STATISTICAL MODELLING OF FINANCIAL STABILITY OF LOGISTICS SYSTEM

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

Keywords: transport logistics system (TLS), identifying of weak spots, benchmarking, financial stability, statistical modelling, systems optimization

In this article the authors proceed with the research of the stability of transport logistics system (TLS) as a set of separate units providing the whole cycle of logistics operations when delivering cargoes from the consignor to the consignee. In the previous papers (see references) the authors presented the research of financial stability of logistics systems under conditions of uncertainty applying different methods of modelling, namely, statistical modelling – Monte Carlo method, dynamic programming, benchmarking as well as nonparametric methods of modelling. In this article the analysis of financial stability of the logistics system being investigated is made. And most attention is paid to modelling and analysis of the state of the required financial reserve of the logistics firm providing the financial stability of the whole logistics system on the example of delivering cargoes from the consignor to the consignee by a Latvian logistics firm (LF).

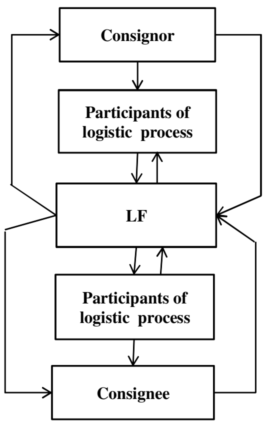

Figure 1: Structure of Transport Logistics System (TLS)

Technological and financial flows among the participants of logistics process as well as the impact of the factors of external and internal environment on the financial stability of TLS are analysed in this article.
By financial stability we understand the ability of all TLS participants to fulfil all the financial obligations undertaken with the view of ensuring complete continuous technological process in the terms agreed.
Applying the basic statements of the theory of constraints the authors analyse the impact of the factors of external and internal environment on the financial stability of the logistics chain and the process of weak points arising in the logistics chain of the financial system.

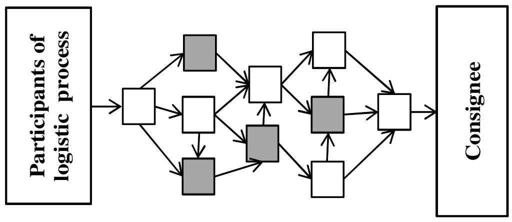

Figure 2: Illustration of Weak Points (Grey Squares) in the Transportation Logistics System (TLS)

1. GENERAL APPROACH AND THEORETICAL BASIS OF SOLUTION OF THE PROBLEM

The logistics process presents coherence and consistency of transport, technological and financial operations to be completed in the period of time when delivering the cargo from the consignor to the consignee. An important part of this process is finding the so called weak points of the logistics system, where deviations from the terms of contract occur due to certain reasons in the real time process. The deviations may comprise:
- deviations (changes) in certain transport and technological operations of TLS and, consequently, additional (not planned before) payments for completing these operations arise;
- deviations (changes) in the terms of making payments for the work completed by TLS participants;
- changes in the payment sums for the TLS transport and technological operations to be made due to fluctuations of the currency exchange rates during the

period of time when the financial operations were made among the TLS participants in different currencies;
- additional technological operations in the logistics process due to external and internal factors of TLS, namely:
- cargo control till the moment of moving the cargo away from the port;
- checking of cargo size in the port;
- customs control of cargo when crossing the national borders and completing other additional technological operations.

Taking as an example a Latvian logistics firm, we will analyze its financial flows with other TLS participants (Figure 3), where $\mathbf{S_{1,i}}$, $\mathbf{S_{2,i}}$ - the planned and actual amounts of receipts on the account of logistics firm (LF) from the **i-**th consignor of cargo, in USD, EUR, LVL, RUR and KZT;

$\mathbf{S_{3,j}}$, $\mathbf{S_{4,j}}$ - the planned and actual amounts of payment to be transferred from the account of LF to the **j-**th participant of TLS (modeled in accordance with contract terms), in USD, EUR, LVL, RUR and KZT;

$\mathbf{T_{1,i}}$, $\mathbf{T_{2,i}}$ - the planned and actual terms of receipt of payment from the **i-**th consignor of cargo on the account of logistics firm (LF);

$\mathbf{T_{3,j}}$,$\mathbf{T_{4,j}}$ - the planned and actual terms of payment of the account by LF to the **j-**th participant of TLS (modeled in accordance with contract terms).

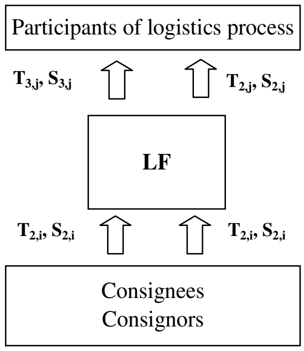

Figure 3: Financial Flows of TLS Participants

Let us also consider in a more detailed way the model of technological and financial operations of the logistics process provided by the Latvian logistics firm (Table 1, Figures 4, 5).

Table 1**:** Main Technological and Financial Operations of the Logistics Process

Logistics operation stage		Type of operation	Execution time of operation				Δ_t	Distribution of value Δt	S	Currency	Distribution of value S	Δ_S	Changes in currency exchange rates	Losses (-) and gains (+) due to currency exchange rates
Payments into LF account	Money transfers from LF account		t1	t2	t3	t4								
A		Contract execution start time						normal		USD	normal			
	B	Sea transportations						even		EUR/USD	even			
B*														
	C	Port operations						even		LVL	even			
	D	Insurance						normal		USD	even			
	E	Customs operations						even		EUR, RUR,KZT	even			
E*														
	F	Rail or road transportations						even		LVL	normal			
F*														
	G	Other operations								EUR, USD, RUR,KZT				
H		Final calculations												

The model of technological and financial operations of the logistics process (Table1) presents the process of cargo delivery from the consignor in the USA to the consignees in CIS countries (cargoes are delivered by sea and rail or road transport). Transaction costs are expressed in US dollars, EUR, LVL, RUR, KZT.

The information about the technological and financial operations of the logistics process to be performed is presented in Table 1. The operations of the logistics process to be performed are designated by symbols A, B, B*, D,... , F, F*, G, H. The financial flows, linked with making the financial calculations of separate stages of the logistics process according to the scheme presented in Figure 4, are divided into the incoming flows (increasing the current account of LF, such flows being designated by symbols A, B*, E*, F*, H), and also outgoing flows (transferred from the current account of LF to the other participants of the logistics process). These financial flows are designated by the symbols B, C, D, E, F, G (see Table 1).

The execution of all the above mentioned financial operations is limited by time t_1, t_2, t_3, t_4.

For the incoming flow A:
- t_1 – the moment of time of signing the contract about the cargo delivery between the Latvian logistics firm and the consignor (or the consignee) of the cargo in the amount $\mathbf{S_{1,i}}$;
- t_3 – the moment of time of advance payment transferred from the consignor (consignee) to the account of the logistics firm in the amount $\mathbf{S_{1,i}}$ ($t_1 = t_2$);
- t_4 – the moment of time of receipt of advance payment on the account of the Latvian logistics firm in the amount $\mathbf{S_{2,i}}$;
For the incoming financial flows (B^*, E^*, F^*, H), increasing the current account of LF the moments of time are the following:
- t_1 – the moment of time of presenting the bill to the consignor (consignee) of the cargo on the part of the Latvian logistics firm as payment for the technological operations of the logistics process completed at a certain stage in the amount $\mathbf{S_{1,i}}$ paid in advance by the Latvian logistics firm;
- t_2 – the moment of time of receipt by the consignor consignee) of the cargo the requirements (bills) on the part of the Latvian logistics firm about the payments settled and transferred from the account of the logistics firm for the technological operations in the amount $\mathbf{S_{1,i}}$;
- t_3 – the moment of time of paying the bill by the consignor (consignee) to the account of the Latvian logistics firm for completed technological operations according to the requirements received in the amount $\mathbf{S_{1,i}}$;
- t_4 – the moment of time of receipt of financial resources (money transfer) on the account of the Latvian logistics firm for completed technological operations according to the requirements received in the amount $\mathbf{S_{2,i}}$.
For the outgoing financial flow H:
- t_1 – the moment of time of presenting the final bill (balance/remaining amount) from the Latvian logistics firm to the consignor (consignee) in the amount $\mathbf{S_{1,i}}$;
- t_2 – the moment of time of receipt by the consignor (consignee) of the cargo the final bill (balance/remaining amount) on the part of the Latvian logistics firm in the amount $\mathbf{S_{1,i}}$;
- t_3 – the moment of time of payment of the final bill (balance/remaining amount) by the consignor (consignee) to the Latvian logistics firm in the amount $\mathbf{S_{1,i}}$;
- t_4 – the moment of time of receipt of financial resources (balance) on the account of the Latvian logistics firm in the amount $\mathbf{S_{2,i}}$.

For the outgoing financial flows (B, C, D, E, F, G) – operations paid from the account of LF to the other participants of the logistics process of LF the moments of time are the following:
- t_1 – the moment of time of completing the current technological operation of the logistics process by any participant of the logistics process and simultaneously the moment of time of presenting the bill to the Latvian logistics firm by another participant of the logistics process for payment of the works completed in the amount $\mathbf{S_{3,j}}$;
- t_2 – the moment of time of receipt of the bill by the logistics firm from another participant of the logistics process for payment of completed works in the amount of $\mathbf{S_{3,j}}$;
- t_3 – the moment of time of payment of the bill by the logistics firm received from another participant of the logistics process for the completed works in the amount $\mathbf{S_{3,j}}$;
- t_4 – the moment of time of transfer of financial resources on the account of another participant of the logistics process for the completed works in the amount $\mathbf{S_{4,j}}$.

By weak points in the financial stability of TLS we understand the violation (delay) of the payment terms among the participants of TLS, changes (overrun) of the contract (agreed) costs of the works to be completed by any of the participants of TLS, as well as deviations in the technological process of cargo delivery caused by the impact of internal and external factors under uncertainty conditions.

In the case of the Latvian logistics firm (LF) mentioned above the conditions of uncertainty are as follows:
a) time delays between scheduled (planned) and actual dates of receipt of payments on the account of logistics firm;
b) continuous changes of exchange rates (currency risks) while making currency transactions among the participants of TLS;
c) fluctuations of prices of energy resources (diesel fuel) during the cargo deliveries from the consignors to the consignees (Figures 4, 5 fluctuations of the currency exchange rates using the method B).

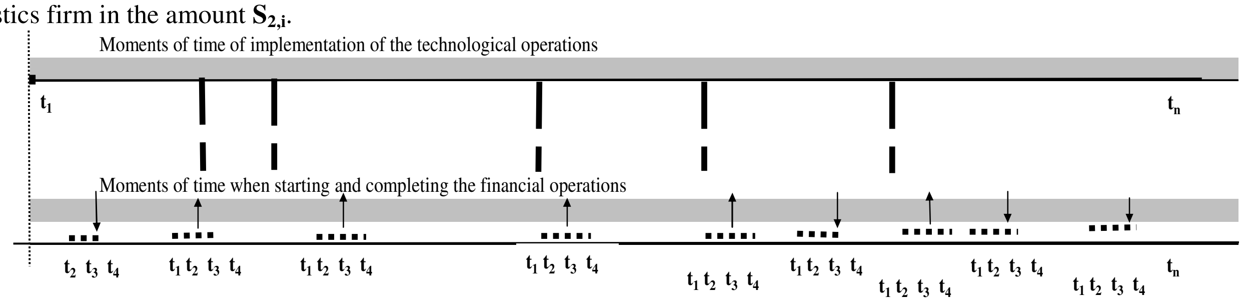

Figure 4: Model of Technological and Financial Operations of a Logistics Process to be Completed

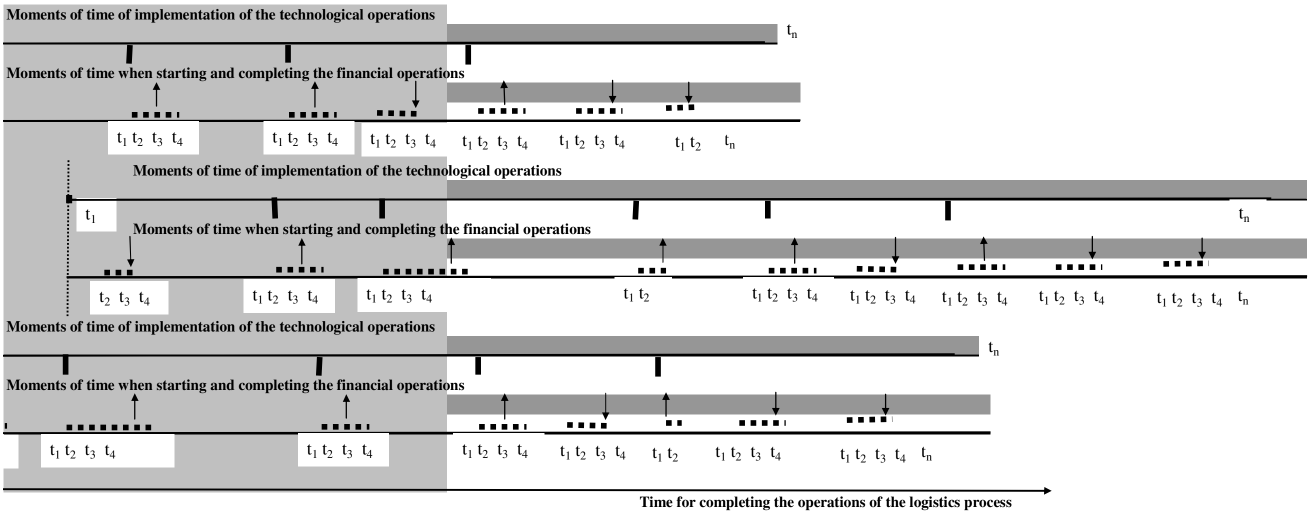

Figure 5: Model of Technological and Financial Operations of Several Logistics Processes to be Completed Simultaneously

Two methods for modelling the fluctuations of the currency exchange rates are considered in this article:
A method, using the empirical information about the fluctuations of the currency exchange rates;
B method, using the stochastic differential equation describing the fluctuations of the currency exchange rates.
The method A is described in a great detail in the research works of many authors (see references). Therefore, this research mainly concentrates on the process of modelling the fluctuations of the currency exchange rates by applying the method B.
B method presents the analysis of the impact of fluctuations in the currency exchange rates on the financial stability of the logistics firm. Therefore, the time delays between the planned and real terms of completing financial operations have also been modeled.
Let us consider the changes of the actual amount of the financial payment S_{t2} when compared to the planned amount of the financial payment S_{t1} when transferring from time t_1 and t_2 ($t_1 < t_2$).

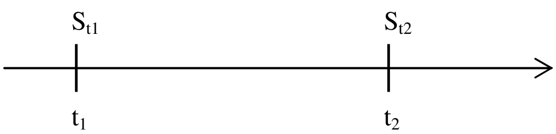

Figure 6: Changes in the Amount of the Financial Payment in the Period of Time t_1 to t_2

Modelling of the actual amount of the financial payment S_{t2} in the moment of time $t_1 < t_2$ is done by applying the correction coefficient K_{t1}:

$$K_{t_1} = \frac{S_{t_1}^{USD}}{S_{t_1}^{EUR}}, \tag{1}$$

where $S_{t_1}^{USD}$ - the amount of financial payment S_{t1} in the moment of time t_1 in US dollars;
$S_{t_1}^{EUR}$ - the amount of financial payment S_{t1} in the moment of time t_1 in euro.
The financial payments among the TLS participants are made in different currencies depending on the terms of contract and requirements of national legislations. For example, moving the cargo from the USA to Kazakhstan across the territory of Latvia and Russia, the financial payments are made using the following currencies: USD, EUR, LVL, RUR, and KZT. When transporting cargoes to other directions, transactions are also made using the national currencies of the states through the territories of which transportation of goods takes place.
The actual amount of the financial payment S_{t2} may be greater or smaller than the planned financial payment S_{t1}. The deviation (difference) ΔS between $S_{t_1}^{USD}$ and $S_{t_1}^{EUR}$ may be calculated using the formula:

$$\Delta S_{t_1,t_2,USD,EUR} = \frac{S_{t_2}^{EUR}}{K_{t_2}} - S_{t_1}^{USD}. \tag{2}$$

In the case of making the financial payments in different currencies at the moments of time t_1 and t_2 ($t_1<t_2$), the formula (2) is expressed in the following way:

$$\Delta S_{t_1,t_2,V_1,V_2} = S_{t_1}^{V_1}\left(\frac{1}{K_{t_1,V_1,V_2}} - \frac{1}{K_{t_2,V_1,V_2}}\right). \tag{3}$$

When $\Delta S_{t_1,t_2,V_1,V_2} > 0$, the actual amount of payment, made on the account of the logistics firm for the technological operation completed, exceeds the planned amount of the payment for the same operation which leads to an additional profit for the logistics firm and increases its financial stability. On the contrary, if $\Delta S_{t_1,t_2,V_1,V_2}$ < 0, the actual amount of the financial payment made on the account of the logistics firm for the technological operation completed would be less than the amount of the financial payment planned for the same operation and it will bring about losses, thus decreasing the financial stability of the logistics firm.

In the same way the changes of the currency exchange rates leave an impact on the payments made from the account of the logistics firm to the other TLS participants. In this case, if $\Delta S_{t_1,t_2,V_1,V_2}$ > 0, the amount of the actual financial payment made from the account of the logistics firm and transferred to another participant of the logistics process would be greater than the financial payment planned and it will lead to additional expenses of the logistics firm and decrease its financial stability. On the contrary, if $\Delta S_{t_1,t_2,V_1,V_2}$ < 0, the actual amount of the financial payment made from the account of the logistics firm for the technological operation completed would be less than the amount of the financial payment planned for the same operation and it will lead to gaining additional profit for the logistics firm and will increase its financial stability.

Changes of the value of $\Delta S_{t_1,t_2,V_1,V_2}$, leaving an impact on the financial stability of LF depend on the changes of the correlation of currency exchange rates V_1, V_2,..., V_n, which are applied when completing financial payments among the TLS participants. Therefore, the necessity arises to model the fluctuations of the currency exchange rates depending on the time of the logistics process.

2. MODELLING OF THE FLUCTUATIONS OF CURRENCY EXCHANGE RATES APPLYING STOCHASTIC DIFFERENTIAL EQUATION

The most suitable method for modelling the fluctuations of the currency exchange rates is the application of diffusion equation which is presented in the following way:

$$\frac{dS}{S} = \mu dt + \sigma dB, \qquad (4)$$

where μ - the parameter describing the constant deviations of the currency exchange rates;

σ - the parameter describing dispersion of the fluctuations of the currency exchange rates;

dB=Zdt – random value describing Viner process (white noise); value Z has normal distribution N(0;1).

From the equation (4) we may derive the equation (5).

$$S_{t+\Delta t} = S_t \cdot \exp(\mu \Delta t + \sigma \cdot Z \cdot \sqrt{\Delta t}), \qquad (5)$$

where S_t is the currency exchange rate at the moment of time t.

The results of modelling of the fluctuations of the currency exchange rates, (the initial value of the currency exchange rate on the axis Oy equals 1) applying the equation (5), are presented in Figure 7 (the unit of the change of time on the axis Ox is the value dt = 1/365).

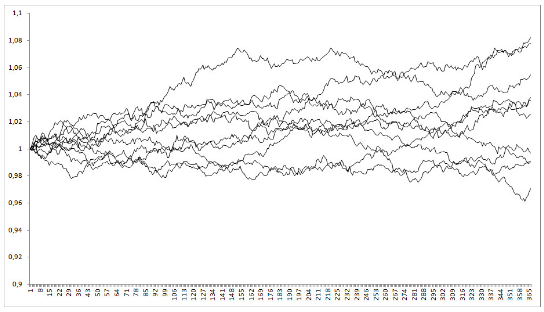

Figure 7: Results of tenfold modelling of fluctuations of currency exchange rates

In this case the fluctuations (changes) of the currency exchange rate may be well described with the help of lognormal distribution (see Figure 8).

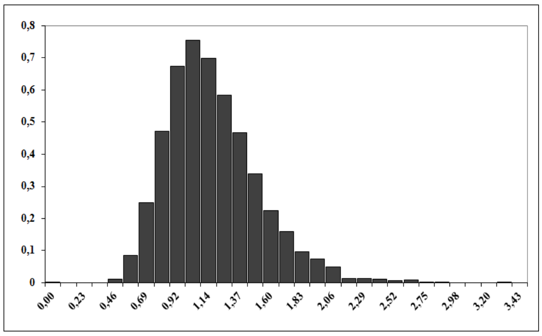

Figure 8: Histogram of Modelled Lognormal Distribution

For determining the parameters μ and σ the following equations were used:

$$\mu = \frac{Average\left[\ln\left(\frac{S_{t+\Delta t}}{S_t}\right)\right]}{\Delta t}, \qquad (6)$$

$$\sigma^2 = \frac{D\_emp\left[\ln\left(\frac{S_{t+\Delta t}}{S_t}\right)\right]}{\Delta t}, \qquad (7)$$

The authors in some other of their research papers (see references) have substantiated the necessity of building and utilizing the financial reserve of the logistics firm for ensuring (providing) the financial stability of the whole logistics system as such (see Figure 9).

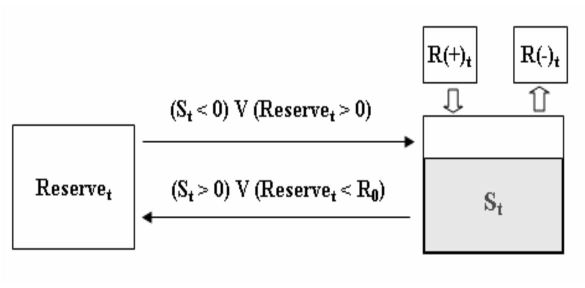

Figure 9: Use of Financial Reserves of Logistics Firm

where $\mathbf{S_t}$ – balance of LF with TLS participants at the moment of time **t**, in euro;
$\mathbf{R\ (+)_t}$ – receipts to the account of LF from the consignor's (consignee's) account at the moment of time **t,** in euro;
$\mathbf{R(-)_t}$ – actual amount of payment to be transferred from the account of LF to the other TLS participants at the moment of time **t**, in euro;
$\mathbf{Reserve_t}$ – current state (modelled) of financial reserves of LF at the moment of time **t**, in euro;
$\mathbf{R_0}$ – initial amount of financial reserves of LF, in euro.

CONCLUSION

The modelling process of economic system stability is implemented using a set of alternative strategies of realization of logistic processes. By using B method of modelling (described in the paper) becomes possible effectively to define weak points in the financial system of TLS, realise more effectively management of transport logistic process and enlarge the zone of stability of TLS by using the same volume of financial reserve of LF. The important research finding is the stochastic distribution of the financial reserve of LF by modelling and recommending efficient use of the financial reserves of LF with the aim to provide the financial stability of the transport logistics system (TLS) and evaluating the risk of exceeding the financial reserve of LF during the time of cargo transportation.
The theoretical and practical results obtained as a result of this research can be applied in practical activities of logistic companies.

REFERENCES

Jurenoks,V., Jansons, V., Didenko, K., 2007. Modelling of financial stability in logistics in conditions of uncertainty. *21-st European Conference on Modelling and Simulation*, pp. 30-36. June 4–6, Prague, Czech Republic.

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,* pp. 295-300. 1-3 April, Cambridge, United Kingdom.

Jurenoks,V., Jansons,V., Didenko,K., 2008. Application of Benchmarking and Index Method in Research of Economic Systems. *X International Scientific Conference "Management and Sustainable Development*", pp. 4-10. March 21-23, Yundola, Bulgaria.

Jurenoks,V., Jansons,V.,Didenko,K.,2009. Investigation of Economic Systems using Modelling Methods with Copula. *XI International Conference on Computer Modelling and Simulation UKSim 2009,* pp. 311- 316. March 25-27, Cambridge, United Kingdom.

Cameron, Colin. A. and Trivedi, Pravin. K., 2006. Micro econometrics: methods and applications. Cambridge University press, 1034 p.

Fitzgerald, John and Gorm, Peter Larsen. 1998. Modelling Systems: Practical Tools and Techniques for Software Development. Cambridge University Press, 288 p.

Dettmer, William H. Goldratt's. 1997: Theory of Constraints: A Systems Approach to Continuous Improvement, Printed in USA, 378 p.

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. 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, 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.). 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 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. The main field of research pursued is planning and optimization of economic processes and systems.
E-mail: konstantins.didenko@rtu.lv.