INVESTIGATION OF ECONOMIC STABILITY OF LOGISTIC PROCESS USING STATISTICAL DYNAMIC MODELLING

Vladimirs Jansons[(a)], Vitalijs Jurenoks[(b)], Konstantins Didenko[(c)]

[(a)]Riga Technical University, Latvia
[(b)]Riga Technical University, Latvia
[(c)]Riga Technical University, Latvia

[(a)]vladjans@latnet.lv, [(b)]vitalijs.jurenoks@rtu.lv, [(c)]konstantins.didenko@rtu.lv

ABSTRACT
Crucial component of the successful performance of all participants of logistic process as an economic system is maintenance of an optimality of functioning of all industrial and economic criteria of the given system. The purpose of the given work is stochastic modelling of the stability of transport logistics system (TLS). The process of deterministic and stochastic modelling of TLS stability is considered in the conditions of uncertainty using bootstrapping and dynamic programming method by Bellman.
It is well known that random character may be an attribute inherent to the majority of economic events and processes of TLS. Modelling of logistical processes in conditions of uncertainty is complicated due to the lack of trustworthy information describing the conditions of uncertainty, and also in view of the random character of occurrences of deviations in the course of processes researched.
Ignoring the evaluation of effect of certain factors during the research of processes occurring in transport logistics system frequently expands "zone of risk", entailing mistakes and discrepancies in the real time situation that, in turn, may finally result in significant material losses.

Keywords: logistics process, financial stability, statistical dynamic modelling, bootstrapping

1. INTRODUCTION
Steady position of TLS in the market is understood as TLS ability to keep or increase the tendency of positive development, that is to keep the volume of the goods or services sold and the profit received from sales of the given goods and services in changing external and internal environment of TLS. The principal objectives of this research work are:
- to consider an option of modelling the financial stability management of TLS participants in conditions of uncertainty;
- to model "zones of risk" of the financial performance of TLS participants in conditions of uncertainty.
The structure of TLS is shown in figure 1.

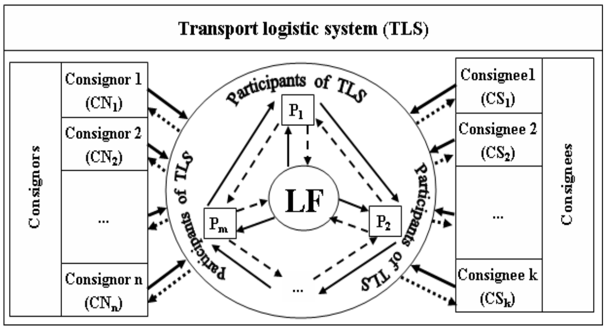

Figure 1: Structure of TLS

Modelling of behaviour of the criterion of TLS stability is based on establishing alternative strategies which are introduced during definite moments of modelling time, thereby supporting stable TLS performance. Thus, the concept „criterion of stability" has been introduced. The primary goal of management of TLS stability is maintaining the criterion of stability with regard to the given interval of allowable values of the chosen criterion of stability. Uncertainty in TLS is understood as a situation when there is incomplete or no information at all about the possible conditions of the system itself and the environment in which the system functions.

2. PROBLEM DESCRIPTION
Conditions of uncertainty are understood as various unexpected fluctuations of some factors of external and internal TLS environment. Steady performance of TLS is the ability of all TLS participants to perform a complete set of functions and also maintain (or even increase) the services to be rendered for a long period of time in the conditions of uncertainty. Ignoring the evaluation of effect of the influence of variable factors during the research of the processes occurring in TLS frequently expands the "zone of risk", thereby leading to mistakes in the real time situation that, in turn, may finally result in significant material losses. The economic stability of TLS is the capability of all participants of TLS to implement their financial liabilities in full on the timeframe set by the contract.

For the evaluation of TLS economic stability it is offered to use:

- complex variable C^F of the financial stability of TLS;
- complex indicator C^Q of the production stability of TLS;
- integral indicator of the stability of the system J, which is the function of several variables and is aggregating the complex evaluation indicators C^F, C^Q of the TLS stability.

The integrated criterion of TLS stability $J^{(t_i)}$ is a function of complex criteria $C^{F(t_i)}$ and $C^{Q(t_i)}$:

$$J^{(t_i)} = f(C^{F(t_i)}, C^{Q(t_i)}) \qquad (1)$$

For the establishment of complex and integrated criteria of TLS stability local criteria of stability of separate TLS participants are used, for example, the criterion of stability of activity of one of the transport companies of TLS, or criteria of stability of some kinds of TLS performance. Complex criteria of stability of TLS must be investigated in a dynamic as well as

Introduction of an integrated criterion of stability of TLS assumes the analysis of all industrial and financial processes in the system, i.e., the internal and external processes of TLS.

The complex criterion of TLS financial stability $C^{F(i,j)}$ is the financial stability of j-th participant of TLS at the moment of time t_i. Under favourable conditions of TLS performance at the moment of time t_i, in the system the issue of insolvency of TLS participants should not arise. That is the balance (B_{ij}) of any TLS participant at the moment of time t_i is a positive value:

$$B_{i,j} > 0 \qquad (2)$$

The complex criterion of the TLS financial stability may be presented as a function:

$$C^{F(i)} = f_1(V_{(-)}^{i,j}, n_{(-)}^{i,j}, \omega) \qquad (3)$$

where: $C^{F(i)}$ - complex criterion of financial stability of TLS at the time moment t_i;

$V_{(-)}^{i,j}$ - normalized criterion of the insolvency of j-th TLS participant at the time moment t_i, should satisfy the inequalities:

$$-1 \le V_{(-)}^{i,j} \le 0 \qquad (4)$$

$n_{(-)}^{i,j}$ - number of insolvent TLS participants at the time moment t_i;

w – random factor.

In real logistics systems there are problems with holding payments in the case of transactions between TLS participants. The breach of the contract and/or partial fulfilment of financial contracts by one of the participants of TLS lead to breaking of the financial stability of the whole system. Thus, it is offered to create and use the financial reserves of the system (Res^{ij}**)** for ensuring the financial stability of TLS. The complex criterion of financial stability of TLS, taking into account the financial reserves $C_{\mathrm{Res}}{}^{F(i)}$, may be presented as a function:

$$C_{\mathrm{Res}}{}^{F(i)} = f_1(V_{(-)}^{i,j}, n_{(-)}^{i,j}, \omega, \mathrm{Re}\, s^{i,j}) \qquad (5)$$

The financial reserves of the system are used for ensuring the limited production resources in the volume required for the TLS performance. The scheme of the use of financial reserves for ensuring the financial stability of TLS is presented in figure 2.

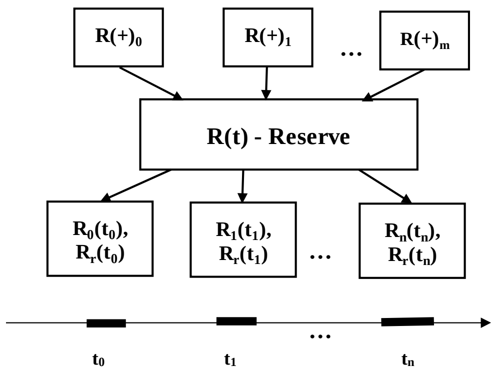

Figure 2: The Scheme of Using and Replenishment of Financial Reserve for Maintenance of TLS Stability in Modelling Time

where R(t) – the total amount of resources in TLS at the moment of time t;

$R(+)_i$ – the value of i^{th} replenishment of financial reserve in modelling time, i=0,1,2, … , m;

$R_j(t_j)$ - the value of financial reserve at the moment of time t_j, j=0,1,2, … ,n;

$R_r(t_j)$ – the requirement value of financial reserve for maintenance of the TLS stability at the moment of time t_j, j=0,1,2, … ,n.

Values R(t), $R(+)_i$, $R_j(t_j)$, $R_r(t_j)$, m, t_0, t_1,…,t_n at every time moment t are random with unknown probabilities distribution. For evaluation of distributions of all this parameters we have used the bootstrapping method.

3. BOOTSTRAP METHODOLOGY

Bootstrapping is a general approach to statistical inference based on construction of distribution for a statistic by resampling from the given sample. Suppose that we draw a sample S={s_1, s_2,…, s_n}from a population P={x_1, x_2, …, x_N} and N >> n (N is very much larger than n). Now suppose that we are interested in some statistic T=t(S) as an estimate of the corresponding population parameter θ=t(P). θ could be a vector of parameters and T the corresponding vector of estimates. A traditional approach to statistical inference is to make assumption about the structure of the population (e.g., an assumption of normality), and, if we have condition of random sampling, to use these assumptions to derive the sampling distribution of T, on which classical inference is based. Nonparametric bootstrap allows us to estimate the sampling distribution of a statistic empirically without making assumption about the form of the population, and without deriving the sampling distribution explicitly. The essential idea of the nonparametric bootstrap is as follows: we proceed to draw a sample of size n from among the elements of S, sampling with replacement. Call the resulting bootstrap sample:

$$S_1^* = \{s_{11}^*, s_{12}^*, ..., s_{1n}^*\} \tag{6}$$

It is necessary to sample with replacement, because we would otherwise simply reproduce the original sample S. In effect, we are treating the sample S as an estimate of the population P; that is, each element s_i (i=1,2,…,n) of S is selected for the bootstrap sample with the probability p=1/n, modelling the original selection of the sample S from population P.

We repeat this procedure a large number of times M, selecting many bootstrap samples. Denote the j^{th} bootstrap sample as:

$$S_j^* = \{s_{j1}^*, s_{j2}^*, ..., s_{jn}^*\} \tag{7}$$

Then the distribution of T^*_j around the original estimate T is analogous to the sampling distribution of the estimator T around the population parameter θ. For example, the average of the bootstrapped statistics:

$$\overline{T}^* = \frac{\sum_{j=1}^{M} T_j^*}{M} \tag{8}$$

Estimates the expectation of the bootstrapped statistics; then $\Delta^* = \overline{T}^* - T$ is an estimate of the bias of T:

$$\hat{V}^*(T^*) = \frac{\sum_{j=1}^{M}\left(T_j^* - \overline{T}^*\right)^2}{M-1} \tag{9}$$

Similarly, the estimated bootstrap variance of T^* evaluates the sampling variance of T. There are several approaches to constructing bootstrap confidence intervals. The *normal-theory interval* assumes that the statistic T is normally distributed , and uses the bootstrap estimate of sampling variance (perhaps bias) to construct a confidence intervals with confidence level a of the form:

$$\theta = \left(T - \Delta^*\right) \pm z_{1-\alpha}\sqrt{\hat{V}^*\left(T^*\right)} \tag{10}$$

where $z_{1-\alpha}$ is the 1-α/2 quantile of the standard-normal distribution. We can use an alternative approach, called the bootstrap percentile interval, is to use empirical quantiles of T^*_j to form a confidence interval for θ:

$$T^*_{(lower)} < \theta < T^*_{(upper)} \tag{11}$$

where $T^*_{(1)}, T^*_{(2)}, ..., T^*_{(M)}$ are the ordered bootstrap replicates of the statistic; lower = [(M+1)*α/2]; upper = [(M+1)*(1-α/2)].

The square brackets indicate rounding to nearest integer. For example, if α = 0.05, corresponding to a 95-percent confidence interval, and M=1000, then lower = 25 and upper = 975.

The method of Monte-Carlo with bootstrapping is used for management of TLS stability. Bootstrapping is a method used in investigation process for evaluation of possible fluctuation zones for TLS parameters. This allows organizations to develop plans on how to adopt such best practice, usually with the aim of increasing some aspects of performance. Now using bootstrap estimation for values R(t), $R(+)_i$, $R_j(t_j)$, $R_r(t_j)$, m, t_0, $t_1,…,t_n$ we can evaluate the main statistics and in modelling process take into account distributions of parameters.

4. MODELLING OF TLS ECONOMIC STABILITY

The complex criterion of the production stability $C^{Q(i)}$ of TLS characterises the ability of all TLS participants to ensure the performance of material flows in accordance with the contracts signed. The complex criterion of TLS production stability is a function of several variables:

$$C^{Q(i)} = f_2(R^{i,j}, n^{i,j}_{(<1)}, \omega) \tag{12}$$

where $R^{i,j}$ - normalized criterion which characterizes the real amount of TLS resources in comparison with the amount of resources needed for ensuring stable TLS performance in accordance with the contract liabilities.

The value $R^{i,j}$ is defined in the intervals [0, 1]:

$$0 \le R^{i,j} \le 1 \tag{13}$$

The condition of production stability of TLS is violated in the case if for any of TLS participants the criterion $R^{i,j} > 1$. The value of the complex criterion of production stability of TLS $C^{Q(i)}$ is defined in the intervals [0, 1]:

$$0 \le C^{Q(i)} \le 1 \quad (14)$$

The integrated criterion of TLS stability $J^{(i)}$ is a function of complex criteria $C^{F(i)}$ and $C^{Q(i)}$:

$$J^{(i)} = f_3(C^{F(i)}, C^{Q(i)}) \quad (15)$$

For the establishment of complex and integrated criteria of TLS stability local criteria of stability of separate TLS participants are used, for example, the criterion of stability of activity of one of the transport companies of TLS, or criteria of stability of some kinds of TLS performance. Complex criteria of stability of TLS must be investigated in a dynamic as well as complex mode.

The modelling process of TLS economic stability is implemented applying a set of alternative strategies of TLS performance by using the dynamic programming and bootstrapping method. The introduction of a set of alternative strategies supports stable functioning of TLS in the conditions of uncertainty. Thus, the integrated criterion $J^{(i)}$ changes its values in the feasible region:

$$\min J_{ij}(t) \le \sum J_{ij}(t) \le \max J_{ij}(t) \quad (16)$$

The change of criteria of TLS stability is a signal for adjusting the functioning strategy of TLS. Taking into account the TLS infrastructure, and also the character of interaction of internal and external factors of the environment of TLS performance and the integrated criterion of stability, it is natural to estimate the integrated criterion of the profit which can be presented as:

$$P(t_0,t_n)=\int_{t_0}^{t_n}\mathrm{Re}v(t)dt-\int_{t_0}^{t_n}C(t)dt \ge K \quad (17)$$

where: (t_0, t_n) - modelling time of functioning of TLS;
$P(t_0, t_n)$ - criterion of the integrated profit from TLS performance for the period of modelling time of TLS performance;
K - minimal value of integrated criterion of the TLS profit for the period of modelling time.

Integrated criterion of the revenue (Rev) of TLS performance for the period of modelling time of TLS performance can be presented as:

$$\mathrm{Re}v(t_0,t_n)=\int_{t_0}^{t_n}\mathrm{Re}v(t)dt \quad (18)$$

The integrated criterion of the expenses of TLS performance for the modelling time of TLS performance can be presented as:

$$C(t_0,t_n)=\int_{t_0}^{t_n}C(t)dt \quad (19)$$

In this paper we shall consider the problem of dynamic modelling of TLS stability in the feasible zone which looks like:

$$\begin{aligned}
&P(t_0,t_n)=\int_{t_0}^{t_n}R(t)dt-\int_{t_0}^{t_n}C(t,dt \ \ge \ K\\
&\sum_{t=t_0}^{t_n}\sum_{i=1}^{n}Q_{i,t}c_{i,j,t} \ \le \ s_j; \ j=1,2,\dots,n\\
&p^{\min}{}_{i,t} \ \le \ p_{i,t} \ \le \ p^{\max}{}_{i,t};\\
&Q^{\min}{}_{i,t} \ \le \ Q_{i,t} \ \le \ Q^{\max}{}_{i,t};\\
&C_{i,j,t} \ \le \ c_{i,j,t};\\
&i=1,2,\dots,n; \ t=t_o,\dots,t_n.
\end{aligned} \quad (20)$$

where: $P(t_0, t_n)$ - integrated profit of TLS at modelling time (t_0, t_n);
$P^{min}_{i,t}$ - minimal value of integrated profit of TLS at the moment of time t (set by conditions of modelling);
$P^{max}_{i,t}$ - maximal value of integrated profit of TLS at the moment of time t;
$Q_{i,t}$ - volume of production (services) of TLS sold (executed) at the moment of time t;
$Q^{min}_{i,t}$ – minimal volume of production (services) of TLS sold (executed) at the moment of time t (set by conditions of modelling);
$Q^{max}_{i,t}$ – maximal volume of production (services) of TLS sold (executed) at the moment of time t (set by conditions of modelling on the basis of information describing the real capacity of the market segment);
$C_{i,j,t}$ – price of a unit of production (service) of TLS sold (executed) at the moment of time t;
$c_{i,j,t}$ – ceiling price of a unit of production (services) of TLS sold (executed) at the moment of time t (set by conditions of modelling on the basis of information about the prices for similar production at the market);
R – amount of resources of TLS considered during modelling time;
t – modelling time;
t_0 – initial time of modelling TLS performance;
t_n – time of ending the modelling process.

Conditions (20) set limits for the integrated profit P changes during the period of modelling time t.

Taking into account the casual character of interaction of internal and external factors of the environment of TLS performance, the necessity arises to include the model of casual parameter w and to have an approximated distribution function. The condition (17) is transferred into (21):

$$P(t_0,t_n,w)=\int_{t_0}^{t_n} R(t,w)dt-\int_{t_0}^{t_n} C(t,w)dt \geq K \qquad (21)$$

where: w – stochastic parameter with a set distribution exerting influence on the TLS under investigation;
$P(t_0, t_n, w)$ – criterion of the integrated profit of TLS performance for the period of the modelling time t;

In this case the stochastic modelling of TLS stability during the modelling time of TLS performance is considered. The problem of stochastic modelling of TLS stability can be formulated as follows:

$$P(t_0,t_n)=E\{\int_{t_0}^{t_n} R(t,w)dt-\int_{t_0}^{t_n} C(t,w)dt\} \geq$$

$$\begin{aligned}
&\sum_{t=t_0}^{t_n}\sum_{i=1}^{n} Q_{i,t}c_{i,j,t} \leq s_j;\; j=1,2,...,n;\\
&p^{\min}{}_{i,t} \leq p_{i,t} \leq p^{\max}{}_{i,t};\\
&Q^{\min}{}_{i,t} \leq Q_{i,t} \leq Q^{\max}{}_{i,t};\\
&C_{i,j,t} \leq c_{i,j,t};\\
&i=1,2,...,n;\; t=t_o,...,t_n.
\end{aligned} \qquad (22)$$

The set of allowable optimum trajectories of functioning of TLS is defined by using the statistical method of bootstrapping and the method of dynamic programming by Bellman.

5. MAIN STAGES OF TLS STABILITY INVESTIGATION

Research of system can be divided into some main stages.

I. Stage. Logistic system description. Construction of model of interrelations between the participants of TLS. Main stages of investigation see in figure 3.

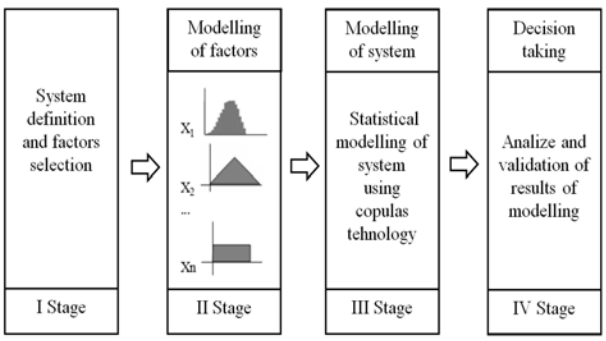

Figure 3: Main Stages of TLS Stability Investigation

II. Stage. Notification of the conditions of TLS financial stability and parameters to provide the TLS stability.

III. Stage. Assessment of feasible regions of changes for TLS parameters to provide the TLS stability, using statistical dynamic modelling, see figure 4.

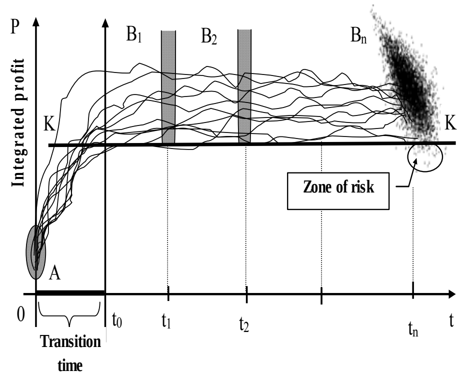

Figure 4: Feasible Regions of Changes for TLS Parameters to Provide the TLS Stability

TLS financial stability means that the trajectory of integrated criterion of TLS stability $J^{(t_i)}$ of system doesn't fall below the line K, see figure 5.

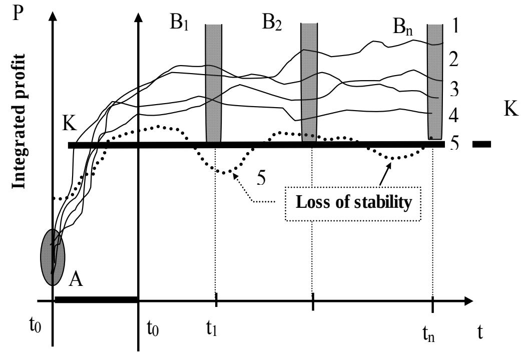

Figure 5: Illustration of the Stability of TLS

IV. Stage. Modelling of financial stability of TLS with financial reserve, using multidimensional statistical method Monte-Carlo with bootstrapping, see figure 6.

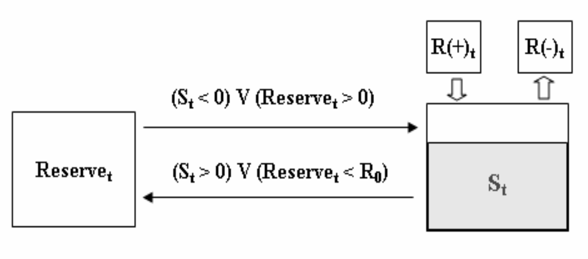

Figure 6: Use of financial reserves for maintaining the stability of TLS

The principal scheme of using of financial reserve for maintenance of TLS financial stability for every time period is shown in figure 7.

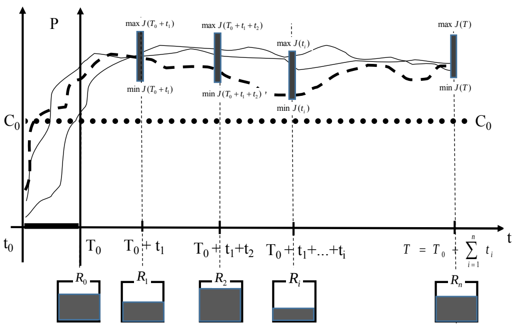

Figure 7: Use of Financial Reserves for Maintaining of TLS Stability

V. Stage. Assessment of feasible regions of changes of financial reserve in providing the stability of TLS.

CONCLUSION

The application of modelling is connected with the fact that frequently it is not possible to provide a definite analytical description of the behaviour of the economic system being investigated. When investigating the dynamic behaviour of the economic system, i.e. by making definite stochastic changes of parameters of the system under investigation, we frequently observe the existence of incidental factors affecting the character of the behaviour of the system. The modelling process of TLS stability is implemented using a set of alternative strategies of TLS performance applying the dynamic programming and bootstrapping method. The introduction of a set of alternative strategies supports stable functioning of TLS in the conditions of uncertainty. Bootstrapping is a powerful statistical tool for investigation the possible range of stability of investigated system.

By using dynamic programming and bootstrapping as well as the Monte Carlo method for modelling of TLS financial stability it has become possible:

1) to set alternative strategies of TLS performance;

3) to model TLS stability using multimodal and nonparametric technique;

2) to model the “risk zones” in which the financial stability of TLS has been distorted;

3) to identify the amount of the financial reserves required for TLS stability in the “risk zones”.

REFERENCES

Anderson, H. and Black, T., 1998. Multivariate data analysis. 7th edition, *Prentice-Hall International, Inc.* 816 p.

Cameron, A. C. and Trivedi, P. K., 2005. Micro Econometrics: Methods and Applications. *Cambridge University press, New York,* 327 p.

Chernick, M. R., 2008. Bootstrap Methods: A Guide for Practitioners and Researchers, Second Edition, *John Wiley & Sons, Inc.*, 369 p.

Efron, B., Tibshirani R. J., 1993. An Introduction to the Bootstrap. *New York: Chapman and Hall.*

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., 2008. Modelling of Stability of Economic Systems Using Benchmarking and Dynamic Programming. *X International Conference on Computer Modelling and Simulation EUROSIM/UKSim 2008.* pp.295-300. April 1-3, Cambridge, United Kingdom.

Jurenoks V., Didenko K., Jansons V., Investigation of Economic Systems using Modelling Methods with Copula. *The 11TH International Mediterranean and Latin American Modelling Multiconference HMS 2008*, pp. 1-6. September 17-19, Amantea, Italy.

Joe, H., 1997. Multivariate Models and Dependence Concepts. 1 edition, *Chapman and Hall/CRC, London,* 424 p.

Proctor S. K., 2004. Building Financial Models with Microsoft Excel: A Guide for Business Professionals. *John Wiley and Sons,* 384 p.

Sullivan, W. G., Wicks, E. M. and Luxhoj, J. T., 2005. Engineering Economy. *Prentice Hall Ptr.* 704 p.

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

AUTHORS BIOGRAPHIES

VLADIMIRS JANSONS was born in Daugavpils, Latvia and is a graduate of the University of Latvia. In 1983 he was awarded the doctoral degree in the mathematical science. The main field of research pursued is simulation and optimization of economic systems. 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. In 1987 was awarded the doctoral degree in the science of economics (Dr.oec.). The main field of research pursued is planning, simulation and optimization of economic processes and systems.
E-mail: vitalijs.jurenoks@rtu.lv.

KONSTANTINS DIDENKO was born in Jelgava, Latvia. 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. The main field of research pursued is planning and optimization of economic processes and systems.
E-mail: konstantins.didenko@rtu.lv.