MODELING TRANSPORTATION OPERATIONS IN THE SUPPLY CHAINS BASED ON JIT MODEL

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ABSTRACT
Transportation is a key logistic function, which determines the dynamic nature of material flows in logistic systems. At the same time, transportation is a source of uncertainty of logistics operations performance in the supply chain. Obviously, the development of a new approach for evaluation of the duration of delivery just in time will improve the efficiency of supply chains in accordance with one of the major criteria, namely customer satisfaction. The paper is devoted to the formation of analytical and simulation models, which allow obtaining the probabilistic evaluation of the implementation of unimodal and multimodal international transportation "just in time"; the developed algorithm takes into account main indices of transportation and various constraints (technical, organizational, administrative); performed calculation examples prove the legitimacy of the developed approach.

Keywords: supply chain management, logistic operations, reliability, modeling

INTRODUCTION
The need for new approaches to improve companies organizational and economic sustainability, maintain their competitiveness and efficiency is due to growing competition in various sectors, increased dynamism of the companies environment and dominating idea of "buyer's market". Given that the issues of cost estimating in the supply chain mainly related to logistics functions, such as inventory management and storage, are developed in sufficient detail, the methods for assessing reliability and quality of customer service have been paid little attention to. This is partly due to the fact that the duration of one of basic logistical operations, namely, transportation, is a random variable and the probability of satisfying delivery "just in time" according to JIT model depends on a number of factors (technical, organizational, administrative-legal, etc.). Obviously, further development of a common methodology for evaluating the effectiveness of supply chains requires developing a complex of decision support methods, which are a synthesis of key logistics operations, namely, inventory management, warehousing and transportation.

1. LITERATURE REVIEW
The "Just in time" (JIT) is a modern concept (technology) of the construction of a logistics system as a whole or the organization of a logistics process in individual functional areas of business, based on the synchronization of material resources delivery processes in the required quantities by the time, when the elements of the logistics system need them, in order to minimize the costs associated with warehousing of reserve stock (Ballou 1999, Bowersox and Closs 1996, Christopher 2011, Sergeev 2014).

JIT concept was used yet in the beginning of last century in the factories of Henry Ford, but has been developed and successfully implemented only in the 1960-1970 years. According to (Stock and Lambert 2001, Waters 2003, Jonsson 2008, Christopher 2011, Kraejewskiy, Ritzman, and Malhotra 2013) is an inventory management philosophy that allows minimizing inventories by eliminating insurance stocks. The purpose of JIT concept is to ensure the delivery of materials directly by the time of performance of specific operations, whereby stocks are practically eliminated.

Some experts (Waters 2003) believe that JIT model successfully works only in certain types of organizations, such as high-power assembly factories that produce a homogeneous product. At the same there is the tendency of expansion of the influence zone of JIT concept on the entire supply chain under different names:

- Quick response, QR.
- Continuous replenishment planning, CPR.
- Efficient consumer response, ECR.
- Lean production, LP, etc.

Modern trends of the application of JIT concept require close correlation of queries of various functional areas (e.g., logistics - production - marketing) as well as with other members of the supply chain (cargo company - supplier).

Obviously, great demand for JIT concept is dictated by the need to reduce the uncertainty of logistic cycles, because the synchronization of logistic functions and operations is becoming increasingly important. It should be emphasized that with the problem of estimating the uncertainty in logistics systems managers meet in the following situations:

- When evaluating the performance and reliability of supply chains, in particular the quality of services (Wolfgang and Thorsten 2006, Bowersox and Closs 1996, Lukinskiy, Lukinskiy, and Churilov 2014).
- When describing and evaluating logistic cycles quantitively (Bowersox and Closs 1996, Stock and Lambert 2001, Lukinskiy et. al. 2007).
- When calculating key performance indicators KPI when considering the balanced scorecard (BSC) and in SCOR – models (Sergeev 2014).

Consider mentioned situations in more detail.

1.1. Uncertainty when evaluating supply chain reliability

Analysis of various sources showed that the present stage of development of logistics and SCM is associated with the appearance of number of new concepts: “durability”, “flexibility”, “adaptability”, “response time” and, of course, “reliability”. In accordance to one of definitions the reliability is a property of the supply chain to keep within the prescribed limits the values of all its indicators and elements that characterize the supply chain ability to perform its functions in accordance with the terms of the contract between its members.

Table 1 shows the systematized data of number of companies (Nissan, Siemens, EMS, Saturn, etc.), that reflect actual reliability indices of performance of transport operations.

Table 1: Reliability Indices Of Performance Of Transport Operations

Indicator's name	Value	Reliability of transportation
Delivery time to consumer	1,0 hour	0,95
Total delivery time	No more than 24 hours	0,90
Permissible delay in delivery	0,25 – 0,50 hour	0,985
Delivery performance	-	0,98-0,995

The analysis of table 1 shows that:

- Quantitative and probabilistic indicators can be used to evaluate the transport operations on the basis of JIT concept (model).
- Each indicator can be taken as an independent criterion. At the same time, the index “permissible delay of indicator” requires information about the index “delivery time”.
- Question about the relationships between the values of temporal and probabilistic parameters remains open, as the distribution function of terms of delivery is not given.
- Indicators should be complemented by estimates of costs for calculating the reliability of the supply chain using discrete-continuous model (Lukinskiy, Lukinskiy, and Churilov 2014).

1.2. Uncertainty when evaluating logistic cycles

One of the basic concepts necessary for the integrated consideration of logistics operations and functions, is the logistic cycle or functional cycle of logistics. The logistic cycle is understood to be the time interval between placing an order and the delivery of the ordered products to the final consumer (receipt of order by the consumer).

There are several kinds of functional cycles; the most important among them are the “cycle of physical distribution” and “functional cycle of procurement” (Bowersox and Closs 1996, Stock and Lambert 2001). So logistic cycle of physical distribution includes five operations (stages):

1. Preparation of an order and its transfer.
2. Order processing.
3. Order picking or production.
4. Transportation.
5. Receipt of an order by the consumer (delivery to the consumer).

According to some experts the first two operations are quite stable; the third operation - order picking - depends on the availability of stocks. If products are not available, then the term of this operation will depend on the time of production or delivery to a distribution center, warehouse.

The greatest uncertainty is typical for the fourth operation (transportation) and to a lesser extent - to the fifth operation (delivery to the consumer). It is known that the transport operations in global (international) and internal supply chains differ significantly. For example, according to (Bowersox and Closs 1996), if at domestic market the transit time is 3-5 days, and the entire functional cycle takes from 4 to 10 days, then at the international level the functional cycle often takes weeks or months. For example, table 2 presents results based on statistical data on the minimum and maximum duration of each operation of logistic cycle as well as their expected (obviously modal) values.

Table 2: Duration Of Logistic Cycle Components

Logistic cycle stage	Duration of logistic cycle stage, days			
	Bowersox and Closs (1996)		Stock and Lambert (2001)	
	Range of values	Anticipated value	Range of value	Anticipated value
Stage 1	0,5 – 3	1	0,5 – 1,5	1
Stage 2	1 – 4	2	1 – 3	2
Stage 3	1 – 20	2	0,5 – 9	1

Logistic cycle stage	Duration of logistic cycle stage, days			
	Bowersox and Closs (1996)		Stock and Lambert (2001)	
	Range of values	Anticipated value	Range of value	Anticipated value
Stage 4	2 – 10	4	1 – 5	3
Stage 5	0,5 – 3	1	0,5 – 1,5	1
Total	5 – 40	10	3,5 – 20	8
Note: *anticipated value of logistic cycle general time is 15 days				

Analysis of the data in table 2 allows us to conclude that:

- Most of distribution functions are asymmetrical and only a few functions are symmetrical and can be approximated by the normal law.
- Operation "order picking" and partly "transportation" cannot be described by a single distribution function and obviously represent superposition (mixture) of the two distribution functions, for example, of the normal law and the uniform density.
- Total distribution function, which is the sum of random variables, is of asymmetric nature that is especially important to consider when assessing the reliability of supply chains.

1.3. Uncertainty when calculating key performance indicators of supply chains

Without going into detail on the nature of SCOR-model (Sergeev 2014), we note that of the five categories effectiveness evaluation (metrics) SCOR-model, two are directly related to the concept of JIT. The first metric "supply chain reliability" include KPI "execution of delivery by a certain date". The second metric "the rate of supply chain response" includes two KPI: "order fulfillment duration" and "duration of certain logistic cycles" (procurement, production, delivery).

For example, table 3 shows the fragment of the strategic map of SCOR-model of company "Delta" (Sergeev 2014).

Table 3: KPI Of "Delta" Company (Fragment)

Metrics	Indicator of supply chain functioning	Fact	Industry average	Competitor	Leader
Supply chain reliability	Execution of delivery by a certain date, %	90	75	87	95
Supply chain response	Order fulfillment duration, days	1-4	2	1	1

The analysis of tables 1-3 shows that all the above kinds of uncertainties are closely related and, therefore, problems of assessing the duration of execution of logistics operations and functions are identical.

Real way out of this situation requires the development of a new approach based on analytical (numerical) methods and supply chain modeling using information technologies (Bruzzone et al. 2004, Curcio and Longo 2009, Ivanov, Sokolov, and Käschel 2011, Taha 2011).

Thus, the following can be stated, firstly, sources of uncertainty are random variables associated with performing the following operations of logistic cycle: transfer of an order, order processing and order picking (or production), transportation and delivery to the consumer. Secondly, it is believed that when making management decisions it is more difficult to quantify the operations that are related to international multimodal (combined) transportation. Thirdly, the most promising tool to solve the problems connected with reducing uncertainty in the supply chain is JIT model and its modifications. Fourthly, whereas most experts consider JIT concept at the conceptual level and some attempts to bring a conceptual approach to the calculation model have not found wide application, it is necessary to develop a new methodical approach for evaluation the transport process quantitatively (in the broad sense) in the form of analytical models and the use of simulation modeling.

2. FORMATION OF TRANSPORTATION MODEL ACCORDING TO JIT CONCEPT

Transportation is a key logistical operation, a description of which is characterized by a large number of indicators and factors. As mentioned previously the most complex in the preparation and decision-making in supply chain management are transportation operations. This is due to the fact that the external environment of these operations is characterized by the uncertainty, which in turn is associated with a variety of risks that differ in frequency and in nature. The main classification criteria of transportation include modes of transport (road, sea, etc.) and the type of transportation (direct, combined, unimodal, multimodal, etc.).

When developing the transportation model the main attention was focused on road transport that does not diminish the importance of other species. At the same time it is known that for the last fifteen years the share of road freight transport compared to other modes of transport of Eurozone (25 countries) increased by almost 10%. During the same period, the share of rail and inland waterway (river) transport decreased by 25%. This suggests that the increase in the share of transportation by road was due to the reduction of transportation by rail and water.

Time characteristic of overcoming complicated circumstances and observing the requirements to international road transport are random and should be taken into account while designing delivery of cargo, planning and arranging freight transportation just in time.

The main source of uncertainty is a route that is characterized by certain length, the type of road surface, restrictions imposed by different countries and other parameters.

International road transport is a more complex process from the point of view of organization, technology and as a result – management, as compared with the domestic (in-land) transportation. Complexity of the international traffic is predetermined by the necessity to cross the borders and be involved in cargo traffic customs regulation, be aware of peculiarities of the national paper turnover, inspection of the technical conditions of a vehicle, observance of weight, overall dimensions and environmental restrictions, as well as the necessity to obey drivers' work-rest schedule and other things.

If the components of transportation process are random values, then the quantitative assessment is made with the help of probabilistic characteristics.

Taking mentioned features into account, the total time of transportation can be determined by means of formula:

$$T_o = \sum_{i=1}^{A} t_{i,i+1} + \sum_{j=1}^{B} \tau_j + \sum_{k=1}^{C} \Theta_k , \tag{1}$$

where $t_{i,i+1}$ – travelling time between i and $(i+1)$ points; τ_j – time of preparation of customs documents in j-point (in the country and at the borders); Θ_k – time for loading, unloading and warehousing in k-point; A,B,C – the number of sections of the roads a car moves, customhouses and loading/unloading points.

Transportation initial time (start) T_{it} is determined by means of formula

$$T_{it} = T_{JIT} - T_o , \tag{2}$$

where T_{JIT} – "just in time" delivery time.

Assuming that average driver's working hours when he performs the international carriage is Tw, the calendar run time is determined by a number of working days and is computed by means of formula:

$$T_L = \frac{T_o}{T_w} . \tag{3}$$

It should be emphasized that similar formulas considering specificity can be used for calculating the time of transportation by other modes of transport; formula (1), taking into account $t_{i,i+1}$ and Θ_k allows evaluating the time of performance of domestic transportation; when considering the multimodal transportation, such as by road and sea transport, the formula (1) should be adjusted by adding summands reflecting the specificity of the respective mode of transport.

The formulas, used for computing average time of transportation and average number of trip days, show the vehicle continuous time on the route, but does not take into account all the peculiarities of the international transportation determined:

- Firstly, by the restrictions of driver's or crew's work-rest regime required by AETR.
- Secondly, by the restriction imposed on heavy haulers in some European countries on Sundays and holidays.
- Thirdly, by the necessity to arrange repair and maintenance activities, particularly, emergency maintenance and other reasons of traffic delays on the road, for example, checking up the axle weight by the road police which are the part of driver's work during his working day besides driving.

Then, taking into account peculiarities of the international transportation, the formula of calculation of the total time on the route should be adjusted and presented as follows:

$$T_o = \sum_{i=1}^{A} t_{i,i+1} + \sum_{j=1}^{B} \tau_j + \sum_{k=1}^{C} \Theta_k + \sum_{l=1}^{D} \varphi_l + \sum_{m=1}^{E} \psi_m + \sum_{n=1}^{F} \eta_n , \tag{4}$$

where φ_l – random component, showing the increase of the trip time for repair and maintenance activities and other reasons; ψ_m – random component reflecting constraints connected with AETR; η_n – random component reflecting bans on the use of heavy-load vehicles; D, E, F – the number of cases of standing idle (considering the mentioned reasons).

When forming the model 4 we took into account characteristics of modes of drivers' work and rest; these characteristics are associated with the accumulation of working time of the driver for the day, week, two weeks that leads to an uneven increase of route time without change of traversed path. This causes the addition the variable ψ to the model. Further specification requires the introduction of a variable in the model of two inequalities-restrictions for each day of driving during the route. The first of them reflects the time of driving:

$$\sum t_{i,i+1} < T_d , \tag{5}$$

where T_d – normalized driving time per day (T_d = 9h.).

The second inequality is related to the duration of the daily rest T_r:

$$\sum \left(t_{i,i+1} + \Theta_k + \tau_j + \varphi_l + \eta_n \right) < 24 - T_r . \tag{6}$$

Peculiarity of application of constraints (5) and (6) is that the general model of delivery time is formed based on the probability of two events (hypotheses). The first hypothesis – H_1 – movement occurs on the route according to the dependence (1), the second hypothesis H_2 – movement occurs on the route according to the dependence (4). Consequently, the distribution function of the total time of delivery may be presented as:

$$F_{\Sigma}(T) = \sum P(H_i) \cdot F_i(T)\,, \qquad (7)$$

where $P(H_i)$ – the probability of the *i*-th event; $F_i(T)$ – the distribution function according to the *i*-th hypothesis.

Thus, the generated model that comprises dependence (1) - (7) allows evaluating execution of transport operations in terms of JIT concept.

2.1. Analytical dependences for calculation of delivery time

Evaluation of the distribution function of delivery time according to the generated model is the sum of random variables t_i, i.e.:

$$T = t_1 + t_2 + \ldots + t_n = \sum_{i=1}^{n} t_i\ . \qquad (8)$$

If t_i are independent, then one should use the following dependence to calculate the density of distribution $f_{\Sigma}(T)$:

$$f_{\Sigma}(T) = f_1(t_1) \cdot f_2(t_2) \ldots f_n(t_n) = \prod_{i=1}^{n} f_i(t_i)\,, \qquad (9)$$

where $f_i(t_i)$ – density of distribution of the execution time of *i*-th operation.

In the general case, the dependence (9) reduces to the recurrence formulas (Ventsel and Ovcharov, 1983). Analysis of several studies has shown that dependences for calculation of $f_{\Sigma}(t)$ and $F_{\Sigma}(T)$ were obtained only for several laws of distribution with different parameters, they include normal, exponential and the Poisson distribution laws.

The probability of delivery “just in time” is estimated by using the following formula:

$$P(T) = \int_{0}^{T_o} f_{\Sigma}(T)dt\ . \qquad (10)$$

For example, in case of normal distribution law the formula for $P(T)$ can be written as:

$$P(T) = \Phi\left(\frac{T_o + T_{\Sigma}}{\sigma_{\Sigma}}\right), \qquad (11)$$

where $T_{\Sigma} = \sum_{i=1}^{n} \overline{t_i}$; $\sigma_{\Sigma}^2 = \sum \sigma_i^2$, $\Phi(\ )$ – normal distribution function (Ventsel and Ovcharov, 1983).

Another approach to the calculation of statistical parameters T_0 is based on the theorems of numerical characteristics of random variables. So the average value of the sum of random variables is calculated by the formula:

$$M\left[\sum t_i\right] = \sum_{i=1}^{n} M[t_i]\,, \qquad (12)$$

and the variance with regard to correlations t_i:

$$D\left[\sum t_i\right] = \sum_{i=1}^{n} D[t_i] + 2\sum_{i\langle j} k(t_i, t_j)\ . \qquad (13)$$

Formulas for the third and fourth central moments also can be found in literature.

To determine the type of distribution laws $F_{\Sigma}(T)$ in the first approximation we can use the correlation coefficient:

$$\nu = \frac{\sqrt{D\left[\sum t_i\right]}}{M\left[\sum t_i\right]}\ . \qquad (14)$$

After checking the correctness of the choice of the distribution law on the basis of tests of fit, the next step is calculation of the probability $P(T)$ by the formula (11).

Considered analytical dependences make possible to obtain the required evaluation of the execution of transport operations according to JIT: average transportation time; the probability of performance of delivery by the time T0 or delivery time with a given probability. The adequacy of these estimates will depend on the number of constraints and their values. But despite that, the presented formulas can be applied during the design of supply chains or in cases of their reengineering.

2.2. Simulation model to estimate the time of transportation in supply chains

Since the application of analytical dependences for evaluating the transportation time is limited, there is an objective need for other versatile tools, such as Monte Carlo method (MCM). It is known that the use of Monte Carlo method lies in reproduction of probabilistic mathematical model, which is being studied, in the form of appropriate “realizations” or “testing”. In this paper we propose to perform modeling of each transportation in the form of a consistent set of realizations in accordance with the route of movement of vehicles and taking into account the various constraints. Following statistical processing allows determining the parameters and the kind of the distribution law of delivery time.

Figure 1 shows a basic block diagram for modeling transport operations on the example of international road transport. Consider some blocks in more detail.

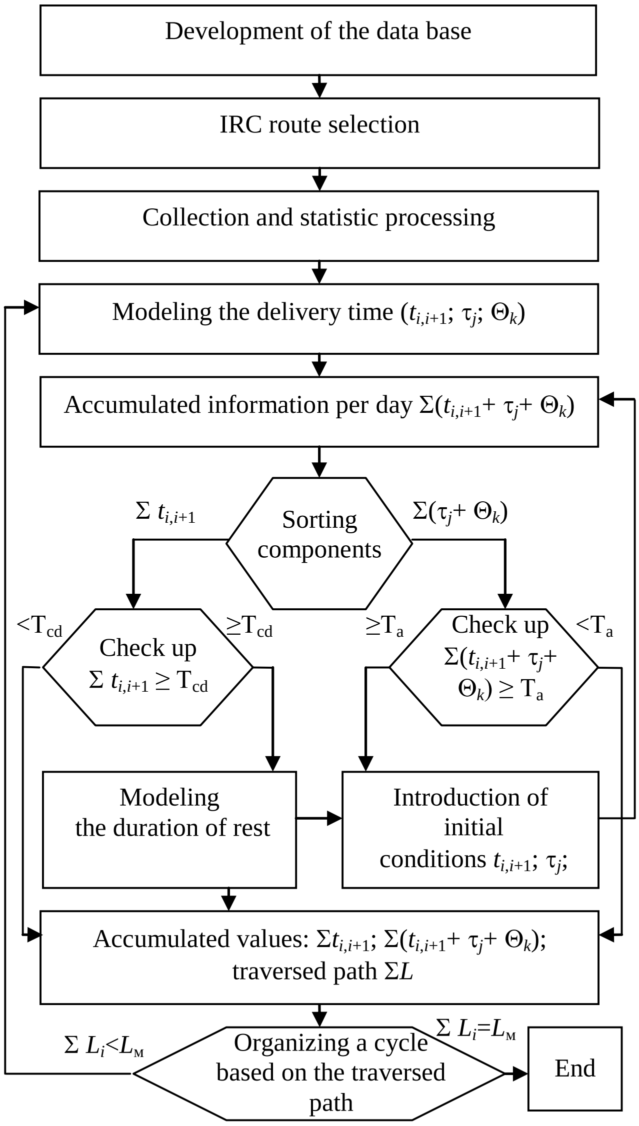

Figure 1: Basic Block Diagram For Modeling Transport Operations (On The Example Of International Road Transport)

In block 2 the type of transportation (unimodal, combined, etc.) and the modes of transport (road, sea, etc.) as well as route options (points, distances, customs, borders crossing, etc.) should be selected.

In block 3, the database of the parameters that are included in the transportation model (such as distribution laws of movement time, idle time, delays due to restrictions, etc.) is formed.

In blocks 4 and 5 simulation of basic transport operations is performed in accordance with the selected distribution laws and three arrays of information are formed: the movement time per day, the time of movement and downtime per day, the total time on the route subject to restrictions. Next in several blocks the analysis is carried out and decision is made in accordance with the restrictions (5) and (6) as well as the array of output data is formed.

The next stage involves the statistical processing of the simulated values and the evaluation of delivery indicators in accordance with the concept of JIT. Obviously, when simulating combined transportation one should include additional blocks in block diagram that take into account the movement time, handling and customs operations as well as particular restrictions, such as the regularity of sending ferries, etc.

3. EXAMPLES OF PERFORMANCE OF DELIVERY “JUST IN TIME”

For approbation of the developed approach the calculations for different routes were made. Given that transportation options are very diverse, for comparative calculations and the refinement of the algorithm two international routes were selected: the first one is a unimodal road transportation and the second one is a multimodal transportation (road and maritime transport).

The data, which are necessary for calculations, were collected on the basis of official information (e.g. tachograph data, etc.), special questionnaires filled out by drivers on real routes and survey results of managers responsible for organizing the international road transport. All simulation results were subjected to statistical processing, that comprises:

- Checking the extreme values of the samples (Arley method).
- Calculation of statistical parameters (means, variances) and the choice of the laws of distribution.
- Determination of the coefficient of correlation between the various transport operations.

3.1. Example 1

The table shows the input data for modeling transportation on the first route. This route includes: the point of departure A - the border B - the point of destination C (loading) - the border D - the point of unloading E.

Table 4 shows that the approximation of statistical data can be made with the help of different distribution laws: for transport operations associated with the movement the normal law is used; for operations related to border crossings and customs procedures, usually asymmetric distribution laws are used such as exponential or Rayleigh laws.

Table 4: Temporal Characteristics Of Transportation On The First Route

Points of the route*	Average value, h.	Root-mean-square deviation, h.	Distribution law
Point A – customs B; M	3,8	1,0	Normal
Customs B; BC + PC	1,8	1,8	Exponential (parameter h=0,55)
Customs B – point C; M	3,0	0,7	Normal
Point C; L + PC	4,9	2,5	Rayleigh (parameter σ_r =3,93)

Points of the route*	Average value, h.	Root-mean-square deviation, h.	Distribution law
Point C – customs D; M	4,2	1,0	Normal
Customs D; BC + PC	3,5	1,8	Rayleigh (parameter σ_r =2,83)
Customs D – point E; M	4,6	0,8	Normal
Point E; U + PC	3	1,0	Normal
*M – movement; BC + PC – border control and procedure of customs; L + PC – loading and procedure of customs; U + PC – unloading and procedure of customs			

Table 5 shows the results of statistical processing of the duration of transportation on the first route. As expected the total delivery time is subject to a normal distribution law. For comparison, calculations were performed using Monte Carlo method and the dependencies for the numerical characteristics of random variables, formulas (12) and (13). Since the correlation coefficients between the transport operations were within 0.1-0.15, the correlation in (13) was not taken into account.

The results of calculations were presented in the form of average values $\overline{T}$ and root-mean-square deviations σ_t; the time of delivery "just in time" with probability P = 0.98 (formula (11)) and the probability of execution of transportation during the time T_g guaranteed by a carrier (in our case, T_g = 55 hours).

Table 5: The Results Of Calculations For Performance Of Transportation "Just In Time"

Route	Calculation method	Distribution law	Parameters, h.		Delivery time (at P= =0.98), h.	Probability of guaranteed delivery
			T	σ_t		
1	Modeling MCM	Normal	49,5	3,5	56,7	0,94
1	Numerical (formulas 12, 13)	Normal	50,7	4,1	59,1	0,85
1 (considering the delays)	Modeling	Different from normal	52	7,0	66,4*	0,5*
2	Modeling	Different from normal	77,5	13,0	104,0	0,92*
*when approximating by the normal law						

3.2. Example 2

Consider such option of route 1, for which in some trips for some reasons there are delays (congestion, traffic accidents, control of weight parameters by the traffic police, etc.). The analysis showed that delays should be attributed to rare events and the probability P of their occurrence in specific realizations adheres to the law of binomial distribution. So for the given route we can take P=0.1. As for the duration of delays, they can be described by the normal distribution law with parameters such as mean value of $\overline{T_l}$ =3.0 hours and root-mean-square deviation σ_l =0.7 hrs. The simulation results are shown in table 2. A characteristic feature of this option is that the distribution of total delivery time differs from the normal law in that it has a "tail" and resembles a superposition of two distributions.

3.3. Example 3

Consider the combined transportation by road and sea transport. It should be pointed out that compared to route 1 in point C the car is placed on ferry, after ferry arrival to point C* car moves to the point of loading, then returns by ferry to point C and continues the movement to point E. The peculiarity of this multimodal transportation is that ferries from points C and C* are sent on a regular schedule at 8.00 and 18.00 each day. Total time of handling and ferry movement adheres to the law of normal distribution with parameters: $\overline{T_f}$ =10.3 h. and σ_f =1 h.

Thus, JIT concept should be applied three times - taking into account the arriving for placing on ferry at point C and C* (on return) as well as to the final point considering the total time of delivery. The table 5 shows the results of modeling, from which it follows that increased deviation from the normal law and increasingly clear display of the superposition of distribution are typical for multimodal transportation.

In conclusion, we note that the results of calculations confirm the validity of the hypothesis of the possibility of describing transportation using random events and random variables. The analysis of the table 5 shows that for some options (especially for unimodal transportation) analytical dependences and simulation results give similar results. For combined multimodal transportation, taking into consideration various constraints, preference should be given to methods of simulation modeling. Comparison of the obtained results with empirical data from tables (1) - (3) is uniquely assesses the reliability of supply chains with relation to transportation. This allows reducing the uncertainty of the entire logistic system.

4. CONCLUSION

1. The developed technique allows obtaining probabilistic estimates of transport operations in supply chains in accordance with JIT concept. The model differs from the existing empirical approach in that it allows decomposing the transportation process into separate components and describing them as separate elements with the use of statistical parameters. The next stage of the development of JIT model is the synthesis of individual transport operations for the transportation

process of the given configuration and subsequent evaluation based on the results of simulation modeling of random processes of delivery “just in time”.
2. To implement the proposed approach it is necessary to organize the collection, analysis and systemization of materials, reflecting the statistical nature of the logistics operations in order to create the database that will be subsequently used in the calculations. Since the average size of motor transport enterprise, which is performing international road transport, according to the IRU is 10-12 vehicles, then in case of performing 5-7 routes a month the statistical information needed for calculations can be collected on the major routes for 3-4 months.
3. Developed approach allows us to describe the process of transportation, taking into account the various limitations (technical, organizational, administrative) and go to the reasoned development of measures to improve the effectiveness of efficiency of individual operations.
4. The obtained dependences allow moving from operational to situational management in case of deviation from a planned target considering the confidence intervals of movement process. In turn, this will require the development of matrix of decision making (fast border passage, selection of toll highways, replacement of crew, etc.) to improve the reliability of performance of transportation “just in time”.

Further research on the development of the proposed approach can be implemented in the following areas.

It is necessary to consider the possibility of using the developed approach for different types of transportation, modes of transport, route options, taking into account the specifics of the transported goods , etc.

Increasing complexity of the description of processes in logistics systems, which are associated with the requirement to increase the reliability, adaptability, flexibility of supply chains, requires the active development of analytical methods and models based on information systems and information technologies. Obviously, the developed approach can be used to form an integrated model combining the capabilities of such software products as Autoroute, navigation system GPS (for quick response and corrections) and the Internet for operational decisions.

One of the promising directions of development of the proposed model is the introduction of economic parameters associated with supply chain management. A detailed analysis of transport operations and their impact on the final result (delivery “just in time”) will allow not only identifying bottlenecks in the supply chain, but also evaluating the costs associated with their removal.

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