MODELLING AND ASSESSMENT OF RISKS IN LOGISTICS USING MULTIDIMENSIONAL STATISTICAL METHODS

Vladimirs Jansons[a], Vitalijs Jurenoks[b], Konstantins Didenko[c], Julia Pushkina[d],

[a]Riga Technical University, Latvia
[b]Riga Technical University, Latvia
[c]Riga Technical University, Latvia
[d] JS Insurance Company "BALTA", Latvia

[a]vladjans@latnet.lv, [b]vitalijs.jurenoks@rtu.lv, , [c]konstantins.didenko@rtu.lv, [d]puskina@inbox.lv

ABSTRACT
Logistics process of cargo delivery from point A in point B, as a chain of consecutive risks, is considered in the article. All risks are shared into three main groups. Authors investigate each risk influence on insurance premium volume, and, therefore, insurance component influence on cargo delivery cost. Ranking of risk factors according to their influence on the cargo insurance premium is carried out by authors. The resulting research model estimates cargo delivery costs, takes into account the ordered risks, and makes it easier to model the logistical task considering the most significant risks of delivery. For modelling of delivery costs risk component is applied Monte-Carlo multidimensional statistical modelling method, similar to modelling process which was presented in the article by Jansons, V., Jurenoks, V., Didenko, K., 2013. Use of modelling for assessment of Latvian road safety and logistics costs minimization.

Keywords:
Logistics, ranking of risks, insurance modelling, cost optimization.

1. CREATION OF MATHEMATICAL MODEL FOR ANALYSIS OF CARGO DELIVERY COSTS

Cargo transportation and logistics services are very important industries in the national economy of Latvia. This is due to geographic location of Latvia and the development of logistics infrastructure. Importance of cargo transportation and logistics services is indicates of their share in the total value added of all economic sectors in Latvia (see table 1).

Table 1: Cargo Transportation And Logistics Services Share In The Total Value Added In Latvia

	2011	2012	2013
Total value added, ths EUR	17 793 585	19 236 456	20 214 557
Cargo transportation and logistics services value added, ths EUR	1 820 167	1 983 771	1 968 685
Cargo transportation and logistics services value added, %	10,2	10,3	9,7

The process of transportation of goods from one point to another is subject to many risks. Many accidents may happen during transportation process, there is no guarantee of delivery safety, and cargo may be damaged or lost. To ensure cargo safety methods of risk management are applied, and the most popular of them in logistics is insurance. In cargo insurance should be interested cargo owners; as the policyholder may be a shipper or a consignee - depending on the conditions of delivery contract and responsibility for the goods and property rights to it, written in the contract. Policyholder may be also freight forwarding companies, in this case the insurance contract is signed in favor of the cargo owners. Insurance costs are an important part of the total delivery costs, so the authors propose to distinguish them of total logistics costs as separate component:

$$C_{delivery} = C_{logistics} + P_{insurance}, \qquad (1)$$

where $C_{delivery}$ – delivery costs,

- $C_{logistics}$ - logistic service costs,
- $P_{insurance}$ – cargo insurance premium.

In a general case, the value of $C_{logistics}$ can be presented as a function of a range of variables (factors characterizing the particular cargo and its terms of delivery), namely:

$$C_{\log istics} = \Phi\ (KF,\ V,\ WT,\ KT,\ FR\ ,\ KR\ ,\ T,\ F_{t_1},\ F_{t_2},\ M\ ,W\ ,Y). \qquad (2)$$

The parameters of the model are follows:

- KF – type of cargo transported (table 2);
- V - total volume of cargo carried in containers;
- WT - transportable cargo weight;
- KT – type of cargo transportation (table 3);
- FR - types of financial risks (table 5);
- KR – the type of roads;
- T - time of delivery from the consignor to the consignee;
- F_{t1} - price of 1L of diesel fuel used by transportation vehicles at the moment of signing the contract;
- F_{t2} - price of 1L of diesel fuel used by transportation vehicles when transporting cargo;
- M - route which is used for transporting cargo;
- W – warehouse costs;

- Y - other factors characterising the particular cargo to be transported and its terms of delivery (for example, expedition service costs, labour costs, etc.).

Table 2: Types Of Cargo Transported (KF)

	KF_i	Risk detailed description
1	Dangerous Goods	high fire and explosion hazard
2	Perishable goods	- sensitivity to temperature changing, - State health authorities' requirements that allow these products to be sold.
3	Live transportation	- special treatment and food supply requirements; - sensitivity to climatic influences; - Veterinary certificates are necessary.
4	Car transportation	- small paint damage the car body; - theft of small components and parts of car.
5	Bulk and liquid cargoes	- the difference in weight when sending and receiving; - pollution; - hygroscopicity; - sensitivity to climatic influences.
6	Non-standard and heavy cargo	-external impact on the goods (damage during loading / unloading or transporting); - theft of small components and parts
7	Consolidated cargo	theft of small components and parts
8	General goods	depending on the type of goods
9	Others types of cargo	depending on the type of goods

Types of cargo transportation are presented in table 3.

Table 3: Types Of Cargo Transportation (KT)

i	KT_i	Risk detailed description
1	Road transportation	- risk of theft or robbery; - risk of theft of the vehicle; - risk of accidents; - risk of vehicle breakdown, - risk of damage to the goods during transportation.
2	Railroad transportation	- risk during loading/ reloading of goods; - risk of injury from fire or accident; - risk of theft or robbery.
3	Sea transportation	- risk during loading/ reloading of goods (damage or theft); - water damage; - risk of total loss of the goods.
4	River transportation	- risk during loading/ reloading of goods (damage or theft); - water damage; - risk of total loss of the goods.
5	Air transportation	- risk of total loss of the goods; - risk of catastrophe.

Cargo transportation in Latvia is divided by types of vehicles rather evenly (see table 4).
River and air transportation share is very small, less than one percent, and are not included in table 4.

Table 4: Cargo Transportation Structure In Latvia

Railroad transportation, mln t	
Total	55,8
domestic	1,2
international	54,6
Sea transportation, mln t	
sent from the latvian port cargo	62,4
delivered to the Latvian ports cargo	8,1
Road transportation, mln t	
Total	60,6
domestic	50,5
international	10,1

Types of financial risks (FR) are shown in the table 5.

Table 5: Types Of Financial Risks (FR)

	FR_i	Risk detailed description
1	Operational risk	People risk, Legal risk
2	Credit risk	Exposure, Recovery rate, Credit event, Sovereign risk, Settlement risk
3	Market risk	Absolute risk, Relative risk, Directional risk (Linear risk exposure), Non Directional risk, Basis risk, Volatility risk
4	Liquidity risk	Asset Liquidity risk, Funding Liquidity risk

Types of roads (KR_i) have been analyzed by authors in the previous articles (see references), and classified depending on owners (state roads, local government, private) and types of road paving (paved roads, gravel roads, not covered roads).
The scheme of the $M_{AWi}{}^{th}$ route of traffic with the relevant road traffic parameters of every section of the route from point A to point B is presented in figure 1.

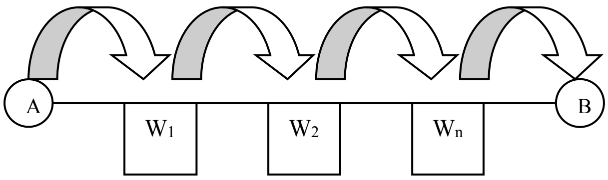

Figure 1: Scheme Of The $M_{AWi}{}^{th}$ Route Of Road Traffic Between Points A And B

Cargo transportation can be multimodal, i.e. using multiple modes of transportation and reloading, during which the goods for a certain period of time stored in warehouses W_1, W_n (see figure 1). Therefore, the authors add to the mathematical model for calculating logistics costs $C_{logistics}$ the component W - the costs of storage, handling and processing of goods in warehouses and terminals.

2. MODELLING OF CARGO INSURANCE PREMIUM

One of the essential components of the logistic service is cargo insurance $P_{insurance}$.
Therefore, it is important to build an economic and mathematical model for calculating the premium $P_{insurance}$ (3) at different parameters of the transportation process.

$$P_{insurance} = F\ (S\ ,\ DP,\ H, T\ , KT,\ KF,\ KR,\ FR\ ,\ M\ ,\ IC,\ DC, W, Y\ ), \qquad (3)$$

where DP – declared value of the goods carried;

- S – amount of insurance sum for cargo calculated by formula (4):

$$S = k \cdot DP, \qquad 0 < k \le 1, \tag{4}$$

where k – correction coefficient of sum for cargo insurance;

- H_i - hazard risk of cargo, according to the IMO (International Maritime Organization) classification;
- T - time of delivery from the consignor to the consignee;
- KT – type of cargo transportation (table 3);
- KF – type of cargo transported (table 2);
- FR - types of financial risks (table 5);
- M_i - route which is used for transporting cargo. The scheme of the M_{AWi}^{th} route of traffic with the relevant road traffic parameters of every section of the route from point A to point B is presented in figure 1.
- W – type of warehouse;
- IC – insurance conditions;
- DC – delivery contract rules.

According to international insurance practice, for cargo insurance as insurance conditions (IC) mainly are used London Institute cargo clauses ICC. Depending on the breadth of coverage insurance companies change the value of the insurance premium, so that the conditions of insurance are also one of the factors affecting the size of the insurance premium $P_{insurance}$.

Institute cargo clauses are attached to a type of marine insurance that covers cargo in transit. These clauses are to specify what items in the cargo are covered should there be damage or loss to the shipment. Institute cargo clauses can cover everything from the cargo itself to the container that holds it to the mode of transportation used to ship it.

There are three basic sets of institute cargo clauses; A, B, C.

These clauses were developed by the International Chamber of Commerce (ICC) as a means of insurance for cargo while it is being shipped from the original location to its final destination.

As the more risks are covered as the higher premium has to pay policy holder. The three clauses are briefly described the same way:

- Institute Cargo Clause A is considered the widest all risks insurance coverage including theft, pilferage and non-delivery, rough handling, piracy and perils covered under ICC (B) & ICC (C);
- Institute Cargo Clause B is considered a more restrictive coverage including washing overboard, entry of sea, lake of river water into vessel, craft, hold, conveyance, container, lift van or place of storage, earthquake, volcanic eruption or lightning, total loss of package lost overboard or dropped whilst loading on to or unloading from vessel or craft , perils covered under ICC (C);
- Institute Cargo Clause C is considered the most restrictive coverage and is limited to those risks as fire or explosion, vessel/craft being stranded, grounded, sunk or capsized, overturning or derailment of land conveyance, collision or contact of vessel, craft or conveyance with external object other than water.

The Incoterms rules are widely used in International trading and delivering processes as international delivery contract rules (DC). The Incoterms rules or International Commercial Terms are a series of pre-defined commercial terms published by the International Chamber of Commerce. The Incoterms rules are intended primarily to clearly communicate the tasks, costs, and risks associated with the transportation and delivery of goods.

The Incoterms rules are accepted by governments, legal authorities, and practitioners worldwide for the interpretation of most commonly used terms in international trade. They are intended to reduce or remove altogether uncertainties arising from different interpretation of the rules in different countries. As such they are regularly incorporated into sales contracts worldwide.

The value of insurance premium depends on the delivery contract rules, because they define the duties of contract parties during cargo transportation, including the responsibility for risk of cargo loss and cargo insurance.

For the calculation of the insurance premium $P_{insurance}$, the empirical data and methods of statistical Monte Carlo simulation are used.

The scheme of financial modelling of insurance process is presented in figure 2.

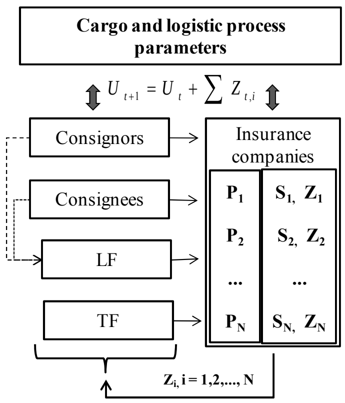

Figure 2: Scheme Of Financial Modelling Of Insurance Process

In figure 2 are presented parameters:

- Z_i – insurance indemnity;
- N – number of insurance objects.

For the insurance process, the possibility of performance of insurance obligations is most significant, irrespective of the intensity of the stream of insured events $\{t_j, Z_j\}$ and size of insurance reserve U_{t+1} in time moment t+1.

$$U_{t+1} - \sum_{i=1}^{N} Z_{t,i} > 0. \tag{5}$$

The insurance process should be financially stable during all the functioning time of the insurance system. We understand the stability of the insurance process as performance of an inequality (5) during all time T ($0 < t \leq T$) of functioning of the insurance process with probability $1-\alpha$. To solve the inequality (5), the premium P is calculated based on the parameters of the insurance process (figure 2). Based on the above, the formula for calculating value $P_{insurance}$ (the insurance premium for cargo) can be presented as:

$$P_{insurance} = P_0 + P_R, \quad (6)$$

where P_0 - risk-free component of the premium, which also includes the burden of insurance;

- PR – risk component of the premium, which is depending on risk factors ri.

$$P_R = DP(r_T + r_{KT} + r_{KF} + r_{KR} + r_M + r_{FR} + r_W), \quad (7)$$

where r_T – risk of exceeding the time of delivery of the goods envisaged in the contract;

- r_{KT} – risk due to the type of cargo transportation;
- r_{KF} – risk due to the type of cargo transported;
- r_{KR} – risk due to the state of the quality of roads along which the goods are transported (estimated by the number of traffic accidents);
- r_M – risk due to the route by which the goods are transported;
- r_{FR} – financial risks;
- r_W – warehousing risks.

Authors offer to apply the analytic hierarchy process for priority of cargo insurance premium risk factors determination and influence on the cargo insurance premium assessment.

3. RANKING OF RISK FACTORS ACCORDING TO THEIR INFLUENCE ON THE CARGO INSURANCE PREMIUM

As is mentioned above, the risk component of the insurance premium P_R depends on many risk factors r_i, which are different for each type of cargo and each carriage. So, delivery risk is function of many variables r_i:

$$R_{delivery} = f(r_T, r_{KT}, r_{KF}, r_{KR}, r_M, r_{FR}, r_W) \quad (8)$$

Authors review an example of practical applying of analytic hierarchy process for priority of three risk factors determination:

- r_{KF} – risk due to the type of cargo transported, which is named in this research as A factor group;
- r_{KT} – risk due to the type of cargo transportation, which is named as B factor group;
- r_{FR} – financial risks, which is named as C factor group.

In each group A, B and C were identified factors:

A group – 9 factors (A1-A9) (table 6);
B group – 5 factors (B1-B5) (table 7);
C group – 4 factors (C1-C4) (table 8).

The group of experts made comparative estimates of factors by the principle everyone with everyone. It is supposed that these groups of factors are poorly connected among themselves that allows to consider them as independent groups at the initial stage of research. In this case to order the factors on extent of their influence on cargo delivery risks it is possible to use analytic hierarchy process method. Realization of this method consists of three stages: Formation of hierarchies; Paired comparison of factors; Calculation of priorities (ranking).

The following hierarchical structure of risk factors is supposed by the authors (see figure 3).

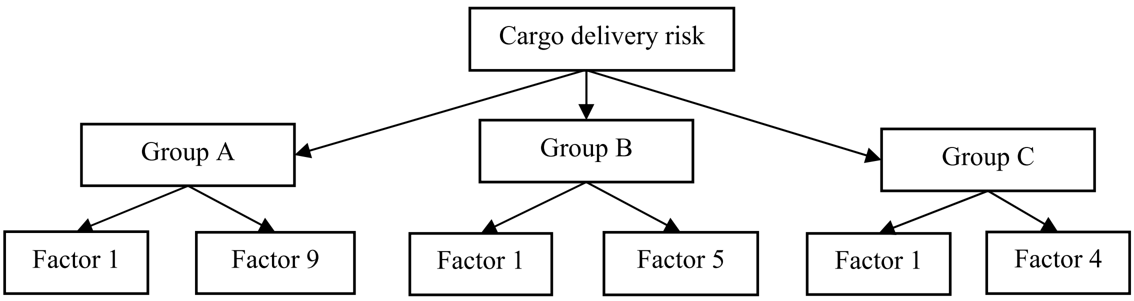

Figure 3: Hierarchical structure of the factors influencing cargo delivery risk

Table 6: Cargo delivery risk factors – A group

	A group (Types of Cargo Transported)
A1	Dangerous Goods
A2	Perishable goods
A3	Live transportation
A4	Car transportation
A5	Bulk and liquid cargoes
A6	Non-standard and heavy cargo
A7	Consolidated cargo
A8	General goods
A9	Others types of cargo

Table 7: Cargo Delivery Risk Factors – B Group

	B group (Types of Cargo Transportation)
B1	Road transportation
B2	Railroad transportation
B3	Sea transportation
B4	River transportation
B5	Air transportation

Table 8: Cargo Delivery Risk Factors – C Group

	C group (Types of Financial Risks)
C1	Operational risk
C2	Credit risk
C3	Market risk
C4	Liquidity risk

Paired comparison of factors groups A, B, C is carried out (see table 9).

Table 9. Paired Comparison Of Factors Groups Of A, B, C

	A	B	C	Σ	PV=Σ/Σ(Σ)
A	1	2	3	6	0,493
B	0,50	1	3	4,50	0,370
C	0,33	0,33	1	1,667	0,137
			Σ(Σ) =	12,167	1,000

The highest priority PV=0,493 (highest influence on insurance premium) has type of cargo transported, the second priority PV = 0,370 has type of cargo transportation, and the lowest priority PV=0,137 has type of financial risks.
As a result of paired comparison for factors in each group we will receive matrixes of paired comparisons were received.
Tables 10, 11, 12 summarize the results (see column PV in the tables) of calculation of factors priorities using the simplest method.

Table 10. A Group Factors Priorities

	A1	A2	…	A9	Σ	PV=Σ/Σ(Σ)
A1	1	2	…	7	39	0,206
A2	0,5	1	…	8	37,5	0,198
A3	0,33	0,5	…	6	26,83	0,141
A4	0,33	0,25	…	7	27,08	0,143
A5	0,2	0,25	…	7	21,03	0,111
A6	0,2	0,2	…	6	16,15	0,085
A7	0,17	0,17	…	6	12,54	0,066
A8	0,14	0,14	…	5	7,27	0,038
A9	0,14	0,13	…	1	2,26	0,012
				Σ(Σ) =	189,66	

Table 11. B Group Factors Priorities

	B1	B2	...	B5	Σ	PV=Σ/Σ(Σ)
B1	1	2	...	6	15	0,324
B2	0,5	1	...	7	13,5	0,292
B3	0,5	0,5	...	5	9	0,194
B4	0,25	0,33	...	5	7,08	0,153
B5	0,17	0,14	...	1	1,71	0,037
				Σ(Σ) =	46,29	

Table 12. C group factors priorities

	C1	C2	C3	C4	Σ	PV= Σ/Σ(Σ)
C1	1	3	5	6	15	0,476
C2	0,33	1	4	5	10,33	0,328
C3	0,2	0,25	1	3	4,45	0,141
C4	0,17	0,2	0,33	1	1,7	0,054
				Σ(Σ) =	31,483	

Using the indicator of coherence of factors assessment CI (see formula 9), it is possible to specify expert estimates of paired comparisons of factors. Than the coherence indicator is closer to zero, especially expert estimates are carried adequately out (usually, CI< 15%-20%).

$$CI = \frac{\lambda_{\max} - n}{n-1} \quad (9)$$

Where size of a matrix (number of investigated factors), λ_{max} – maximal value of a matrix. After carrying out all these calculations, it is possible to define final arrangement of priorities for all factors. It gives the chance to choose such factors which with sufficient degree of reliability will estimate risks factors influence on insurance premium.
Using special software, the authors calculated λmax for each of A, B and C groups. As a result, the indicator CI can be calculated:

A group: n=9, λmax = 10,319, CI_A = 0,1649= 16,49%;

B group: n=5, λmax = 5,179, CI_B = 0,0448= 4,48%;

C group: n=4, λmax = 4,209, CI_C = 0,0697= 6,97%.

CONCLUSION

The attention in the article is paid to the assessment of the logistics risks, as well as the analysis and estimation of the cargo insurance premium and modelling of logistics service costs $C_{logistics.}$
The methods used in the study (statistical simulation method for assessing risks of the logistics process, method for modelling the financial risks, hierarchical

method for risks significances evaluation, expert method for risks comparing) allow us in a more complete and accurate way assess the borders of the changes of the logistic service cost, using more significant risks.

The application of statistical modelling using Monte Carlo method together with risks assessment allows:

- to investigate the safety of Latvian roads;
- to analyse the dynamics of changes of road accidents taking into consideration the time factor);
- to define economic losses caused by logistics risks;
- to model the value of the cargo insurance premium P and logistics service costs $C_{logistics}$.
- to set alternative strategies of insurance system performance;
- to manage functioning of insurance system.

Road traffic accidents prevention must be incorporated into the development and management of road infrastructure. The theoretical and practical results obtained as a result of this research can be applied for evaluation of premium values for different scenarios of insurance process in conditions of uncertainty.

REFERENCES

Harrington S. E., Niehaus G.R. 2003. Risk Management and Insurance. New York, 672 p.

Jansons, V., Jurenoks, V., Didenko, K., 2013. Use of modelling for assessment of Latvian road safety and logistics costs minimization. 10th International Multidisciplinary Modeling & Simulation Multiconference. Athens, Greece, September-25-27, 2013. pp. 1-5.

Jansons, V., Jurenoks, V., Didenko, K., 2012. Safety Control of Latvian State Road Network Using Statistical Modelling Methods. The 14 th International Conference on Harbor Maritime Multimodal Logistics Modelling & Simulation HMS 2012, pp. 1-6. September 19-21, Vienna, Austria.

Jansons, V., Jurenoks, V., Didenko, K., 2011. Investigation of Financial Flows in Logistics Using Multivariate Statistical Modelling Methods. The 13 RD International Conference on Harbor Maritime Multimodal Logistics Modelling & Simulation HMS 2011, pp. 7-13. September 12-14, Rome, Italy.

Jurenoks, V., Jansons, V., Didenko, K., 2010. Investigation of Economic Systems using Modelling Methods with Copula. The 13 TH International Conference on Harbor Maritime Multimodal Logistics Modelling & Simulation HMS 2010, pp. 1-6. October 13-15, Fez, Morocco.

Jurenoks, V., Jansons, V., Didenko, K., 2010. Modelling of Stability of Economic Systems Using Benchmarking and Dynamic Programming. X International Conference on Computer Modelling and Simulation EUROSIM/UKSim, pp. 295-300. April 1-3, Cambridge, United Kingdom.

Jurenoks, V., Jansons,V., Didenko, K., 2008. Investigation of Accident Black Spots on Latvian Roads Using Scan Statistics Method. 22nd EUROPEAN Conference on Modelling and Simulation ECMS 2008, pp.393-398. May 3-6, Nicosia, Cyprus.

Magee, J. F., Capacino, W. F. and Rosenfield, D. B. 2001. Modern Logistics Management: Integrating Marketing, Manufacturing and Physical Distribution.1 edition. John Wiley & Sons, Inc., 430 p.

Winston, Wayne L. 2004. Microsoft Excel Data Analysis and Business Modeling. Microsoft Press, 624 p.

Джонсон, Д., Вуд Д. Ф., Вордлоу Д. Л. и Мерфи-мл., П. Р. 2005. Современная логистика. 7-е издание, Пер. с англ. Издательский дом Вильямс, 538 с.

Лоу, А. М., Кельтон, В. Д. 2004. Имитационное моделирование. Классика CS, СПБ Питер, Киев, Издательская группа BHV. 847 с.

AUTHORS BIOGRAPHIES

VLADIMIRS JANSONS was born in Daugavpils, Latvia and is a graduate of the University of Latvia, where he studied mathematical science and obtained his degree in 1970. For eight years he has worked in the Computing Centre of the University of Latvia. Since 1978 he has been lecturing at Riga Technical University, where in 1983 he was awarded the doctoral degree in the mathematical science.
E-mail: vladjans@latnet.lv.

VITALIJS JURENOKS was born in Riga, Latvia. In 1976 he graduated from the Faculty of Engineering Economics of Riga Technical University, and for ten years, has worked in an industrial enterprise in Riga. Since 1986, he has been lecturing at Riga Technical University, and in 1987 was awarded the doctoral degree in the science of economics (Dr.oec.). E-mail: vitalijs.jurenoks@rtu.lv.

KONSTANTINS DIDENKO was born in Jelgava, Latvia. In 1969 he graduated from the Faculty of Engineering Economics of Riga Technical University. Since 1969 he has been lecturing at Riga Technical University where in 1985 he obtained the doctoral degree in the science of economics. In 2006 he was elected a corresponding member of the Latvian Academy of Sciences. E-mail: konstantins.didenko@rtu.lv.

JULIA PUSHKINA, was born in Latvia. In 1998 she graduated from the Faculty of Economics and Management of Latvian University (Master degree). Since 2001 she has been working at JS Insurance Company "BALVA" as Head of Department, since 2009 as a Member of the board of "BALVA". Since 2013 she has been working at JS Insurance Company "BALTA" as a Head of department. E-mail: puskina@inbox.lv