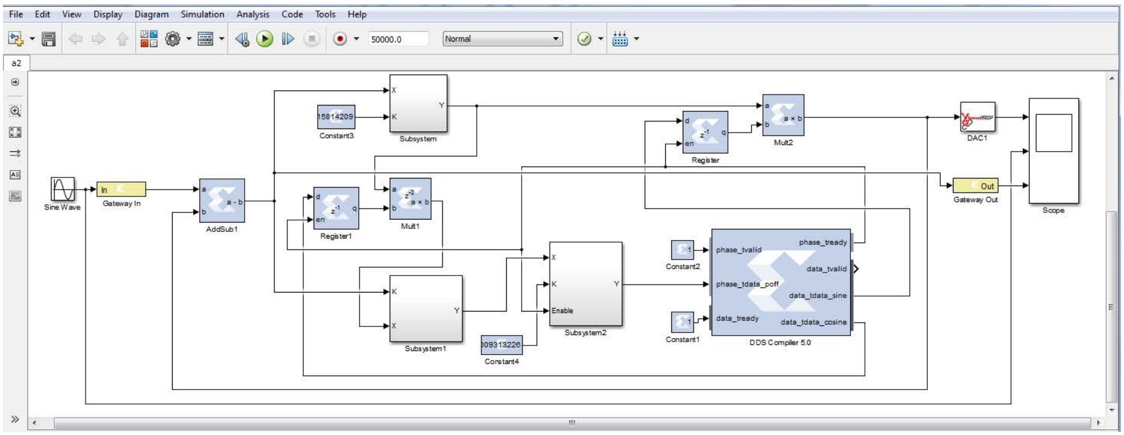

Figure 7. Configuration of FPGA for implementation of the system (13)

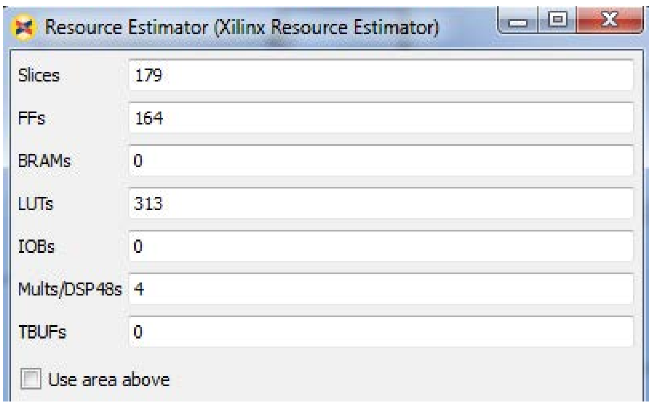

Figure 8. Report of Xilinx Resource Estimator about applied FPGA resources

As it is seen from a small number of the required computational resources, not exceeding even 2% of the available ones in the applied FPGA, a multivariable system of parallel restoration of a number of harmonic components of the distorted signal may be developed on the basis of one micro scheme.

7. Conclusions

The task of acquisition of non-stationary harmonics of currents and voltages in the autonomous circuits of water transport craft has been solved. There have been found simple and effective mathematical tools which make it possible to solve the outlined task by means of FPGA. It allows restoring simultaneously dozens of target components.

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Transport and Telecommunication, 2015, volume 16, no. 1
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CUMULATIVE INDEX

TRANSPORT and TELECOMMUNICATION, volume 16, no. 1, 2015 (Abstracts)

Paramonov, Yu., Tretyakov, S., Hauka, M. Inspection Program Development for an Aircraft Fleet and an Airline on the Basis of the Acceptance Fatigue Test Result, *Transport and Telecommunication*, vol. 16, no. 1, 2015, pp. 1–8.

An inspection interval planning is considered in order to limit the probability of any fatigue failure (FFP) in a fleet of N aircraft (AC) and to provide an economical effectiveness of airline (AL) under the limitation of fatigue failure rate (FFR). A solution of these two problems is based on the processing of the result of acceptance fatigue test of a new type of aircraft. During this test an estimate of the parameter $\hat{\theta}$, of a fatigue crack growth trajectory has been obtained. If the result of this acceptance test is too bad then this new type of aircraft will not be used in service. A redesign of this project should be done. If the result the acceptance test is pretty good then the reliability of the aircraft fleet and the airline will be provided without inspections. For this strategy there is a maximum of FFP (a maximum of FFR) as a function of an unknown parameter θ. This maximum can be limited by the use of the offered here procedure of the choice of the inspection number. The economic effectiveness of the AL operation is considered using the theory of Markov process with rewords.

Keywords: Monte Carlo, Markov chains, Minimax, inspection program and approval test, fleet reliability, economic effectiveness

Adamos, G., Nathanail, E. How to Train Safe Drivers: Setting up and Evaluating a Fatigue Training Program, *Transport and Telecommunication*, vol. 16, no. 1, 2015, pp. 9–20.

Fatigue is considered as a serious risk driving behavior, causing road accidents, which in many cases involve fatalities and severe injuries. According to CARE database statistics, professional drivers are indicated as a high-risk group to be involved in a fatigue-related accident. Acknowledging these statistics, a training program on driving fatigue was organized, aiming at raising awareness of professional drivers of a leading company in building materials, in Greece. Selected experimental methods were used for collecting data before and after the training program, which allowed monitoring and assessing the potential behavioural changes. A questionnaire survey was conducted before the program implementation to 162 drivers of the company, while two months after the program, the same drivers replied to a second questionnaire. Impact assessment of the program relied on statistical analysis of the responses. Results showed the degree of penetration of the training program in the professional drivers' behavior towards safe driving.

Keywords: fatigue; program; impact assessment; professional drivers

Winslott Hiselius, L., Smidfelt Rosqvist, L., Adell, E. Travel Behaviour of Online Shoppers in Sweden, *Transport and Telecommunication*, vol. 16, no. 1, 2015, pp. 21–30.

Online shopping opportunities are transforming travel behaviour for shopping and could potentially reduce the overall travel demand. Despite numerous studies on online shopping, only a few have taken an approach that includes trips for all travel purposes. Based on a web-survey, this paper provides results on travel behaviour for physical shopping for frequent, regular, and infrequent online shoppers in Sweden. The results indicate that frequent online shoppers make as many car trips (for both shopping and other errands) as others. Also, frequent online shoppers in total make as many trips to a physical store as infrequent online shoppers – although by more sustainable modes of transport – and that the time saved from online shopping is spent on both additional shopping trips and trips for other errands. The conclusion is that online shopping might facilitate changing travel behaviour but does not in itself represent a good stand-alone measure for reducing vehicle mileage.

Keywords: Online shopping, travel behaviour, modal split

Bazaras, D., Yatskiv, I., Mačiulis, A., Palšaitis, R. Analysis of Common Governance Transport System Development Possibilities in the East–West Transport Corridor, *Transport and Telecommunication*, vol. 16, no. 1, 2015, pp. 31–39.

Equitable access to efficient economic infrastructure and effective public services is essential to achieving the future economic growth. Insufficient transport infrastructure and long border crossing procedures limiting international accessibility for goods and passengers are the biggest present problems in the East–West transport corridor. The joint action plan must highlight the areas and components of the transport system, which are important for the effective interconnectivity of the individual networks, and/or for absorbing the steadily increasing intraregional and transcontinental freight flows. The successful East–West transport corridor activities' governance first of all needs to identify the corridor's administrative structure, non-governmental organizations' (NGO) place in the management structure, partnerships between the transport hubs in the EWTC mechanism and the possibility of cooperation between private and public sectors.

The latest events and constantly changing environment show that the impact of political solutions on business is prevalent in the CIS and the EU countries. Thus, the analysis of economic, political, managerial, legal, even moral aspects that affect the interests of the stakeholders remain significant.

Keywords: transport corridors, management, governance, planning, infrastructure

Lukinskiy, V., Lukinskiy, Vl. Formation of Failure Models for the Evaluation of the Reliability of Supply Chains, *Transport and Telecommunication*, vol. 16, no. 1, 2015, pp. 40–47.

Logistics and supply chain management is a comparatively new scientific field which has been rapidly developing.

Apart from the criterion of total logistics costs, that is used to evaluate the efficiency of supply chains, another criterion - total satisfaction of consumer needs - is being increasingly used for the same purpose. It can be explained by the transition to such new logistics concept as the sustainability of supply chains, which is characterized not only by flexibility, rate of response, strength, adaptability, but mostly by the reliability of functioning of the logistics system's elements.

The paper presents critical analysis of the existing approaches to the formation of failure models in supply chains, the methodical approach and classification of failures for the key logistics functions (purchasing, order processing, transportation, storage, warehousing and materials handling) as well as some developed and improved failure models for a number of logistics functions and operations; there have been also given some examples of calculating the reliability indices for the elements of the supply chain.

Keywords: supply chains, reliability, failures, calculation models

Vaculík, Ju., Tengler, Ji., Maslák, O. Application of EPC Standards and Mobile Networks Services to Enhance the Quality of Postal Service, *Transport and Telecommunication*, vol. 16, no. 1, 2015, pp. 48–60.

This article deals with new technologies and methods to optimize the transport and delivery of postal mails. Introduction of this article defines the technologies and procedures that postal operators have started to use. The main part of the article describes specific implemented solutions of several postal operators and their benefits. The last part shows using of EPC standards in a processes chain. The conclusion of the article is devoted to the evaluation of these technologies and their potential in the area of postal sector.

Keywords: delivery mails, mobile technology, post, RFID technology, EPC standards

Kabashkin, I., Lučina, Je. Development of the Model of Decision Support for Alternative Choice in the Transportation Transit System, *Transport and Telecommunication*, vol. 16, no. 1, 2015, pp. 61–72.

The decision support system is one of the instruments for choosing the most effective decision for cargo owner in constant fluctuated business environment. The objective of this Paper is to suggest the multiple-criteria approach for evaluation and choice the alternatives of cargo transportation in the large scale transportation transit system for the decision makers - cargo owners. The large scale transportation transit system is presented by directed finite graph. Each of 57 alternatives is represented by the set of key performance indicators Kvi and set of parameters Paj. There has been developed a two-level hierarchy system of criteria with ranging expert evaluations based on Analytic Hierarchy Process Method. The best alternatives were suggested according to this method.

Keywords: Transport model, transit, decision support, Baltic Sea Region

Chernyi, S., Zhilenkov, A. Modeling of Complex Structures for the Ship's Power Complex Using Xilinx System, *Transport and Telecommunication*, vol. 16, no. 1, 2015, pp. 73–82.

One of the most essential tasks for a number of systems of the automatic controls in the autonomous electric power systems of the water transport is accurate calculation of variable harmonic components in the non-sinusoidal signal. In the autonomous electric power systems operating with full semiconductor capacity, the forms of line currents and voltages are greatly distorted, and generator devices generate voltage with inconsistent frequency, phase and amplitude. It makes calculation of harmonic composition of the distorted signals be a non-trivial task. The present paper provides a mathematical set for solution of the outlined problem including the realization in the discrete form. The simplicity and efficiency of the system proposed make possible to perform its practical realization with the help of cheap FPGA. The test of the developed system has been performed in the medium Matlab.

Keywords: power systems, intellectual systems, harmonic components, ship

TRANSPORT and TELECOMMUNICATION, 16. sējums, Nr. 1, 2015 (Anotācijas)

Paramonovs Ju., Tretjakovs S., Hauka M. Lidmašīnas un aviolīnijas apskašu programmas plānošana, izmantojot noguruma pieņemšanas testu rezultātus, *Transport and Telecommunication*, 16. sējums, Nr. 1, 2015, 1.–8. lpp.

Ir apskatīta inspekciju intervālu plānošana, lai ierobežotu noguruma atteices varbūtību gaisa kuģu parka no N lidmašīnām un nodrošināt aviokompānijas ekonomisko efektivitāti pēc noguruma atteicu biežuma ierobežošanas. Šo divu problēmu aprēķins ir balstīts uz jaunas lidmašīnas noguruma izmēģinājuma rezultātiem. Šo izmēģinājumu rezultātā ir iegūts noguruma plaisas augšanas trajektorijas parametrs $\hat{\theta}$. Ja izmēģinājuma rezultāts ir slikts, tad tāds lidaparāts nebūs pielaists servisam. Šī projekta pārprojektēšana ir nepieciešama. Ja izmēģinājuma rezultāts ir pietiekami labs, tad gaisa kuģa un parka drošums būs nodrošināts bez inspekcijām. Šai stratēģijai ir maksimāla atteices varbūtība ka funkcija no nezināma parametra θ. Šis maksimums var būt ierobežots, izmantojot šeit piedāvāto inspekcijas intervāla izvēles procedūru. Aviokompāniju ekonomiska efektivitāte ir apskatīta ar Markova procesu teoriju ar ienākumiem.

Atslēgvārdi: Monte Carlo, Markova ķēdes, Minimax, pārbaudes programma un apstiprināšanas tests, flotes uzticamība, ekonomiskā efektivitāte

Adamos G., Nathanail E. Kā apmācīt drošus autovadītājus: noguruma apmācības programmas izveide un novērtēšana, *Transport and Telecommunication*, 16. sējums, Nr. 1, 2015, 9.–20. lpp.

Nogurums tiek uzskatīs par nopietnu risku, kas ietekmē transporta līdzekļa vadītāja uzvedību, izraisot ceļu satiksmes negadījumus, kas daudzos gadījumos beidzas ar smagām traumām vai letāli. Profesionālie autovadītāji ir iekļauti augsta riska grupā saistībā ar noguruma izraisītiem negadījumiem. Atbilstoši šai statistikai, tika izveidota apmācības programma par noguruma ietekmi uz transporta līdzekļu vadīšanu, kuras mērķis bija Grieķijas vadošā būvniecības materiālu uzņēmuma profesionālo autovadītāju informētības uzlabošana. Izvēlētās eksperimentālās metodes tika izmantotas datu savākšanai pirms un pēc apmācības programmas, kas ļāva novērtēt un uzraudzīt iespējamās uzvedības izmaiņas. Pirmā anketēšana tika veikta pirms programmas realizācijas, aptaujāti tika 162 uzņēmuma autovadītāji, savukārt divus mēnešus pēc programmas realizācijas tie paši autovadītāji atbildēja uz otro anketu. Programmas ietekmes novērtējums balstījās uz sniegto atbilžu statistikas analīzi. Rezultāti nodemonstrēja profesionālo autovadītāju attieksmi pret drošu braukšanu.

Atslēgvārdi: nogurums; programma; ietekmes novērtējums; profesionāli autovadītāji

Winslott Hiselius L., Smidfelt Rosqvist L., Adell E. Tiešsaistes pircēju ceļošanas uzvedība Zviedrijā, *Transport and Telecommunication*, 16. sējums, Nr. 1, 2015, 21.–30. lpp.

Iespēja veikt pirkumu Internetā pārveido ceļošanas uzvedību attiecībā uz pirkumiem, un iespējams, varētu samazināt kopējo ceļojumu pieprasījumu. Neskatoties uz daudzajiem pētījumiem par pirkumiem internetā, tikai dažos no tiem aplūkota pieeja, kas ietver ceļojumus ar dažādiem ceļošanas mērķiem. Balstoties uz interneta aptauju, šis darbs nodemonstrē regulāru, biežu un retu Zviedrijas interneta pircēju ceļošanas uzvedību. Rezultāti liecina, ka tie, kuri bieži iepērkas internetā, ceļo ar automašīnām (mērķis var būt gan pirkumi, gan citi uzdevumi) tikpat bieži, cik pārējie. Kā arī kopumā tiešsaistes pircēji iepērkas veikalā fiziski tikpat daudz, cik tie, kuri iepērkas internetā reti, kaut gan laiks tiek patērēts papildus iepirkšanās braucieniem un citiem uzdevumiem. Secinājums norādīts, ka iepirkšanās internetā varētu veicināt ceļošanas paradumu maiņu, bet pats par sevi tas nekalpo par līdzekli transportlīdzekļu nobraukumu samazināšanai.

Atslēgvārdi: pirkumi internetā, ceļošanas uzvedība

Bazaras D., Jackiva I., Mačiulis A., Palšaitis R. Kopīgo transporta sistēmas vadības iespēju attīstība Austrumu-Rietumu transporta koridorā, *Transport and Telecommunication*, 16. sējums, Nr. 1, 2015, 31.–39. lpp.

Turpmākajai ekonomikas izaugsmei būtiska ir piekļuve efektīvai ekonomikas infrastruktūrai un efektīviem sabiedriskajiem pakalpojumiem. Nepietiekama transporta infrastruktūra un sarežģītas robežas šķērsošanas procedūras, kas ierobežo preču un pasažieru starptautisko pieejamību ir nozīmīgākās Austrumu-Rietumu transporta koridora problēmas. Kopīgā rīcības plāna uzdevums ir akcentēt transporta sistēmas atsevišķās komponentes, kas nozīmīgas atsevišķu tīklu efektīvai savienojamībai un/vai pakāpeniski pieaugošo starpreģionālo un transkontinentālo kravu plūsmu absorbēšanai. Veiksmīgai Austrumu-Rietumu transporta koridora darbības pārvaldībai vispirms nepieciešams noteikt koridorus administratīvajā struktūrā, nevalstiskās organizācijas (NVO) vietu pārvaldes struktūrā, partnerattiecības starp transporta mezgliem EWTC mehānismā un sadarbības iespējas starp privāto un valsts sektoru.

Pēdējie notikumi un nepārtraukti mainīgā vide liecina, ka NVS un ES valstis ir izplatīta politisko risinājumu ietekme uz uzņēmējdarbību. Tādējādi, joprojām nozīmīgas ir ieinteresēto pušu ekonomisko, politisko, vadības, juridisko, un pat morālisko aspektu analīze.

Atslēgvārdi: transporta koridori, vadība, pārvaldība, plānošana, infrastruktūra

Lukinskiy V., Lukinskiy Vl. Neveiksmes modeļu izveide piegādes ķēžu uzticamības novērtēšanai, *Transport and Telecommunication,* 16. sējums, Nr. 1, 2015, 40.–47. lpp.

Loģistikas un piegādes ķēdes vadība ir salīdzinoši jauna zinātnes joma, kas strauji attīstās.

Neatkarīgi no kopējo loģistikas izmaksu kritērija, kas tiek izmantots, lai novērtētu piegādes ķēdes efektivitāti, vēl viens kritērijs - patērētāju vajadzību kopējā apmierinātība - arvien vairāk tiek izmantots šiem pašiem mērķim. To iespējams izskaidrot ar pāreju uz tādu jaunu loģistikas koncepciju, kā piegādes ķēdes ilgtspēja, ko raksturo ne tikai loģistikas sistēmas elementu elastība, reaģēšanas tempi, izturība, spēja pielāgoties, bet galvenokārt funkcionēšanas drošums.

Rakstā tiek kritiski izvērtētas esošās pieejas neveiksmes modeļu izveide piegādes ķēdēs, metodiskā pieeja un galveno loģistikas funkciju neveiksmju klasifikācija (pirkšana, pasūtījuma apstrāde, transportēšana, uzglabāšana, novietošana noliktavā, materiālu apstrāde), kā arī tiek apskatīta neveiksmes modeļu attīstība un uzlabošana vairākām loģistikas funkcijām un darbībām. Kā arī sniegti daži piemēri par uzticamības indeksu aprēķiniem attiecībā uz piegādes ķēdes elementiem.

Atslēgvārdi: piegādes ķēdes, uzticamība, neveiksmes, aprēķinu modeļi

Vaculík Ju., Tengler Ji., Maslák O. EPC standartu un mobilo tīklu pakalpojumu izmantošana pasta pakalpojumu kvalitātes uzlabošanai, *Transport and Telecommunication,* 16. sējums, Nr. 1, 2015, 48.–60. lpp.

Rakstā aprakstītas pasta vēstuļu pārvadāšanas un piegādes optimizācijas jaunās tehnoloģijas un metodes. Raksta ievadā minētas pasta operatoru izmantotās tehnoloģijas un procedūras. Tālāk aprakstīti vairāku pasta operatoru konkrēti ieviestie risinājumi un to sniegtās priekšrocības. Raksta beigu daļā nodemonstrēta EPS standarta izmantošana procesu ķēdē. Secinājumi veltīti šo tehnoloģiju un potenciāla pasta nozarē novērtēšanai.

Atslēgvārdi: pasta piegādes, mobilās tehnoloģijas, post, RFID tehnoloģijas, EPC standarti

Kabaškins I., Lučina Je. Atbalsta modeļa attīstīšana alternatīvai izvēlei transporta tranzīta sistēmā, *Transport and Telecommunication,* 16. sējums, Nr. 1, 2015, 61.–72. lpp.

Lēmuma atbalsta sistēma ir viens no izvēles instrumentiem, pieņemot visefektīvāko lēmumu patstāvīgi svārstīgā biznesa vidē. Šī referāta mērķis ir lēmumu pieņēmējiem, kravu īpašniekiem ieteikt vairāku kritēriju pieeju, lai novērtētu alternatīvas kravu transportēšanā liela mēroga tranzīta sistēmā. Liela mēroga transportēšanas-tranzīta sistēma ir attēlota noslēgtā grafikā ar norādnēm (bultām). Katra no 57 alternatīvām tiek attēlota ar veiktspējas rādītāju kopu Kvi un parametru kopu Paj. Ir attīstīta 2 līmeņu hierarhijas sistēma ar vairāku ekspertu novērtējumu, kas balstīta uz analītiskās hierarhijas procesa metodi. Saskaņā ar šo metodi tika ieteiktas labākās alternatīvas.

Atslēgvārdi: transporta modelis, tranzīts, lēmuma atbalsts, Baltijas jūras reģions

Chernyi S., Zhilenkov A. Sarežģītu struktūru modelēšana kuģa Power Complex, izmantojot Xilinx sistēmu, *Transport and Telecommunication,* 16. sējums, Nr. 1, 2015, 73.–82. lpp.

Viens no būtiskākajiem uzdevumiem vairāku sistēmu automātisko kontroles autonomās elektroapgādes sistēmām ūdens transportā ir mainīgo harmoniku komponentu nesinusoidālas signālu precīzs aprēķins. Autonomajās elektroapgādes sistēmās, kas darbojas ar pilnu pusvadītāju jaudu, līniju strāvu un spriegumu formas ir ļoti izkropļotas, un ģeneratoru iekārtas rada spriegumu ar nekonsekventu frekvenci, fāzi un amplitūdu.

Tas padara deformēto signālu harmoniskā sastāva aprēķinu par netriviālu uzdevumu. Šajā darbā sniegts aprakstītās problēmas atrisināšanas matemātiskais komplekts, tostarp realizācijai diskrētā formā. Sistēmas vienkāršībai un efektivitātei tika ierosināts veikt tās praktisko realizāciju, izmantojot lētu FPGA. Izstrādātās sistēmas pārbaude veikta vidē Matlab.

Atslēgvārdi: enerģijas sistēmas, intelektuālās sistēmas, harmoniskās sastāvdaļas, kuģis

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