MODELLING OF LOGISTICS SERVICE COSTS BY MEANS OF NONPARAMETRIC METHODS

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ABSTRACT

The main objectives of the research are:
1. To combine the modelling process with real information describing the implementation of the logistic process in real time.
2. To consider the non-linear dependences of the factors of the model.
3. To construct the logistic process in the online regime.
Simulation is one of the most widespread methods of research of economic objects and systems. The parametric method of modelling is the most frequently used method to model incidental multivariate distribution values in simulation. In this case it is necessary to establish parameters of common distribution of incidental values characterizing the factors under consideration. Usually this is done by means of evaluation of parameters of multivariate distribution, i.e. by establishing the most suitable distribution (copula), deriving from the available empirical data. This approach will not be justified when establishing the value of cargo delivery price from the point of dispatch to the point of destination $\mathbf{P}_{delivery}$, since empirical information is frequently insufficient for credible assessment of parameters offered by the distribution function. For resolving the particular problem it is necessary to use nonparametric modelling methods. Besides distribution parameters of incidental values are established based on nonparametric estimates of these values.

GENERAL APPROACH AND THEORETICAL BASIS OF SOLUTION OF THE PROBLEM

The aim of delivery logistics is movement of cargoes from the sites of purchasing of the goods to the point of destination and the point of transfer of the goods to the authorised consignee. Presently, participants of the logistics process are specialised logistics firms offering consignors and consignees a whole range of specialised services, i.e.:

- cargo forwarding in the port;
- handling customs clearance documentation;
- delivery of goods from the consignor to the nominated place of destination;
- dealing with transportation firms;
- tracing of cargoes that are being transported;
- cargo insurance;
- other kinds of logistics services.

Delivery of transit cargoes transported through the territory of Latvia is usually carried out by the following two modes of transportation:

- water and rail transport, and
- water and road transport.

Figure 1 presents a scheme of cargo flow directions offered by one of the logistics firms based in Latvia.

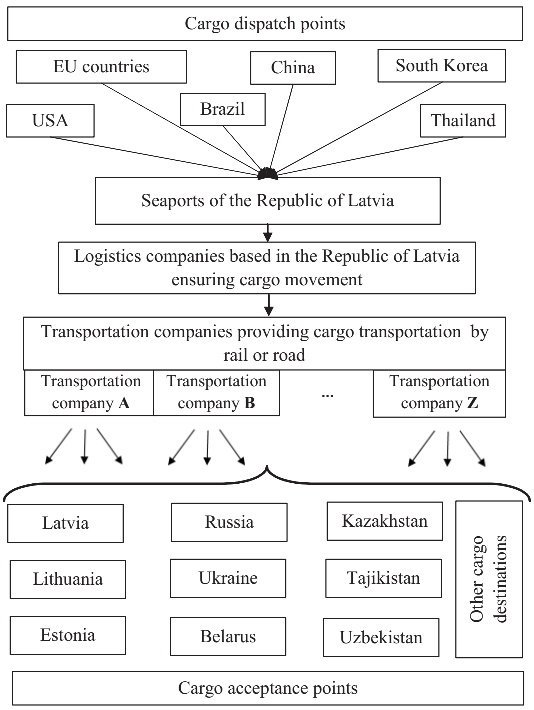

Figure 1: Scheme of Cargo Flow Directions serviced by one of the Logistics Companies based in Latvia

Organisation of logistics processes requires optimisation of cargo transportation time and cost parameters. At the same time, a problem arises to establish the agreement price for the delivery of cargo from the point of dispatch to the point of destination $\mathbf{P}_{delivery}$.

The scheme of interaction of participants of the logistics process and formation of the price of delivery $\mathbf{P}_{delivery}$ is presented in figure 2.

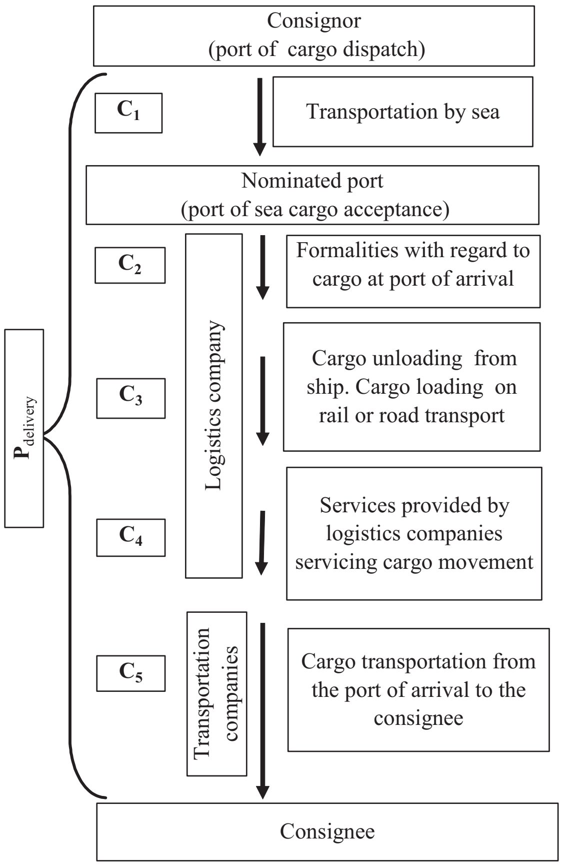

Figure 2: Scheme of Interaction of Participants of the Logistics Process and Formation of Delivery Price $\mathbf{P}_{delivery}$

According to figure 2, the cargo delivery price from the point of dispatch to the point of destination $\mathbf{P}_{delivery}$ is a complex value, incorporating the price of separate jobs and services performed in the process of cargo movement from the consignor to the consignee.

Based on the scheme presented in figure 2 the value of $\mathbf{P}_{delivery}$ can be calculated as follows:

$$P_{deliv} = C_1 + C_2 + C_3 + C_4 + C_5 \qquad (1)$$

where: $\mathbf{C_1}$ – cost of transportation of one loaded container from the port of loading to the port of discharge (unloading) (a port in the Republic of Latvia);

$\mathbf{C_2}$ – the value of customs duties and charges and other compulsory payments for moving the cargo on the territory of the Republic of Latvia;

$\mathbf{C_3}$ – cost of cargo handling (loading-unloading operations) in the port;

$\mathbf{C_4}$ – cost of services of the logistics firm ensuring cargo delivery from the consignor to the consignee;

$\mathbf{C_5}$ – cost of delivery of one loaded container from the port of discharge (unloading) to the port of destination and transfer of cargo to the consignee.

It is logical to conclude that the value of $\mathbf{P}_{delivery,}$ as well as the value of separate components forming the said value ($\mathbf{C_1}$, $\mathbf{C_2}$,…, $\mathbf{C_5}$), depends on a big number of factors characterizing the particular cargo and its terms of delivery.

Table 1 presents factors that affect the changes in the value of $\mathbf{P}_{delivery}$.

Table 1: Impact of Factors Characterising Cargo and Cargo Delivery Terms on $\mathbf{P}_{delivery}$

	Factors characterizing cargo and cargo delivery terms affecting delivery price $\mathbf{P}_{delivery}$							
	D_1	D_2	B	T	W	Q	H	Other factors
C_1	x		x	x		x	x	x
C_2					x		x	x
C_3					x	x	x	x
C_4				x	x			x
C_5		x	x		x	x	x	x
$P_{delivery}$	x	x	x	x	x	x	x	x

where: $\mathbf{D_1}$ – distance of cargo transportation by sea;
$\mathbf{D_2}$ – distance of cargo transportation by rail or road;
B – price of 1 US gallon of diesel fuel used by transportation vehicles when transporting cargo;
T – urgent deliveries of goods;
W – cargo weight transported in one container. Standard cargo weight transported in one 20` container constitutes no more than 18t. Cargo transportation in such a container, irrespective of cargo weight, is provided at fixed rates.
If cargo weight in the container exceeds 18t, cargo transportation is performed at contractual prices.
Q – type of equipment used for cargo transportation (20` or 40` steel dry cargo containers).

The dimensions of a 20` steel dry cargo container are:

	outside dimensions	inside dimensions
length	6.06m	5.90m
width	2.44m	2.35m
height	2.59m	2.39m.

The dimensions of a 40` steel dry cargo container are:

	outside dimensions	inside dimensions
length	12.19m	12.03m
width	2.44m	2.35m
height	2.59m	2.39m.

H – cargo hazard risk, according to the IMO (International Maritime Organization) classification.

The information presented in table 1 allows presenting a set of parameters affecting the cargo delivery price $\mathbf{P}_{delivery}$ from the point of dispatch of cargo to the point of destination. In a general case, the value of $\mathbf{P}_{delivery}$ can be presented as a function of a range of variables (factors characterising the particular cargo and its terms of delivery), namely:

$$P_{deliv} = f(D_1, D_2, B, T, W, Q, H, ..., Y) \quad (2)$$

where **Y** – other factors characterising the particular cargo to be transported and its terms of delivery.

In most cases, when modelling logistics problems, parametric methods of modelling are used, i.e., it is assumed that the laws of distribution of incidental values characterising the logistics process are known.
For evaluating the parameters of distribution the available empirical information is used.
If the relations between separate components forming the model are comparatively simple and can be accurately described, the required information can be obtained by using analytical methods.
However, most of the economic processes and systems are complex entities, consisting of a great number of interrelated sub-systems (which, in their turn, also are complex objects and require a detailed study) and are changing their positions in space and time.

In Latvia, taking into account the comparatively short history of operation of logistics firms, the amount of empirical information characterising the process of formation of $\mathbf{P}_{delivery}$ is insufficient for establishing the dependence of $\mathbf{P}_{delivery}$ on the factors characterising cargo and terms of delivery (see table 1 and formula 2).
For researching such economic systems (e.g., logistics problem) it is impossible to create an appropriate effective model by applying analytical methods. In such cases it is necessary to use simulation methods in combination with nonparametric methods.

Simulation is usually applied for researching economic processes and systems. Such factors are called incidental variables or incidental values, and their behaviour is described by means of common probability distribution functions.

Simulation without parameterisation may be used for tackling a wide range of economic problems (logistics, design and analysis of industrial systems, stock management, balancing of production capacities, allocation and optimisation of investment funds, optimisation of service flows etc.). Nonparametric methods of modelling are a way how to maximally use the existing empirical information for evaluating dependence (2).
In the simplest case, distribution of each incidental value may be represented by means of a nonparametric method – a block chart.

For example, figure 3 shows, how, derived from the block charts of distribution of two incidental values – factors $\mathbf{X}_1$ and $\mathbf{X}_2$, it is possible to model a bivariate common distribution considering the dependence between the factors.

The technique of nonparametric modelling is sufficiently thoroughly described in many books and articles devoted to such a mathematical object as copula.

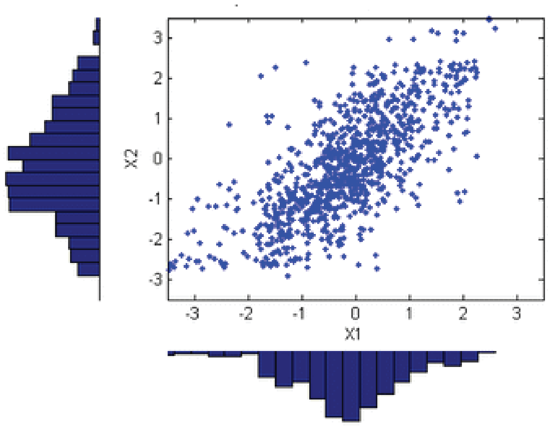

Figure 3: Example illustrating the Process of Modelling of Bivariate Incidental Value, based on Nonparametric Evaluation of their Distribution – Histogram

Discrete distribution is used for incidental factors characterising the logistics process in nonparametric modelling, represented by histogram and correlation dependences. The histogram represents marginal distributions for constructing a copula, presenting a common distribution of factors.
The nonparametric method proposed by Genest and Rivest [3], described also by Frees and Valdez [2], has been used for modelling the dependences between the factors, for example, for two random factors **X** and **Y**.

The estimation of θ from the observed value of Kendall's τ has been chosen for constructing a copula.
Kendall's τ can be established by its definition. If data arrays do not contain equal values, it is defined as:

$$\tau = \frac{c-d}{c+d} \quad (3)$$

where c is the number of pairs of variables, which are concordant, but d is the numbers of pairs of variables, which are discordant.
The corresponding formula for estimation of τ is

$$\tau = \binom{n}{2}^{-1} \cdot \sum_{i<j} sign[(X_i - X_j) \cdot (Y_i - Y_j)] \quad (4)$$

If data arrays contain equal values, another formula has to be used

$$\tau = \frac{c-d}{\sqrt{(c+d+e_x)\cdot(c+d+e_y)}} \quad (5)$$

where $\mathbf{e}_x$ is the number of pairs with equal values of **X** and $\mathbf{e}_y$ is number of pairs with equal values of **Y**.

In order to be able to forecast the values of incidental factors for some continuous range of values of incidental factors, it is necessary to carry out smoothing of empirical distribution function by means of, e.g., the most suitable nucleus, and then to create an interpolation table (interpolation tables allow speeding up the modelling process).

Figure 4 presents the process of smoothing of empirical function of distribution for incidental factor X_1.
The nonparametric methods can be especially effectively used when applying contemporary computer technologies.
Sufficiently powerful computers allow implementing contemporary methods of modelling of multivariate incidental distributions from the existing empirical information, as well as performing quick analysis of the model of logistics problem being investigated and accepting the most appropriate management decision.

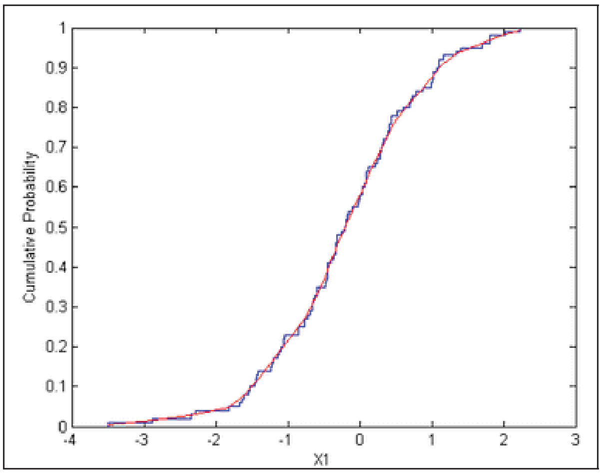

Figure 4: Example illustrating the Process of Smoothing of Empirical Distribution Function for Incidental Factor X_1

PRACTICAL USE OF THE NONPARAMETRIC METHOD FOR MODELLING THE PRICE $P_{delivery}$

The paper will present an example of modelling of cargo delivery price $P_{delivery}$ from the consignor to the consignee via a port in Latvia.
The participants in this logistics process are a Latvian logistics company and specialised transportation companies handling cargo shipments by sea and by road. The example suggested considers only one cargo transportation direction and only one cargo type.

That is, the values of parameters D_1, D_2, **W**, **Q**, **H** and **Y** used in modelling are constant, namely:
D_1 = 8500 km;
D_2 = 1000 km;
W = 18 t;
Q = 20` steel cargo container;
H = 1 (standard cargo – safe for transportation)
Y = (impact of other factors – the number of containers to be shipped in the given direction in the period since the 1st quarter of 2002 to the 4th quarter of 2005). The value of parameter **B** is variable.

Before starting modelling the basic indicator $P_{delivery}$, it is necessary to investigate (model) the character of changes of separate constituent parameters of cargo delivery price (C_1, C_2, ..., C_5), depending on the changes of the variable **B**. It has been noted that cargo delivery price is a complex value (see formula 1).
As can be seen from table 1, the value of parameter **B** directly impacts the changes in the value of parameters of $P_{delivery}$ C_1 and C_5. Therefore the example considers only the dynamics of variation of model parameters, which are referred to above.
Figure 5 presents the dynamics of variation of value of parameters C_1, C_5 by quarters, starting from the 1st quarter of 2002 to the 4th quarter of 2005.

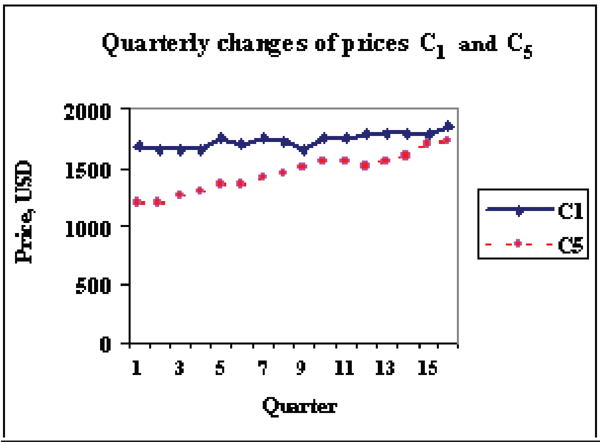

Figure 5: Dynamics of Changes of the Values of Parameters C_1 and C_5

Figure 6 presents the dynamics of the value of parameter **B** for the period from the 1st quarter of 2002 to the 4th quarter of 2005.

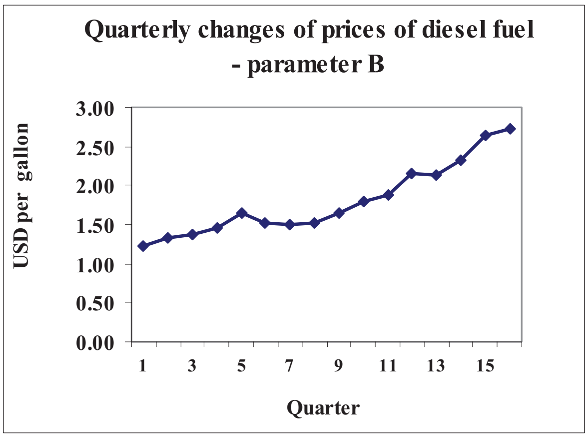

Figure 6: Dynamics of Changes in the Value of the Price of diesel fuel – Parameter **B**

Table 2 presents statistical information characterising the dynamics of variation in $P_{delivery}$ parameters C_1, C_5, **B**, **Y** for the period from the 1st quarter of 2002 to the 4th quarter of 2005.

Table 2: Dynamics of Changes of Parameters
$\mathbf{P}_{delivery}$, $\mathbf{C_1}$, $\mathbf{C_5}$, **B**, **Y**

Quarters		$\mathbf{P}_{deliv}$	$\mathbf{C_1}$	$\mathbf{C_5}$	**B**	**Y**
2002	I	3300	1680	1200	1.22	32
	II	3300	1650	1200	1.33	29
	III	3350	1660	1250	1.38	36
	IV	3350	1650	1300	1.46	36
2003	I	3450	1750	1350	1.66	35
	II	3400	1700	1350	1.52	48
	III	3480	1750	1410	1.51	47
	IV	3480	1720	1450	1.53	40
2004	I	3480	1650	1500	1.64	37
	II	3650	1750	1550	1.80	29
	III	3650	1750	1550	1.88	45
	IV	3650	1780	1510	2.15	53
2005	I	3700	1800	1560	2.13	40
	II	3750	1800	1600	2.32	55
	III	3800	1790	1700	2.63	67
	IV	3800	1860	1730	2.72	62

The statistical analysis (in the simplest case it is possible to use the regression analysis) of the existing empirical information shows that parameters $\mathbf{C_1}$ and $\mathbf{C_5}$ statistically depend on parameter **B**. In its turn, parameter $\mathbf{P}_{delivery}$ in the particular case depends on parameters $\mathbf{C_1}$ and $\mathbf{C_5}$.
Therefore for investigating the behaviour of parameter $\mathbf{P}_{delivery}$ it is sufficient to model the behaviour of parameters $\mathbf{C_1}$ and $\mathbf{C_5}$. Such modelling can be realised by using a bivariate copula (see figure 3).
A bivariate copula is the joint distribution function of a pair of variables with marginal uniform distributions on the [0, 1]. Thus a copula is a function: **C**: $[0, 1]^2 \to [0, 1]$.
As a result, it is possible to set the task of creating an efficient procedure for generating incidental parameter values constituting the factors of an imitation model, to consider the asymmetric distribution of parameter $\mathbf{P}_{delivery}$, to create an adequate model of non-linear dependence between the factors.
The distribution block chart of parameters $\mathbf{C_1}$ and $\mathbf{C_5}$ (without taking into account the determined constituent) is presented in figures 7 and 8.

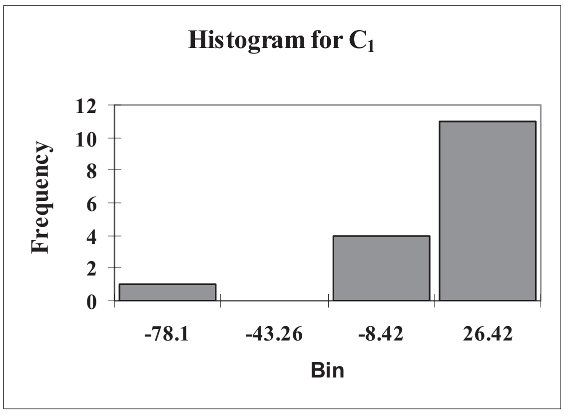

Figure 7: Histogram for Parameter $\mathbf{C_1}$

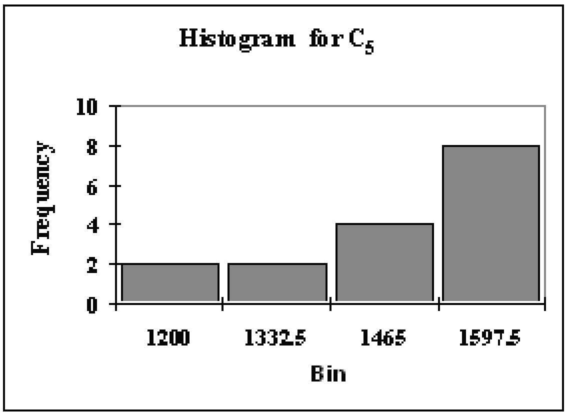

Figure 8: Histogram for Parameter $\mathbf{C_5}$

The linear Pearson's correlation coefficient for parameters $\mathbf{C_1}$ and $\mathbf{C_5}$ is equal to 0.824, which means that there is a strong linear correlation between these parameters.
In nonparametric modelling of $\mathbf{P}_{delivery}$, it is necessary to calculate parameter θ, which describes the dependence between two random factors $\mathbf{C_1}$ and $\mathbf{C_5}$ (see formula 3, 5). The fragment of MathCad program used for calculation of parameter θ, is presented,

```
tau(X,Y) := | S ← 0
            | n1 ← 0
            | n2 ← 0
            | n3 ← 0
            | n4 ← 0
            | n ← length(X)
            | for i ∈ 1..n
            |   for j ∈ i..n
            |     | a ← sign[(X_i − X_j)·(Y_i − Y_j)]
            |     | S ← S + a
            |     | b ← [(X_i < X_j)·(Y_i < Y_j) + (X_i > X_j)·(Y_i > Y_j)]
            |     | n1 ← n1 + b
            |     | c ← [(X_i < X_j)·(Y_i > Y_j) + (X_i > X_j)·(Y_i < Y_j)]
            |     | n2 ← n2 + c
            |     | d ← (X_i = X_j)
            |     | n3 ← n3 + d
            |     | e ← (Y_i = Y_j)
            |     | n4 ← n4 + e
            |                      S
            | ------------------------------------------------
            | sqrt((n1 + n2 + n3 − n)·(n1 + n2 + n4 − n))
```

In this case Kendall's τ for $\mathbf{C_1}$ and $\mathbf{C_5}$ is equal to. tau($\mathbf{C_1}$, $\mathbf{C_5}$) = 0.68154. Further, by using the obtained nonparametric values of distribution and dependence, common distribution of factors $\mathbf{C_1}$ and $\mathbf{C_5}$ is modelled.
The impact on the size of the value of factors of $\mathbf{P}_{delivery}$, presented in table 1 and formula 2, is of objective character, and this impact can be determined by analysing statistical information.
However, it has to be noted that formation of values of $\mathbf{P}_{delivery}$ is also affected by subjective factors, namely,

the conflict of interest between different participants involved in the logistics process.

It is natural that logistics as well as transportation companies involved in the logistics process include in the price of the services offered a definite profit ratio. Moreover, it is reasonable and justified that these companies want their profit rate to be maximum.
The consignor and the consignee, on the contrary, are interested in the lowest possible cargo delivery price $\mathbf{P}_{delivey}$ from the point of dispatch to the point of destination.

The substantial number of participants in the logistics services market and tough competition among logistics companies forces the participants of the logistics process to find a mutually acceptable compromise when establishing the size of cargo delivery price $\mathbf{P}_{delivery}$.
The given compromise is usually achieved via negotiations between the participants of the logistics process, the agreement being concluded only if each of the participants attains certain advantages with regatrd to the size of cargo delivery price $\mathbf{P}_{delivery}$.
Thus formula 2 has to consider the impact of the subjective factor/factors on the changes of $\mathbf{P}_{delivery.}$
The formula thus will be as follows:

$$P_{deliv} = f(D_1, D_2, B, T, W, Q, H, ..., Y, ...Z) \qquad (6)$$

where **Z** – subjective factor/factors impacting the size of cargo delivery price $\mathbf{P}_{delivery.}$
It is especially complicated to account for and describe the impact of the subjective factors on the value of $\mathbf{P}_{delivery}$. The subjective factors can be established by expert valuation methods by developing a grade scale for assessing the degree of the impact of subjective factors on the value of $\mathbf{P}_{delivery}$. After receipt and processing of expert valuation results of the impact of subjective factors on the value of $\mathbf{P}_{delivery}$, it is possible to carry out modelling of $\mathbf{P}_{delivery}$, based on the methodology described above by using nonparametric modelling methods.

CONCLUSION

The experience of modelling by using nonparametric methods demonstrates sufficiently good approximation possibilities and is comparatively simple for modelling $\mathbf{P}_{delivery}$, as it does not require the use of massive and frequently unjustified mathematical apparatus.
With an increase of operational capacities of computers, nonparametric methods of modelling for the purposes of practical operational decision-making will also enjoy wider application not only among companies directly involved in the logistics processes, but also companies dealing with commercial activities. Therefore theoretical and practical results of the research described in this publication can be of practical interest to all the parties involved.

REFERENCES

1. Sklar, A. 1959, "Functions de repartition a n dimensions et leurs marges". Publ. Inst. Statist. Univ. Paris 8, 229-231.
2. Frees, E. W., and Valdez, E. A., 1998. "Understanding Relationships Using Copulas", North American Actuarial Journal, V 2, No 1, 1-25.
3. Genest, C., Ghoudi, K., and Rivest, L. 1995. "A Semiparametric Estimation Procedure of Dependence Parameters in Multivariate Families of Distributions". Biometrika 82(3), 543-552.
4. Joe, H. 1997. "Multivariate Models and Dependence Concepts". Chapman & Hall, London.
5. Lindskog, F. 2000. "Modelling Dependence with Copulas". Master Thesis-MS-2000-06, Department of Mathematics, Royal Institute of Technology, Stockholm, Sweden.
6. Ledford, A. W., and Tawn, J. A. 1996. "Statistics for near independence in multivariate extreme values", Biometrika 83, 139-148.
7. Venter, G. 2001. "Tails of Copulas". ASTIN Conference, 25.
8. Roberto de Matteis. 2001. "Fitting Copulas to Data", Diploma Thesis, Univ. Zurich, 98.
9. Кельтон В., Лоу А. 2004. „Имитационное моделирование". Классика CS. 3-е изд. – СПб.: Питер; Киев: Издательская группа BHV, 847.
10. Мур, Джеффри, Уэдерфорд, Ларри., и др. 2004. „Экономическое моделирование в Microsoft Excel". 6-е изд.: Пер. с англ. – М.: Издательский дом "Вильямс", 1024.

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