Stochastic algorithms in multimodal 3PL segment for the digital environment

S Krasnov, E Zotova, S Sergeev, A Krasnov, M Draganov
Peter the Great St. Petersburg Polytechnic University, St. Petersburg, Russia

hsm.krasnov@gmail.com; sergeev2@yandex.ru; zea0284@gmail.com;
alex073ul@mail.ru

Abstract. This paper discusses the problem of creation of control algorithms when working in the Third Party Logistic concept. It considers the process of supply management when several means of transport and an intermediate distribution center are used. It is assumed that goods are processed in the Machine-to-Machine mode by means of machine-readable codes. The controlling server processes the data and makes a decision either to use one or another mode of transport, or to store the cargo temporarily at the distribution center. An option is provided when an emergent stock of a limited quantity is placed directly at the end point so that the impact of market uncertainty in demand can be mitigated. The methods of mathematical modeling in the time of uncertainty of the operational environment are applied. The algorithm is based on the stochastic programming method. The practical focus of the work lies in orienting the results on multimodal logistics, which makes the model scalable. The computations, which use the algorithms developed in the paper, provide commercial network managers with a convenient tool for planning current activities taking into account market uncertainty in all operations, when dealing both with consumers and suppliers throughout the business chain, including distribution centers as independent nodes of machine-to-machine interaction. The implementation of the proposed models not only will bring economic benefits and reduce the global traffic, but will also help improve the environment and give a significant social effect.

1. Introduction

Globalization provides a wide area for business opportunities. At the same time, the coverage of the potential consumers is not limited spatially and geographically, and among the variety of markets the manager has to choose the best options from an economic point of view [1]. As work in any segment of the economy takes place in conditions of demand uncertainty, it is necessary to involve the mathematical tools [2], the criterion, as a rule, is the functionality formed from the profit maximization condition.

In the transition to the Machine-to-Machine interaction concept [3], a number of problems arise, associated with both the identification of items (goods in any container), as well as addressing the process of their movement. The widespread use of intelligent automation tools such as laser and radio frequency scanners, robotic warehouse complexes, inter-operational autonomous transport is based on the use of machine-readable codes [4]. For example, to solve the identification problem, it is possible to use the entire set of tools, ranging from linear barcode and 2D QR (Quick Response Code) to RFID (Radio Frequency Identification) tag recognition tools.
The practicability of application is primarily subject to the conditions of the item identification throughout the track, as well as restrictions on the equipment used in the transportation process. According to the accepted standards EAN/UCC and ITF [5], the maximum allowable encoding has from 10208 to 23648 characters. The size of the data array depends on the possibility of error correction, starting from the lower L level (allows recovery of up to 7% of information loss) with intermediate M and Q levels and ending with the upper H level (restores up to 30% of the information lost due to the ambient environment and other adverse factors).

The current level of machine-to-machine interaction is organized on the basis of cloud Internet solutions, so as control objects logistics algorithms [6] use both single units of cargo and large quantities formed in blocks. In this case, combined schemes based on RFID tags containing addresses of individual units and requiring access to the forwarding server are used. Such identification allows to switch to M2M algorithms during cross-docking and pick-by-line selection procedures [7], which are present in the vast majority of logistics schemes.

The difference in these technologies lies in the fact that cross-docking does not imply changing the machine labeling during processing by 3PL (Third Party Logistic) operator. Its advantage is a high speed SKU (Stock Keeping Unit) processing of a goods items. This minimizes the time spent within the DC (distribution center). Pick-by-line technology includes SKU processing, the restructuring of unit loads, which implies their deconsolidation. Thus, the goods are not delivered to the stock, but to the unloading zone. Accordingly, each of the smaller units must have its own machine-readable label with complete information.

This type of interaction covers exceptionally large data arrays, millions of records, each has 10-15 thousand characters, since today the global trend is to consolidate commercial structures in the network under a single brand, for conduction of unified distribution and marketing policy. In addition, it is in the paradigm of commercial networks and on the basis of SCM (supply chain management) technologies [8] distribution centers formed as the nodes, and the concept of third-party logistics emerged. Today, 3PL providers are actively working in the segment of commercial and, primarily, retail chains.

Due to the flexibility of M2M technologies and alternative transportation modes, as well as the expansion of functionality, a higher level of service such as 4PL and 5PL has formed in the world. Such forms are more common in other segments of the economy, for example, in P2P (Peer-to-Peer or Partner-to-Partner) networks, online auctions, etc. In this work, they can be considered as a prospect of applying the obtained results.

2. Statement of a problem
Consider the problem of digital technologies usage in the concept of Machine-to-Machine interaction and machine-readable standard codes with corrective properties in order to switch to the end-to-end automation in the most common segment of multimodal transport of the 3PL concept.

The conducted analysis of the world experience in the digital tracking application showed that the main effect of the implementation can be achieved only by applying the capabilities of formalized algorithms based on the mathematical theory of optimal processes [9], as it is much more effective than a simple reduction in the forwarding costs. The practical orientation of this study is the focus of the results on multimodal logistics and the creation of a scalable model. This will allow to develop the results in the areas of the following, higher levels of third-party logistics.

Let us introduce the formal descriptions necessary for building a mathematical model. We define that the planning of the multimodal transport operator (MTO) is carried out in conditions of market uncertainty, which is expressed in a set of random variables \( c_i \), where \( i = 1, 2, ..., m \). This includes quantitative values of supply requests, volumes of raw materials, components, traffic, consolidated supply and their known distribution functions, based on statistical analysis of market data. Such factors of the market environment as demand, prices, personnel, risks affect corresponding figures of the mathematical expectation \( m_i = E(c_i) \) and dispersion \( D_i \). The only limitation is the Lindeberg condition: for any \( r > 0 \), the following must be true
\[
\lim_{t \to 0} \frac{1}{B_n} \sum_{x \in [m_k,m_k + A_k]} \int (x - m_k)^2 c_i(t) dt = 0
\]

(1)

where \( B_n = \sum_{j \neq i} D_{ij} \), \( c_i(t) \) is the distribution density, \( t \) - time, \( x \) - parameter.

Moreover, the dependence of the values \( c_j \), as a rule, are seasonal [10]. For this purpose, use the following expression obtained in [11]:

\[
m_j = A_j + \sum_{k} A_{jk} \cos(2\pi \frac{1}{12}(k + \theta_j))
\]

where \( A_{jk} \) is a planning period number, \( A_j, A_{jk}, \theta_j \) are Fourier expansion coefficient.

Next, we introduce control variables \( x_j; x_j \geq 0; j=1,2,\ldots,n \) which define both the traffic volume by individual modes of transport, and the choice of routes, including the impact of capacity, and data related to the indicators of distribution centers used as route nodes.

The task is to determine the variables \( x_j, j=1,2,\ldots,n \) in the conditions of stochastic nature of information on the actual values taken \( c_j, j=1,2,\ldots,n \).

Next, we introduce the deterministic values \( a_{ij} \), \( i=1,2,\ldots,m; j=1,2,\ldots,n \), as well as the parameters \( b_i \), defining the constraints of the model. This includes such values as carrying capacity of the vehicles, the timetable of the railway, port, storage capacity, the performance of stevedores, the operating costs of warehouses, cost of rent and energy.

We formulate the problem in terms of separable functions. It is necessary to optimize the functional

\[
\sum_{j=1}^{n} c_j x_j,
\]

with condition \( \sum_{j=1}^{n} a_{ij} x_j = b_i, i=1,2,\ldots,m \).

The simplest interpretation of one set of constraints, for example, is deadweight of the consolidated transport pool.

By analyzing the search for the optimization of the quality functional, it can be separately noted that when only the \( x_j, j=1,2,\ldots,n \) values are determined in the absence of complete information about the values \( c_j \), the required solution of the optimum of the mathematical expectation \( E \left[ \sum_{j=1}^{n} c_j x_j \right] \) under these constraints is reduced to the solution of the equivalent conventional deterministic linear programming problem. For this purpose, based on the properties of random functions, the condition functional is rewritten as \( \sum_{j=1}^{n} E \left[ c_j \right] x_j \). At this, the expected values of the corresponding coefficients of the original problem are chosen as the coefficients in the expression for the objective function.

However, in cases where even some of the \( x_j \) require information for a more accurate determination, the problem of stochastic linear programming can not be solved by such a simple method.

One of the methods of solving [12] can be the application of mathematical game theory, discussed in detail in [13], but it is necessary to take into account additional factors for the multidimensional model. First of all, it should be noted that an extended planning horizon is always considered and the problem becomes multistage, and, with a large length of the optimization vector, it is necessary to form iterative procedures that are convenient for programming. In such conditions, it is possible to propose another method of obtaining the desired result, we outline it below.

3. Development of practical algorithm for the limited dimension problem

Let the subdivision of the commercial network be engaged in planning of multimodal transportation and utilization of distribution centers for a well-known long time horizon.

The total volume of cargo required for business activity in the planning period is limited by the value \( T \) (the dimension is arbitrary, for example, in tons or pallets).
At the beginning of each of the periods that comprise the planned horizon, the enterprise should calculate the following controlled variables:

- \( x_i \) is the amount of goods and cargo transported by one mode of transport (e.g., rail cars);
- \( x_j \) is the amount of goods and cargo transported by the second mode of transport (as a rule, road transport);
- \( x_k \) is a goods and cargo processed at distribution centers.

The dimension of \( x_i, x_j, x_k \) is arbitrary, for example, in tons or pallets.

In order to implement the delivery program \( x_i \), units \( a_i x_i \) of the first type of transport will be required for the planned period, respectively, for delivery \( x_j \), units \( a_j x_j \) of the second transport will be required for the planned period. We introduce the designation \( D_i \) and \( D_j \) for the quantitative characteristics of the maximum [13] fleet of each of the transport modes.

Next, we introduce the price list for the unit load of the first mode of transport equal to \( r_i \) and \( r_j \) for the second mode. At the same time, the costs for each transportation are equal \( r_j (a_j x_j) \) for each track \( j \) \( (j = 1, 2) \).

In the model, we should consider the associated costs for the maintenance of units of transport, stevedoring, insurance, etc. Its amount depends directly on, for example, conditions of deliveries. The amount of such costs varies significantly for different terms of delivery. Let's denote them by servicing units of each modes of transport \( j \) \( (j = 1, 2) \), equal to \( e_j \). Thus, the value \( e_j x_j \) is the total associated costs for mode \( j \). To form an optimization criterion, we calculate the cost value \( Q \):

\[
Q = (a_i r_i + e_i) x_i + (a_j r_j + e_j) x_j + c_s x_k
\]

(2)

where \( c_s \) is handling costs per unit of cargo from \( x_k \). Then, by introducing the notation:

\[
c_j = r_j a_j + e_j \quad (j = 1, 2)
\]

we rewrite the cost optimization criterion in a form of minimum search:

\[
\min \left( Q = \sum_{j=1}^{3} c_j x_j \right).
\]

(3)

Note, what with deterministic \( a_j \) \( (j = 1, 2) \), \( c_j \) \( (j = 1, 2, 3) \) and \( D_j \), the problem can become trivial [14] and be solved by linear programming method. In commercial applications, it is necessary to minimize \( Q \) taking into account the limitations:

\[
\sum_{j=1}^{3} x_j = T, a_i x_i + s_i = D_i, a_j x_j + s_j = D_j, x_j \geq 0, s_j \geq 0,
\]

(4)

where \( s_j \) is the deficit of corresponding units of transport.

Due to the conditions of market uncertainty described above, in practice enterprise managers will be able to have real data on costs \( r_i, r_j \) (and, accordingly, values \( c_i, c_j \)), only a certain time lag after making a decision on the values \( x_i, x_j, x_k \).

In addition, there are values \( a_i, a_j \) in a range of random variables, as well as potential levels \( D_i, D_j \) of the transport pool. Therefore, in practice the \( s_i, s_j \) indices will only be known once the exact values \( a_i \) and \( D_j \) are obtained. It follows that under conditions of market uncertainty [15] the \( a_i \) and \( D_j \) coefficients are random and the structure of the model constraints is not completely defined.

For completeness of the optimization problem, it is necessary to take into account that the multimodal transport operator delivers an additional amount of cargo that is not specified in the contract at a higher price. This formally corresponds to the excess of \( a_j x_j \) over \( D_j \).

In order to take this factor into account, we add \( (t_1 + t_2) \) to the left side of the balance ratios (4), and \( f_i t_i + f_j t_j \) to the formula (2) of the objective function. This is interpreted by the \( t_i \geq 0 \) values as the
excess of volumes over the contracted ones for transport \( j \), and \( (f, t_i) \) introduces the appreciation factor \( f_j \) for the delivery mode of \( t_i \) cargo units.

Finally, we formulate the optimization problem as a search for the minimum cost of the extended criterion \( Q' \). Let us introduce the following formal description:

\[
Q' = \sum_{j=1}^{3} c_j x_j + f_i t_i + f_{ij} t_j , \quad \text{under constraints}
\]

\[
a_i x_i + s_i - t_i = D_i ; \quad a_i x_i + s_i - t_i = D_i ; \quad \sum_{j=1}^{3} x_j = T
\]

(5)

The coefficients of appreciation in the directions \( f_i \) have a random nature, their values at the beginning of the planning period and at the time of determining the indicators for \( x_j \) are known only at a level of the probability distribution function. In addition, real data \( t_i \), and, accordingly, \( s_i \), are calculated after the values of random variables that define this mathematical model are determined.

4. Development and programming of machine-to-machine interaction

The solution of this problem can be reduced to an iterative algorithm of machine-to-machine interaction. Here, data about cargo parameters such as dimensions, weight, destination, time limits and restrictions on the transportation mode is written in QR code and computer automatically reads it. This serves as the source data for the calculation.

The degree of market uncertainty \( \sigma \) is used as a parameter of the normal (Gaussian) distribution, expressed as a percentage of the expected value. The computation consists of four basic steps outlined below.

1. Using simplex method on PC, we calculate values \( x_1, x_2, x_3 \) on the basis of certain data only relative to the values \( e_1, e_2 \) and \( c_i \).

2. From market monitoring, Internet survey data, we obtain an analytics by random values \( c_i, c_2, f_i, f_3, a_i, a_2, D_1, D_2 \) and the degree of their correlation with the values \( x_1, x_2, x_3 \).

3. Using PC, we calculate values \( c_i, c_2, t_1, t_2 \).

4. We carry out the calculation of \( x_1, x_2, x_3 \), using the condition of minimization of the functional \( Q' \).

Since when conducting real business, risk management is a must, it becomes possible to determine the final number \( W \) of states characterized by a set of indicators \( f_i, f_3, a_i, a_2, D_1, D_2 \) and their probabilities vector \( \overline{P} \) of the same length. To program the algorithm, we reduce these states to a \( \Omega \) matrix of \( W \times 6 \) size. If \( W = 3 \), then the matrix and vector have the form:

\[
\Omega = \begin{bmatrix}
  f_{i1}, f_{i2} & a_{i1}, a_{i2} & D_{i1}, D_{i2} \\
  f_{i3}, f_{i2} & a_{i1}, a_{i2} & D_{i3}, D_{i2} \\
  f_{i3}, f_{i2} & a_{i1}, a_{i2} & D_{i1}, D_{i3}
\end{bmatrix}, \quad \overline{P} = (p_1, p_2, p_3), \quad \sum_{i=1}^{3} p_i = 1
\]

(6)

In this case, the calculation is carried out using mathematical expectations. We obtain:

\[
E[a_j] = \sum_{q=1}^{3} p_q a_{qj} , \quad \text{and knowing} \quad E[r_j] \text{ and } e_j, \quad \text{define} \quad E[c_j] = E[r_j] \cdot E[a_j] + e_j, \quad j = 1, 2.
\]

Finally, the formulation of the model is as follows:

Minimize the expression

\[
E[c_1] x_1 + E[c_2] x_2 + c_3 x_3 + p_1 [f_{i1} t_{i1} + f_{i2} t_{i2}] +
+p_2 [f_{i3} t_{i1} + f_{i2} t_{i2}] + p_3 [f_{i3} t_{i1} + f_{i2} t_{i2}]
\]

under following limitations:

\[
\sum_{j=1}^{3} x_j = T
\]

(7)
planned activities of multimodal transport. There
means of transport is
2012. This fact should be taken into account when multimodal logistics
use in the delivery process.
only on the degree of market uncertainty
maintenance the end point and, accordingly,
when multimodal logistics pool
number of park units on the operat
Intermediate DC
Emergent DC
| option 1 | \( D_i \leq 12 \) | option 3 | \( D_i \leq 12 \) |
|---------|-----------------|---------|-----------------|
| option 2 | \( D_i \leq 20 \) | option 4 | \( D_i \leq 20 \) |

| 20 pct | 10 pct | 70 rbl/pcs | 90 rbl/pcs | 40 pcs | 40 pcs |
|-------|-------|-------------|-------------|-------|-------|
| 15 pct | 15 pct | 110 rbl/pcs | 80 rbl/pcs | 60 pcs | 30 pcs |
| 10 pct | 20 pct | 70 rbl/pcs | 90 rbl/pcs | 30 pcs | 60 pcs |

According to the model, it was assumed that decisions are made on the entire track without the participation of managers, which is equivalent to machine-to-machine interaction. However, this assumes that all the information needed for the solution is contained in the machine-readable code.

In the calculation process the computer makes from 1000 to 5000 iterations to find a solution. The calculation stops when the specified accuracy level is reached.

Figures 1-4 show the results of computer simulation of planned activities of multimodal transport operator using the machine-to-machine interaction. The value of the standard deviation of demand expressed as a percentage of the average value is shown on the X-axis. The calculation problem is formulated for two means of transport, with the park having limitations by number \( D_1 \) and \( D_2 \). There is also an option of an emergent DC to smooth out fluctuations in demand. This corresponds to two limitation options for the transport pool and the position of the distribution center in the supply chain.

Note that the Y-axis shows the initial values of the amount of cargo moved by two means of transport and located in DC, corresponding to the deterministic problem.

Figure 1 and Figure show the obtained results and we can see that the dynamics of using the intermediate DC changes as soon as one of the means of transport is fully loaded. In addition, it follows from the results of the calculation that the influence of the second means of transport is smaller than the first one. This can be explained by the smoothing of the load due to the intermediate DC. The calculations in Figure 3 and Figure 4 show the strong influence of the limitations by the number of park units on the operation of the emergent DC. This fact should be taken into account when multimodal logistics is designed. This is due to the fact that the emergent warehouse is located at the end point and, accordingly, in direct proximity to the customers. As a rule, the costs of its maintenance are many times higher than those of an intermediate DC.

The analysis of the obtained data leads to the conclusion that decisions are strongly dependent not only on the degree of market uncertainty \( \sigma \), but also on the role of configuration and technologies used in the delivery process.
Figure 1. The plan under limitation on \( D_1 \).

Figure 2. The plan under limitation on \( D_2 \).

Figure 3. The plan under limitation on \( D_2 \).
Figure 4. The plan under limitation on $D$.

So, if the distribution center is located between transition from one transport to another (figures 1-2), its utilization is reduced, but if it is located in the area of the final recipient (figures 3-4), then it plays the role of the emergent stock that helps to smooth the uneven demand.

The formulas for three levels of the set of indicators obtained for a particular example are actually scalable and allow to write the algorithm in a matrix form. The dimension of the model is not limited, not only parameters related to multimodal transportation can be used as the control variables, but also related processes such as cross-docking, pick-by-line, which are included in the overall machine-to-machine interaction chain. We can separately consider joint optimization when taking into account the Private Label segment [16], which accounts for up to 25% of the turnover of retail chains. A distinctive feature for the part of the variables is that they will be determined for this position, but for their distribution parameters it is necessary to specify zero dispersion and use the same expressions.

Also, you can include in the parameters such important indicators for cross-border commerce [17] as customs clearance, border control, including delays in crossing state borders and change of transport operator. At the same time, it is necessary to control the volume of machine-readable codes on the transported loads so that it contains the information necessary for the algorithm.

6. Conclusion
The proposed mathematical model allows one to choose the optimal load ratio when several means of transport and intermediate storage are used. Also, a distinctive feature of the model is the consideration of the stochastic nature of the demand for goods, which reflects market uncertainty. In addition, the model takes into account the location of the warehouse for intermediate storage, either between transportation stages, as in the cross-docking technology, or at the final unloading point in a form of a consolidation warehouse. The main application area of these results is the automation of decision-making in planning [18] the activities of the multimodal transport operator. The advantage of this method is the possibility of using machine-to-machine interaction technologies, including cloud-based ones. Due to the obtained algorithm, it is possible to automate some procedures used on the controllers of automated warehouses, palletized robots, and interoperation automatic transport. Such intelligent systems will make it possible not only to exclude human forwarders from the technological process, but also to improve economic performance by reducing costs, and choosing the best inter-transport interaction. Their usage towards higher levels of third-party logistics is promising. Since additional conditions can be introduced in the calculation process, it will allow us to observe cargo handling modes and to take into account their limitations on storage periods. Implementing the
subsystems [19] in the software applications used by managers of network commercial enterprises, in a form of an expert system, will provide a tool of competitive advantage when current activities are planned.

Acknowledgment
The research carried out with the financial support of the grant from the Program Competitiveness Enhancement of Peter the Great St.Petersburg Polytechnic University, Project 5-100-2020.

References
[1] Ilin I V, Izotov A V, Shirokova S V, Rostova O V and Levin A I 2017 Method of decision making support for it market analysis. Paper presented at the Proceedings of 2017 20th IEEE International Conference on Soft Computing and Measurements, SCM 2017, 812-814. doi:10.1109/SCM.2017.7970732
[2] Alexandrova I and Zhabko A 2018 A new LKF approach to stability analysis of linear systems with uncertain delays Automatica, 2018, vol. 91, pp. 173-178
[3] Glukhov V V and Balashova E 2015 Operations strategies in info-communication companies Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 2015, No. 9247, pp. 554-558
[4] Kravets O J, Barkalov S A, Butyrina N A, Sekerina V D and Gorokhova A E 2018 Processes of multidimensional classification of scoring objects with heterogeneous features based on the neural networks modeling International Journal of Pure and Applied Mathematics. 2018. vol. 119. no. 7a. C. 875-879
[5] Krasyuk I A, Bakharev V V, Kozlova N A and Mirzoeva D D 2017 Staffing in the sphere of trade: the main issues and prospects of solution Proceedings of 2017 IEEE 6th Forum Strategic Partnership of Universities and Enterprises of Hi-Tech Branches (Science. Education. Innovations), SPUE 2017 6. 2018. pp. 48-50.
[6] Tsatsulin A N, Babkin A V and Babkina N I 2016 Analysis of the structural components and measurement of the effects of cost inflation in the industry with the help of the index method Proceedings of the 28th International Business Information Management Association Conference Vision 2020: Innovation Management, Development Sustainability, and Competitive Economic Growth, pp. 1559-1573
[7] Yanenko M 2016 Cost-Based Brand Management International Business Management Year: 2016. Volume: 10. Issue: 26. Page No.: 5991-5995.
[8] Babkin A V and Kudryavtseva T J 2015 Identification and analysis of instrument industry cluster on the territory of the Russian Federation Modern Applied Science, 9 (1), pp. 109-118. DOI: 10.5539/mas.v9n1p109
[9] Shchukin T 2014 Neuronet: the next generation communication environment Technowars - 2014. № 5. p. 66-85
[10] Borisoglebskaya L N and Sergeev S M 2018 Model of assessment of the degree of interest in business interaction with the university Journal of Applied Economic Sciences 2018, vol. XII, Iss. 8 (54) Winter 2017, pp. 2423-2448
[11] Aleksandrov A and Zhabko A 2014 Delay-independent stability of homogeneous systems Applied Mathematics Letters. 2014. vol. 34. no. 1. pp. 43-50.
[12] Babkin A V, Plotnikov V A and Muraveva S V 2015 Integrated industrial structures in the economy of Russia: Organizational forms and typology Proceedings of the 25th International Business Information Management Association Conference - Innovation Vision 2020: From Regional Development Sustainability to Global Economic Growth, IBIMA 2015, pp. 1286-1293
[13] Podvalny S L and Provotorov V V 2015 The questions of controllability of a parabolic systems with distributed parameters on the graph // International Conference "Stability and Control Processes" in Memory of V.I. Zubov (SCP) 2015. pp. 117-119
[14] Provotorov V V 2015 Boundary control of a parabolic system with distributed parameters on a graph in the class of summable functions *Automation and Remote Control*. 2015. vol. 76. no. 2. C. 318-322.

[15] Karvanen Juha, Rantanen Ari and Luoma Lasse 2014 Survey data and Bayesian analysis: a cost-efficient way to estimate customer equity *Quantitative Marketing and Economics* 12 (3) pp. 305–329

[16] Krasnov S V, Sergeev S M, Mukhanova N V and Grushkin A N Methodical forming business competencies for private label *Reliability, Infocom Technologies and Optimization (Trends and Future Directions)* 6th International Conference ICRITO 2017, p. 569-574

[17] Kapustina I V, Kirillova T V, Ilyina O V, Razzhivin O A and Smelov P A 2017 Features of Economic Costs of Trading Enterprise: Theory and Practice *International Journal of Applied Business and Economic Research* vol. 15. №11. 2017. pp.1-10

[18] Lavrova D, Pechenkinc A and Gluhov V 2015 Applying correlation analysis methods to control flow violation detection in the internet of things *Source of the Document Automatic Control and Computer Sciences*, 49 (8), pp. 735-740. DOI: 10.3103/S0146411615080283

[19] Kagermann H, Wahlster W and Helbig J 2013 Recommendations for implementing the strategic initiative Industrie 4.0 *Final report of the Industrie 4.0 Working Group* 2013