INVESTIGATION OF FINANCIAL FLOWS IN LOGISTICS USING MULTIVARIATE STATISTICAL MODELLING METHODS

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ABSTRACT
Multivariate statistical modelling is used to investigate complex economic systems in cases when random values are characterized as arbitrary (nonparametric). When modelling the financial stability of the logistics firm (LF) and transport logistics system (TLS) in general, it is most essential to detect the statistical character of the interrelationships among all participants (subsystems) of TLS. In real systems these interrelationships are correlated. In this case when modelling the financial stability of TLS and the statistical character of interrelationships it would be rational to use copula as a tool of multivariate statistics.

Use of the copula and Monte-Carlo methods make it possible to approximate joint distribution of the significant factors of TLS and to estimate the behaviour of financial stability of the investigated TLS in relation to probabilities and therefore its expected values which is impossible to be achieved by classical statistical methods.

Keywords: transport logistics system, scan statistics, weak points, multivariate statistical modelling, financial stability

INTRODUCTION
Multivariate statistics is a form of statistical analysis of many statistical correlated variables. Application of methods of multidimensional statistics allows defining relations between the variables included in the model and also their impact on the problem studied. One of the multivariate statistics methods used in this article for modelling of financial flows of logistics process is the copula method. When establishing the distribution of parameters describing the behaviour of investigated TLS from empirical information most frequently it is insufficient for credible assessment of parameters offered by the function of distribution. In these cases it is necessary to use nonparametric modelling methods, given distribution of incidental values and then modelling of appropriated distribution. (Cameron and Trivedi 2006). Figure 1 presents the scheme of interrelationship of TLS subsystems in 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 different currencies

(US dollars, EUR, LVL, RUR, and KZT).

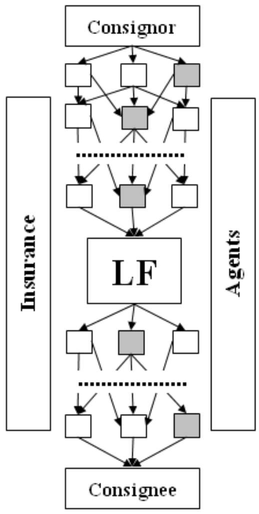

Figure 1: Scheme of Interrelationship of TLS Subsystems in the Process of Cargo Deliveries from the Consignor to the Consignee

The financial stability of TLS is the capability of all participants of TLS to implement their financial liabilities in full on the timeframe agreed upon in the contract.
Modelling of financial stability is directed towards defining the value of the "zones of risk" or “system weak points” when the TLS for satisfying financial liabilities should use financial reserves, as well as for finding the point of first time of positiveness of the financial flow. 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 (Jurenoks, Jansons, Didenko, 2009). Modelling is frequently associated with the factor of uncertainty (or risk), description of which goes outside the confines of the traditional statistical modelling, which, in its turn, complicates the modelling process (Jurenoks, Jansons, Didenko 2008).

Thus, the authors using multivariate statistical modelling investigate the impact of the factors of TLS subsystems on the financial stability of TLS in general. The main factors considered are:

- deviations of the actual timing of payments on the contract terms (payments delayed);
- deviation of actual payments from the contract amounts;
- change in the exchange rate affecting the real value of payments;
- energy price fluctuations, in particular, for diesel fuel.

The financial reserves of the TLS are used for ensuring the limited production resources in the volume required for the TLS performance. The model of using of financial reserves for maintenance the financial stability of TLS is presented in Figure 2 (Jurenoks, Jansons, Didenko 2007).

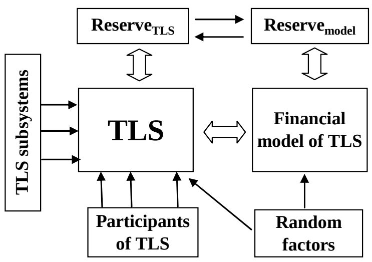

Figure 2: Model of Using Financial Reserves for Maintenance of TLS Financial Stability

Scan statistics as an instrument of research of statistical dynamics of the development of the object under investigation in space and time has been used (Jurenoks, Jansons, Didenko 2008). Research is made of statistics of weak points of the financial system in the logistics process. The methodology of research of weak points of the financial system in logistics process in space and time enables to detect the necessity of using the financial reserves (**Reserve $_{TLS}$**) for maintenance of the financial stability of TLS.

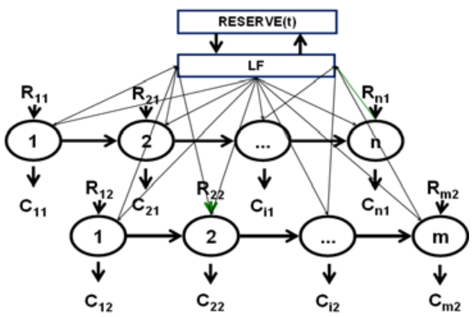

Figure 3: Financial Structure of TLS

where: R_{ij} and C_{ij} are incoming and outgoing payments. In the article (Jansons, Jurenoks, Didenko 2010) on the research subject the authors described the results of the study of the financial structure of the logistics process. The scheme of financial structure of the logistics system TLS is shown in Figure 3.

In this article the multivariate statistical modelling of the financial stability of TLS is presented. The mechanism of optimization of financial reserves of the logistics firm to compensate the negative impact of factors of the system (TLS) is studied.

The main objectives of the article are:

- to apply multivariate statistical modelling methods (copula methods, scan statistics, detection of weak points) for investigation of the financial stability of TLS;
- to model financial interrelations between TLS subsystems in dynamics;
- to investigate the financial losses of TLS and detect the weak points of TLS caused by accidental factors;
- to investigate the behaviour and statistical distribution of the level of financial losses of TLS.

Most attention is paid to the analysis of intervals of change of the required financial reserve of the logistics firm providing the stability of TLS on the whole.

1. DESCRIPTION OF THE SYSTEM

The model of technological and financial operations of the logistics process (Table 1) 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 3, are divided into 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 $S_{1,i}$;
- t_3 – the moment of time of advance payment transferred from the consignor (consignee) to the account of the logistics firm in the amount $S_{1,i}$ ($t_1 = t_2$);
- t_4 – the moment of time of receipt of advance payment on the account of the Latvian logistics firm in the amount $S_{2,i}$;

For the incoming financial flows (B*, E*, F*, H), increasing the current account of LF the moments of time are the following:

Table 1: Implementation of Technological and Financial Operations of the Logistics Process in Time

Directions — 1st route - USA - Kazakhstan

Type of operation	Logistics operation stage: Incoming payments	Logistics operation stage: Outgoing payments	t	S	Currency (C)	Δ_t	Δ_S
Contract execution start time	A		$t1_1$	$S1_A$_contract	USD	-	-
			$t3_1$	$S2_A$_accepted	USD	-	X
			$t4_1$	$S2_A$_received	USD	X	X
Sea transportation		B	$t1_1$	$S3_B$_bill	USD		-
			$t2_1$	$S3_B$_bill received	USD	X	-
			$t3_1$	$S4_B$_accepted	USD	X	X
			$t4_1$	$S4_B$_paid	USD	X	X
Next incoming payment	B*		$t1_1$	$S1_{B*}$_bill	LVL	-	-
			$t2_1$	$S1_{B*}$_bill received	LVL	-	-
			$t3_1$	$S1_{B*}$_accepted	LVL	X	
			$t4_1$	$S2_{B*}$_received	LVL	X	X
Port operation		C	$t1_1$	$S3_C$_bill	USD		-
			$t2_1$	$S3_C$_bill received	USD	X	-
			$t3_1$	$S4_C$_accepted	USD	X	X
			$t4_1$	$S4_C$_paid	USD	X	X
Insurance		D	$t1_1$	$S3_D$_bill	LVL	-	-
			$t2_1$	$S3_D$_bill received	LVL	X	-
			$t3_1$	$S4_D$_accepted	LVL	X	-
			$t4_1$	$S4_D$_paid	LVL	X	-
Custom operations		E	$t1_1$	$S3_E$_bill	LVL	-	-
			$t2_1$	$S3_E$_bill received	LVL	-	-
			$t3_1$	$S4_E$_accepted	LVL	X	X
			$t4_1$	$S4_E$_paid	LVL	X	X
Next incoming payment	E*		$t1_1$	$S1_{E*}$_bill	USD	-	-
			$t2_1$	$S1_{E*}$_bill received	USD	-	-
			$t3_1$	$S1_{E*}$_accepted	USD	X	-
			$t4_1$	$S2_{E*}$_received	USD	X	X
Rail or road transportation		F	$t1_1$	$S3_F$_bill	RUR	-	-
			$t2_1$	$S3_F$_bill received	RUR	-	-
			$t3_1$	$S4_F$_accepted	RUR	X	X
			$t4_1$	$S4_F$_paid	RUR	X	X
Next incoming payment	F*		$t1_1$	$S1_{F*}$_bill	USD	-	-
			$t2_1$	$S1_{F*}$_bill received	USD	-	-
			$t3_1$	$S1_{F*}$_accepted	USD	-	-
			$t4_1$	$S2_{F*}$_received	USD	-	-
Other operations		G	$t1_1$	$S3_G$_bill	KZH	-	-
			$t2_1$	$S3_G$_bill received	KZH	X	-
			$t3_1$	$S4_G$_accepted	KZH	X	X
			$t4_1$	$S4_G$_paid	KZH	X	X
Final calculations	H		$t1_1$	$S1_H$_bill	USD	-	-
			$t2_1$	$S1_H$_bill received	USD	-	-
			$t3_1$	$S1_H$_accepted	USD	X	X
			$t4_1$	$S2_H$_received	USD	X	X

Directions — N th route - USA - Kazakhstan

Incoming	Outgoing	t	S	C	Δ_t	Δ_S
A		$t1_N$	$S1_A$_contract	USD	-	-
		$t3_N$	$S2_A$_accepted	USD	-	-
		$t4_N$	$S2_A$_received	USD	X	X
	B	$t1_N$	$S3_B$_bill	USD		-
		$t2_N$	$S3_B$_bill received	USD		-
		$t3_N$	$S4_B$_accepted	USD	X	X
		$t4_N$	$S4_B$_paid	USD	X	X
B*		$t1_N$	$S1_{B*}$_bill	LVL	-	-
		$t2_N$	$S1_{B*}$_bill received	LVL	-	-
		$t3_N$	$S1_{B*}$_accepted	LVL	X	X
		$t4_N$	$S2_{B*}$_received	LVL	X	X
	C	$t1_N$	$S3_C$_bill	USD		-
		$t2_N$	$S3_C$_bill received	USD	-	-
		$t3_N$	$S4_C$_accepted	USD	X	X
		$t4_N$	$S4_C$_paid	USD	X	X
	D	$t1_N$	$S3_D$_bill	LVL	-	-
		$t2_N$	$S3_D$_bill received	LVL	X	-
		$t3_N$	$S4_D$_accepted	LVL	X	X
		$t4_N$	$S4_D$_paid	LVL	X	X
	E	$t1_N$	$S3_E$_bill	LVL	-	-
		$t2_N$	$S3_E$_bill received	LVL	-	-
		$t3_N$	$S4_E$_accepted	LVL	X	X
		$t4_N$	$S4_E$_paid	LVL	X	X
E*		$t1_N$	$S1_{E*}$_bill	USD	-	-
		$t2_N$	$S1_{E*}$_bill received	USD	-	-
		$t3_N$	$S1_{E*}$_accepted	USD	X	-
		$t4_N$	$S2_{E*}$_received	USD	X	X
	F	$t1_N$	$S3_F$_bill	RUR	-	-
		$t2_N$	$S3_F$_bill received	RUR	-	-
		$t3_N$	$S4_F$_accepted	RUR	X	X
		$t4_N$	$S4_F$_paid	RUR	X	X
F*		$t1_N$	$S1_{F*}$_bill	USD	-	-
		$t2_N$	$S1_{F*}$_bill received	USD	-	-
		$t3_N$	$S1_{F*}$_accepted	USD	X	X
		$t4_N$	$S2_{F*}$_received	USD	X	X
	G	$t1_N$	$S3_G$_bill	KZH	X	X
		$t2_N$	$S3_G$_bill received	KZH	X	-
		$t3_N$	$S4_G$_accepted	KZH	X	X
		$t4_N$	$S4_G$_paid	KZH	X	X
H		$t1_N$	$S1_H$_bill	USD	-	-
		$t2_N$	$S1_H$_bill received	USD	-	-
		$t3_N$	$S1_H$_accepted	USD	X	X
		$t4_N$	$S2_H$_received	USD	X	X

- 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 S1,i paid in advance by the Latvian logistics firm;
- t_2 – the moment of time of receipt by the consignor consignee) of the cargo 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 $S_{1,i}$;
- 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 $S_{1,i}$;
- 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 $S_{2,i}$.

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 $S_{1,i}$;
- 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 $S_{1,i}$;
- 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 $S_{1,i}$;
- t_4 – the moment of time of receipt of financial resources (balance) on the account of the Latvian logistics firm in the amount $S_{2,i}$.

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 $S_{3,j}$;
- 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 $S_{3,j}$;
- 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 $S_{3,j}$;
- 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 $S_{4,j}$.

2. DETECTION OF WEAK POINTS IN THE SYSTEM

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.

Figure 4 presents the moments of the possible emergence of weak points in the logistics process. In Table 1 the symbol X represents the periods of time during which the delays of technological or financial flows of the logistics process may occur that, in turn, may cause the emergence of weak points in the logistics system in general.

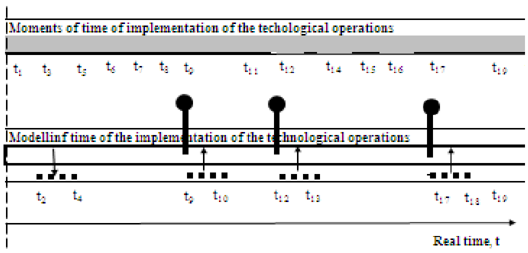

Figure 4: Scheme of Detection of Weak Points

3. INVESTIGATION OF FINANCIAL FLOWS USING THE MONTE-CARLO METHOD FOR MODELLING

When modelling the financial flows in the logistics process aimed at identifying the weak points the authors have used the Monte-Carlo method. Besides, it is necessary to model the following random values as well:

- t_{1i}, t_{2i}, t_{3i}, t_{4i}, where i=1, 2, …, N (see Table 1).

The delay time of technological and financial operations of the logistics process and, namely:

- S_{1i}, $S_{2,i}$, $S_{3,i}$, $S_{4,i}$ – planned (contract) and actual amounts of incoming and outgoing payments of the logictics firm;
- $\Delta S_i^{Incoming}$, $\Delta S_i^{Outgoing}$ – difference of amounts received to the account of LF and paid from the account of LF (formulas 1 and 2):

$$\Delta S_i^{Incoming} = S_{1i} - S_{2i}, \qquad (1)$$

$$\Delta S_i^{Outgoing} = S_{3,i} - S_{4,i}, \quad (2)$$

where:
- r_{t1} – currency exchange rate at the time moment t_1;
- r_{t3} – currency exchange rate at the time moment t_3;
- p_{t1} – price of fuel at the time moment t_1;
- p_{t3} – price of fuel at the time moment t_3.

The functional model of financial losses of TLS is presented in (3)

$$F = f(r_{t1}, r_{t3}, p_{t1}, p_{t3}, t_1, t_2, t_3, t_4, S_{1i}, S_{2i}, S_{3i}, S_{4i}, \Delta S_i^{Incoming}, \Delta S_i^{Outgoing}, N), \quad (3)$$

where: N – number of routes.
Graphical illustration of interaction of values S_{1i}, $S_{2,i}$, $S_{3,i}$, $S_{4,i}$, r_{t1}, r_{t3}, p_{t1}, p_{t3} in the interval of time t_1 и t_3 are given in Figure 5.

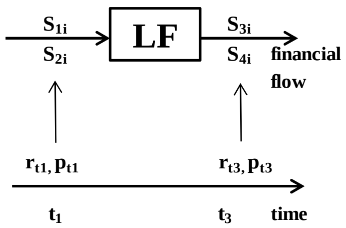

Figure 5: Interaction of Values S_{1i}, $S_{2,i}$, $S_{3,i}$, $S_{4,i}$, r_{t1}, r_{t3}, p_{t1}, p_{t3} in the Interval of Time t_1 and t_3

Let us consider the changes of the actual amount of the financial payment S_{t3} when compared to the planned amount of the financial payment S_{t1} when transferring from time t_1 and t_3 ($t_1 < t_3$).
Modelling of the actual amount of the financial payment S_{t3} in the moment of time $t_3 > t_1$ is done by applying the correction coefficient $K_{t1,t3}$

$$K_{t_1,t_3} = \frac{r_{t_1}}{r_{t_3}}. \quad (4)$$

The value of parameters r_{t1} и r_{t3} by currency types are taken from the statistical sources of information.
According to the scheme (Figure 5) the actual amount of the financial payment S_{t3} may be greater or smaller than the planned financial payment $S_{t1.}$ The deviation (difference) $\Delta S_{t1i,t3i}$ between $S_{t1,i}$ and $S_{t3,i}$ may be calculated using the formula

$$\Delta S_{t_1,t_3} = S_{1i} \cdot \left(\frac{r_{t_3}}{r_{t_1}} - 1 \right). \quad (5)$$

When $\Delta S_{t1,\,t3} > 0$, 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 $\Delta S_{t1,\,t3} < 0$, 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.

Changes of the value of $\Delta S_{t1,\,t3}$, leaving an impact on the financial stability of LF depend on the currency exchange rates 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. The real currency exchange rate dynamics for the time period from May 13 2010 to 29 April 2011 is presented in Figure 6.

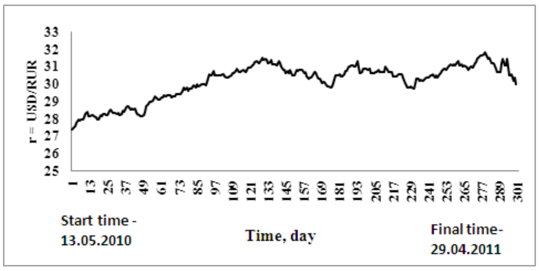

Figure 6: Currency Exchange Rate USD/RUR Dynamics from May 13 2010 to 29 April 2011

During modelling the authors alongside with the real values of parameter r (Figure 6) used the results of statistical modelling where stochastic differential equation was applied (Jansons, Jurenoks, Didenko 2010).
When modelling the delay time of completion of technological and/or financial operations of the logistics process Table 2 is used where:
A - is the minimum delay time of incoming payments to the account of the logistics firm (S_{1i}, $S_{2,i}$);
B – is the maximum delay time of incoming payments to the account of the logistics firm (S_{1i}, $S_{2,i}$);
C – is the minimum delay time of outgoing payments from the account of the logistics firm ($S_{3,i}$, $S_{4,i}$);
D – is the maximum delay time of outgoing payments from the account of the logistics firm ($S_{3,i}$, $S_{4,i}$) – see Tables 2,3 and 4.

Table 2: Intervals of Time Delays of Incoming and Outgoing Payments

	Incoming payment	Outgoing payment
delay_min =	A	C
delay_max =	B	D

For modelling the delay time of incoming and outgoing payments two basic uniform U(a, b) and normal distributions N(μ, σ) were used with parameters:

for uniform distribution a = A and b = B;

for normal distribution μ = (A+B)/2 and σ = (A – B)/6. The empiric table of values of the given values in the period of time starting from 13 May 2010 to 29 April 2011 was used for modelling values of $\Delta S_i^{Incoming}$, $\Delta S_i^{Outgoing}$.

Table 3: Extract from the Table of Frequency Distribution of Incoming Payment Values on the Account of LF and Outgoing Payment Values from the Account of LF

p	Bin	f
0.00120	800	1
0.00120	1100	1
0.00120	1500	1
………………………………		
0.08043	3400	67
0.20168	2200	168
0.63625	1100	530

4. RESULTS OF MODELLING

Graphical illustration of the state of balance during the modelling time from 13 May 2010 to 29 April 2011 is presented in Figure 7.

Figure 7: Dynamics of Modelled Balance of LF

When modelling the routes of cargo transportation applying the currency exchange rate dynamics from May 13 2010 to 29 April 2011 and values of parameters A, B, C, D (see Tables 2, 3 and 4).

Table 4: Modelled Intervals for Time Delays of Incoming and Outgoing Payments

	Income	Payment
delay_min =	7	3
delay_max =	30	20

the following distribution of possible losses for LF was obtained due to fluctuations of the currency exchange rate (Figure 8).

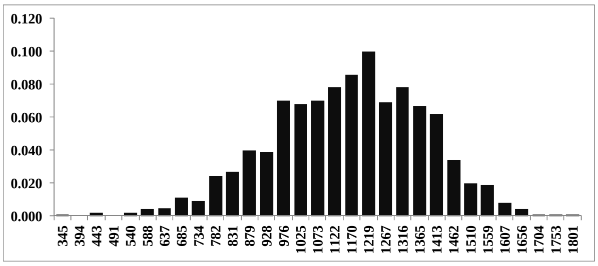

Figure 8: Histogram of Modelled Losses of LF

The distribution obtained is characteristic for describing all of the 27 routes of cargo transportations to be analysed. The results of the research may form the basis for calculation of possible risks and losses of LF and other participants of the logistics process.

CONCLUSION

The article shows the possibilities for applying the multivariate statistical modelling method for investigation of financial stability of TLS, in particular modelling the emergence of weak points in the logistics system. Impact of changes of the factors in the model is analysed, namely, impact of currency exchange rate on changes of the state of financial stability of LF and TLS in general. The research subject is the total set of routes of cargo transportation from the consignors to consignees. The authors modelled the impact of financial and organisational factors on the changes of financial and organisational stability of TLS.

The application of multivariate statistical method for modelling activity of TLS allows:

1) modelling of TLS stability using multimodal and nonparametric technique;

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

3) optimization of the process of TLS functioning.

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