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ЦЕЛИ И ЗАДАЧИ

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CONCERNING THE PROBLEM OF SEMANTIC CONTRADICTIONS ARISING WHEN USING THE TERMS "INTERMODAL" AND "MULTIMODAL" PASSENGER CARRIAGES

Bludyan N.O., Paramonova L.A.

This article examines Russian and foreign regulatory documents, concerning the issues of intermodal/multimodal passenger carriages, shows the essence of intermodal transportation in passenger transport, includes the analysis of various approaches to the concepts of "intermodal passenger transportations" and "multimodal passenger transportations" and contains proposals for legislative consolidation of the mentioned terms and for the implementation of intermodal technologies in passenger transport.

Keywords: *intermodal/multimodal carriages of passengers; construction of an effective transportation system; carriers' liability; a new ticket system; interchange points.*

Introduction

In the conditions of economic globalization, intensifies the value of the transportation industry. This is due to the increase in passenger demand for movements and to the necessity of construction of an effective transportation system. The priorities and the requirements of passengers to the quality of transport services have changed, there has formed a new factor in the field of preferences – comfort.

Thus, at present the main criteria when choosing a mode of transport are time and financial costs, comfort, the desire of passengers to organize their journey on their own through the Internet and security.

Intermodal and multimodal technologies are best suited to meet the demands of consumers of transport services. Maximum use of the advantages of each mode of transport, which is realized in the organization of intermodal / multimodal passenger carriages, allows to optimize time costs and provide a high level of service, to reduce financial costs in accordance with the pricing policy in the market of intermodal carriages – a single operation must be cheaper than the total cost of separate carriages by various modes of transport for a particular route.

The introduction of the technology of intermodal passenger transportation is a key direction of development of the transport network in many foreign countries.

Implementation of intermodal technology not only provides benefits to passengers and encompasses economic interest for carriers, but also modifies the form of competition: instead of the usual competition between different modes of transport competition develops between the transport companies within a particular mode of transport.

This kind of competition should be considered the most logical, since in view of the fact that each mode of transport has its advantages, in certain areas carriers are not competitive due to technical, organizational and other factors.

1. The essence of intermodal transportation in passenger transport

Currently, the Russian law as well as internationally, the concept of “intermodal” and “multimodal” in relation to passenger transport is not fixed.

There are several approaches to determining the meaning of the terms “intermodal” and “multimodal”.

In accordance with one of the approaches multimodal passenger transportation, also referred to as a mixed type of transportation by various modes of transport, suggests the use of two or more modes of transport for the trip.

Intermodal passenger transportation is considered as transportation, in which the transportation is carried out with registration of the contract wherein responsibility for transportation lies with the operator, which in turn has a contractual relationship with other participants, providing a particular service.

Thus, according to this source, the difference between these two types of transportation is only in the liability sharing between carriers that can be split in accordance with their respective segments of transportation, or assigned entirely to the specific operator.

It is also noted that the term “mixed passenger transportation” used in Russian Federation combines two concepts: “multimodal” and “intermodal”.

Another point of view on the differences between these terms belongs to A.S. Romanova, who believes that the term “multimodal transportation” is preferred to use at the international and national levels. [1] In her opinion, the term “intermodal” has more economic and sociological than legal affiliation”.

However, this condition is not indisputable, since in the case of passenger traffic, the term “intermodality” has a legal affiliation in the sphere of regulation of carriers’ responsibility.

In this regard, it can be concluded as applied to passenger transport systems that interpretation, revealing the meaning of the terms “intermodal”, “multimodal”, “mixed”, has approximately the same contents and doesn’t describe the differences.

Professor A.S. Skaridov [2] gives the following interpretation of intermodal transport: “Under the intermodal transportation it should be understood the carriage of goods or passengers by more than one mode of transport in a single transport operation, executed by a single relevant contract of carriage”.

Thus, A.S. Romanova and A.S. Skaridov are committed to a single point of view, which is diametrically opposed to the one described at the beginning of the study on the responsibility for transportation.

In foreign practice, both terms are used without any semantic difference.

In foreign sources, the terms “multimodal” and “intermodal” in relation to passenger carriages are not fixed in legal documents, but in all documents (projects, the European Commission reports and other documents) they mean:

- “Characteristics of transport network, which involves the use of at least two different modes of transport for one journey from origin to destination.”
- “Characteristics of transportation, in which at least two different types of transport for one journey from origin to destination are used.”
- “Characteristics of a nodal point, which allows you to transfer (transplant) between at least two different modes of transport.”

The study of all points of view leads to the conclusion that the most logical distinction between “multimodal” and “intermodal” is the based on the extent of carrier’s liability. At the same time, when coordinating and unifying the concepts it should be noted that the transportation document must be single. The degree of responsibility will be registered in the contracts between carriers. The following situations are possible:

a) one of the carriers will be responsible for the entire carriage;

b) there must be a responsible carrier for each segment of the carriage, which he operates, at the time of connection the responsibility will be shared according to the terms of the agreement;

c) companies will appoint a third-party operator – an organizer of transportation; this option can be selected if the value of the probable losses from breach of transportation (with high probability) is significantly higher than the cost of services of a third-party operator and of insurance services.

2. Background to the introduction of intermodal and multimodal technologies in Russia

2.1. The term "Direct mixed transportation"

The Russian Civil Code [3] provides the concept of "direct mixed transportation", enshrined in Art. 788 of Chapter 40, which establishes that in case of direct mixed transportation the carriage of passengers and baggage is operated by different modes of transport under a single transport document; the order of the organization of such carriages is determined by agreements between the organizations of the relevant modes of transport, concluded in accordance with the law on direct mixed (combined) traffic, but to date this law has the status of a bill.

The Ministry of Transport of the Russian Federation has prepared a bill of the Federal Law "On direct mixed (combined) traffic", but at the moment it is not yet included in State Duma of the Federal Assembly of Russian Federation. [4] His analysis (Article 2) shows that the two key points, allowing to classify the transportation of passengers and baggage as a direct mixed, should be highlighted:

– different modes of transport should be used in the carriage;
– the transportation is implemented by a single transportation document issued for the whole journey.

A single transportation document is defined as a document of carriage (travel document) (such as a ticket, baggage check of direct mixed transportation), which confirms the conclusion of a contract of direct mixed transportation of passengers and luggage.

The issue of liability of carriers is very important in the construction of the intermodal transport chain.

Article 23 of the Bill contains a list of circumstances exempting carriers from liability and the conditions under which the carrier is relieved from liability. But in this article the question of determining the person responsible for the elimination of the consequences of these circumstances and for the implementation of the conditions of the contract (transportation of passengers and luggage to the destination), if there has been a breakdown in the transportation process for reasons not dependent on the carrier, is overlooked.

As a result of the study of the Bill it can be concluded that the term "direct mixed transportation" in its meaning fully (completely) corresponds to the term "multimodal passenger transport."

In foreign practice, there are transportations from the point of origin to the point of destination involving such modes of transport as air, rail, and water, which imply transplantations, in which the need to provide a passenger with a seat for each type of transport and the docking. This means that the carrier himself suggested this route or that a passenger has built it with the consent of the carrier; advance payment of the entire cost of the whole passenger transportation ensures following this route (in case of changes in conditions or of a passenger's refusal of transportation service charges may be levied). In this connection, the carrier shall be liable, including, for the moment of docking, in contrast to the urban traffic, when a passenger at any time can change the route: it is not known in advance to the carrier, and seat and docking are not provided by carriers. Two types of transportation should be divided. Accordingly, service technology will be different. State regulation will also differ from the point of view of responsibility.

It is proposed to distinguish intermodal transportation, under which the question of responsibility for the docking will be regulated by the government, from multimodal (direct mixed transportation), in which the carriers are not responsible for it.

The legal acts should reflect the provision that in case of intervention of circumstances beyond the control of carriers, the person responsible for the elimination of the effects of those circumstances as soon as possible and for fulfilling the obligations on carriage is determined by agreement between the carriers. As mentioned above, at the discretion of carriers liability may be carried by one carrier, it can be distributed between them in any ratio, or an additional agreement may be entered with a third party organization responsible for organizing the whole transportation.

The table shows the identification characteristics of multimodal and intermodal passenger transport.

Table 1.

The identification characteristics of multimodal and intermodal passenger transport

Title of feature	Multimodal transportation	Intermodal transportation
The presence of a single transportation document	+	+
Schedule		
Coordination for the carriage of passengers to a point of destination	–	+
Coherence in whole	+	+
Payment for carriage		
Prepayment	–	+
Payment or debit of funds in a vehicle	+	–
The one-time write-off of funds for transportation as a whole in all modes	–	+
Sphere of application		
Urban and suburban transportation	+	–
Transportation over long distances	–	+
System of mutual settlements		
The presence of passengers' responsibility to the carrier in case of refusal to follow on any of the following transportation segments	–	+
Liability of the carrier		
The presence of responsibility for transportation on a particular route segment	+	+
At the moment of docking (for docking)	–	+
Sales channels		
Internet – the main sales channel	–	+
Representations of carriers (agencies, offices, etc.)	+	+
Fare rules		
The presence of passenders' obligation to inform the carrier in case of refusal to follow on any segment	–	+

End of the Table 1/

The presence of single published fares	–	+
The technology of route construction		
Passenger self-construction of route (route selection, search of stops, the calculation of transit time)	+	–
The presence of an opportunity to build the required route in a special program (all routes are docked)	–	+

Analysis of the table leads to the conclusion that it is appropriate to use the term "intermodal transport" for the organization of passenger transportation on long distances by air, rail, automobile and water transport modes. Multimodal transport is appropriate to urban and suburban transportation of passengers, for example, as part of the transport system of Moscow agglomeration.

In connection with the above it is offered to formulate the concept as follows:

Intermodal passenger transportation is a transportation of passengers, baggage and hand luggage from origin to destination by more than one mode of transport under a single transport document, in which the responsibility for the entire transportation process, including docking in interchange nodes, lies on a specific carrier / s or on a third-party operator.

Multimodal passenger transport is a transportation of passengers, baggage and hand luggage from origin to destination by more than one mode of transport under a single transport document, in which the carriers are liable only for particular segment/-s of route, operated by them.

2.2. Organization of multimodal / intermodal passenger transportation in Moscow

Transportation system in Moscow includes the following types of transport: ground urban public passenger transport, the Moscow Metro (hereinafter – the "Metro"), The Moscow Central Circle (MCC), a commuter railway transport, taxi, private transport, cycling infrastructure, car sharing [6] and others.

The goals, objectives and actions for the development of the transport system of Moscow are contained in the "State programme of the City of Moscow" Development of Transport System "for the period 2012–2016 and up to 2020" [5].

Among the basic conceptual directions of development of the Moscow transport hub can be distinguished:

- Providing the benefits of public transport in the implementation of passenger transportation;
- Enhancing the role of railways in the implementation of the suburban and urban transportations;
- Improving of the quality of services provided by the transport system, based on effective interaction between urban systems, suburban and inter-regional transport;
- Introduction of a new ticket menu and development of tariff policy, and others.

These directions and the idea of introduction of multimodal technology in passenger transport are interdependent.

The Program provides for the implementation of a number of activities that are aimed to reduce the average overall travel time during peak hours by increasing the carrying capacity of public transport by 40%. Organization of multimodal passenger transportation will be an additional factor affecting the attractiveness of the Moscow transport system, and will help to reduce the share of private cars.

In the list of results of the State Programme realization there are envisaged the introduction of intermodal tickets (tickets, valid on various types of public transport) – as they are named in the programme – and the reduction of the time passengers spend on a change between types of transport in major transport interchange nodes from 15 to 8–10 minutes.

Currently, ticket agglomeration system is represented by cards "Troika", "Strelka" and the combined card "Troika" and "Strelka" [7]. "Troika" enables passengers to pay for travelling by metro, by the MCC, by Moscow ground passenger transport, by suburban trains, in

Aeroexpress [8] etc. "Strelka" [9] is valid in Moscow Oblast and the combined card – in Moscow and in Moscow Oblast [10], [11].

Thus, a single transport document as one of the components of multimodal passenger transportation has already been implemented.

Organization of multimodal passenger transportation will facilitate to build an effective system of transport services, to combine different modes of transport in order to use the advantages of each type and to optimize time and financial costs, as well as to implement other tasks. For example, the implementation of measures aimed at improving the work of the suburban railway transport provides an opportunity to reduce the load on metro and on ground urban passenger transport.

Construction of a single TPU system (system of transport interchange hubs) and of new modern bus stations in Moscow and in the Moscow Region, improvement of the work of TPU (reducing time to transfer, ease of use by passengers and so on) increases the comfort and attractiveness of the transport system services [12], [13]. Involvement of cycling in Moscow transport system, as well as its inclusion in the chain of multimodal passenger transportation, contributes to the increase of mobility, increases transport accessibility between districts of the city, reduces the time costs and the negative impact on the environment. To activate the cycling in the system of multimodal passenger transportation it is necessary to ensure the availability of parking points in the immediate vicinity of the stopping points of other modes of transport, especially the metro station and the MCC.

At present, the transport infrastructure of Moscow is being developed, improved, reorganized, updated rapidly. Implementation of multimodal technology will make it more effective [14], [15].

Conclusion

As a result of the analysis of the legal framework governing intermodal transportations involving road, rail and air transport and multimodal urban and suburban transportations, it was revealed that in the Russian and the international legislation the terms "intermodal" and "multimodal" in relation to passenger services are not fixed. The absence of the formulated concepts in the Russian legislative acts leads the participants of the transportation process to semantic contradiction, which does not allow to develop a unified technology of intermodal / multimodal passenger transportations.

The studies lead to the conclusion that it is appropriate to consider the term "multimodal" equivalent to the term "direct mixed transportation," and it's logically correct to divide multimodal and intermodal transportations on the point of responsibility for the docking in the interchange nodes.

When attaching the term "intermodal passenger transportation" and "multimodal passenger transportation," there is a need to amend the existing legislation, due to the fact that the conditions of transportations change. For example, in the case of intermodal transportation the terms of the ticket sales, ways of implementation conditions of carriage of certain categories of passengers are to change. It is proposed to draw up the necessary amendments as a separate section in the Bill and to make reference to this document in the existing legislation (The Civil Code, the transport charters and codes, etc.). There can be formulated common rules for operations with a single transport document in this document. It should be electronic. Requirements for baggage, carry-on baggage must be formed on the basis of the most stringent of existing, for transportation not to be interrupted due to the violation of certain rules on some mode of transport.

For the development of a single transportation document there will be required the harmonization and unification of requirements to the ticket and to the details indicated in it. Development and implementation of a single transportation document is associated with a number of other problems. These include:

- lack of technical equipment in the ticket sales points and lack of skills in the majority of staff to work with different electronic systems used on different types of transport;
- no single information space;
- issues related to the formation of tariffs.

The organization of intermodal transportation is an innovative technology, which requires the development of a legal instrument, the implementation of the relevant researches, development or improvement of software products, significant financial and labor costs, but at the same time allowing to take maximum advantage of each mode of transport, improve transportation efficiency, speed, comfort, increase the level of security on individual modes of transport and to reduce the cost of transportation.

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EVALUATION OF THE FREQUENCY OF DIAGNOSTICS OF COMPONENTS AND ASSEMBLIES FOR TRANSPORT AND TECHNOLOGICAL MACHINES ON THE BASIS OF HIDDEN MARKOV CHAINS

Nikolaev A.B., Sakun B.V., Karelina M.Yu., Satyshev S.N., Bugrimov V.A.

In this article a statistical analysis of supply volumes of spare parts, components and accessories was carried out, with some persistent patterns and laws of distribution of failures of major components revealed. There are suggested evaluation models of components and assemblies reliability for the formation of order management procedures of spare parts, components and accessories for the maintenance and repair of transport and technological machines. For the purpose of identification of components operational condition there is proposed a model of hidden Markov chain which allows to classify the condition by indirect evidence, based on the collected statistics.

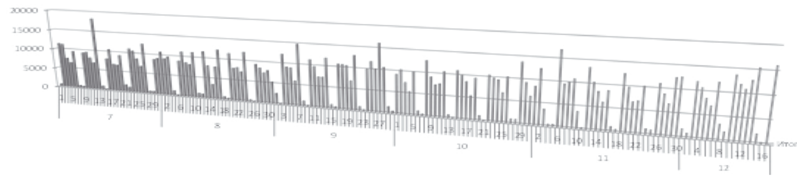
Keywords: *Transport machines; diagnostics; components and assemblies; Markov chains; statistical analysis; maintenance; repair and orders management.*

1. Introduction

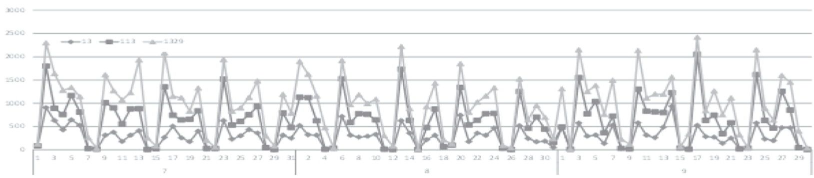
In the general case, maintenance services of transport and technological machines can be divided into the following main groups [1–3]: preventive, aimed at routine maintenance (diagnostics, mounting, checking, oiling and adjusting works after a certain run); repair – carried out for elimination of failures appeared and restoring to working condition (replacement or repair of components, devices and assemblies, as well as body, fitting and mechanical, electro-mechanical works and other); ensuring operation – supply of fuel, oil, antifreeze and others. Thus the problem of modeling the reliability schemes and preventive replacements for the formation of components and assemblies reserves of auto transport enterprise (ATE) is relevant enough [4–6].

2. Statistical analysis of failures of components and assemblies for transport and technological machines

Solution of the problem of supply control synthesis is primarily based on the prognosis of various financial indicators [7]. The carried out analysis of the dynamics of order flow in a number of enterprises included in the service area of one dealer network, allowed to plot a chart of the volume of orders given in Fig. **1**.a. Rankings of ATE by the order flow volume showed that almost 20% of the orders flow accounts for 5 of the 200 enterprises. For the first three ATE conducted more detailed analysis of the orders flow (Fig. **1**.b). It demonstrates a significant correlation within certain groups of spare parts (Fig.**2**.a) [8, 9]. There was conducted an analysis of autocorrelation functions of time series (Fig. **2**.b).



a) Orders flow of all enterprises

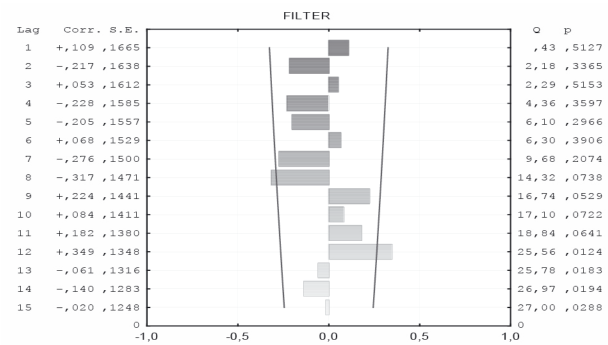


b) Orders flow of the main enterprises

Fig. 1. Time series of orders flow for accessories

Variable	Correlations (Rez_Sol_2_Корр.sta) Marked correlations are significant at p < ,05000 N=33 (Casewise deletion of missing data)				
	Means	Std.Dev.	AIR_REF	GASKET	FILTER
AIR_REF	14213,97	5843,132	1,000000	0,956394	0,987831
GASKET	20482,39	8065,382	0,956394	1,000000	0,965744
FILTER	20334,42	8275,620	0,987831	0,965744	1,000000

a) Table of correlations



b) Autocorrelation function

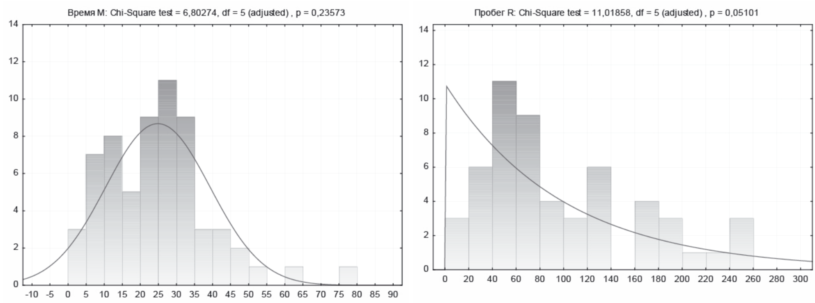
Fig. 2. The average monthly demand rate for the main parts

On the basis of the carried out analysis of the demand rate for spare parts and accessories it is given a task of modeling of time series with the set (obtained on the basis of statistics) values of correlation evaluations and autocorrelation functions.

In terms of repair of the platform lifting mechanism (PLM) there was conducted an analysis of reliability indices [3, 11]: 1. mean life to the first failure (thous. km.); 2. confidence interval (thousand km.); 3. standard deviation (thous. km.); 4. variation coefficient; 5. Weibull parameter ***b***; 6. Weibull parameter ***a***; 7. gamma – percentile life at γ= 90% (to the first failure); 8. gamma – percentage life at the given value γ= 90% (to the second failure); 9. failure rate per given operating time t_1 = 30 thous. c. (to the first failure); 10. failure rate for the given operating time t_1 = 30 thous. c. (to the second failure); 11. Index $C_{pz}(t)$ of calculation methodology; 12. Index $C_0(\Delta t)$ of calculation methodology.

There were revealed main types of failures and malfunctions of PLM parts under specified operation conditions. There was calculated mean life of details, limiting platform lifting mechanism reliability, as mathematical expectation: $t_{co} = \frac{1}{N_0}\sum_{i=1}^{N_0} t_i$ thous. km, where t – run to limit state of the Ist element; N_0 – number of controlled elements.

For the approbation of failure models there was performed a statistic analysis and obtained main characteristics of the distribution by mean time between failures and run. On the basis of available data was made approximation of distribution functions: mean time between failures – by normal distribution law; for the run – by log-normal (Fig. 3).



/Time/ /Run/

Fig. 3. Approximation of distributions of the mean time between failures

Verification of compliance of general population sample characteristics showed that the experimental data on the distribution of parts life, limiting the PLM reliability are consistent with the theoretical Weibull laws of distribution and normal [12–15].

On the basis of the carried out analysis it follows that details life, limiting the reliability of the platform lifting mechanism, are within the 67–238 thous. kilometers and have variation coefficient of V = 0,27–0,77. Processing and analysis of statistical data, as well as the specific failures and malfunctions of parts, limiting the reliability, allowed to develop a chart of platform lifting mechanism reliability of MAZ dump trucks.

3. Assessment problem of optimal frequency of components diagnostic

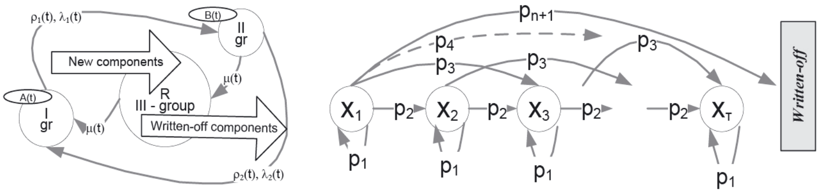
In order to determine optimal frequency of components diagnosis there was developed a model describing the change of operational status. A flow chart of this model is shown in Fig. 4.a. All components being in operation, were divided into three groups: the components satisfying the standards corresponding to operation season by their parameters (group I); components that remain functional, but not meeting current standards by their parameters (group II); components being repaired, new components, being prepared for use and components to be written off (buffer group III). The following indications were adopted in the model:

- $A(t)$, $B(t)$ – distribution of components due to the time in operation, respectively, in the I, II and III groups;
- $\lambda_1(t)$ – respectively rate of distribution and intensity of the flow of components transitions from the group I to the group II;
- $\lambda_2(t)$ – respectively rate of distribution and intensity of the flow of components transitions from the group II to the group I;
- $\mu(t)$ – flow rate of placing under repair or write-off and flow rate of putting new and renovated components into operation.

The analytical expressions for A(t) and B(t) were received both in the absence and in the presence of components reliability control system due to the condition. These solutions also describe part of components in pre-failure condition. This part depends both on the frequency of diagnosis and on the parameters of distribution laws for the probability functions being fundamental for $\lambda_1(t)$ and $\lambda_2(t)$. In its simplest form (without diagnostics), these expressions have the following form:

$$A(t)=A_0P_1(t),\ B(t)=B_0P_2(t)e^{-\mu t}. \qquad (1)$$

The authors proposed an assessment model of the frequency of inspections of the brake discs in order to minimize the loss of resources and working time for their bore in accordance with statistical data (wear-out measurements) obtained on each specified ATE. Construction of the model was carried out using a known apparatus of graph charts describing a discrete set of states of the object with a particular set of functions and transitions between these states – peaks of the flow-chart (Fig. **4**.b). [16–18].



a) Distribution of technical condition **b)** Flow-chart of components states

Fig. 4. Markov model of the change of components states

As peaks were taken moments of time corresponding to the facts of machining of parts. At the same time in order to find functions of the transition between states (determined in each particular case for different parts) are required statistical data on changes in the technical state of details in real operating conditions, taking into account boundary conditions of the problem having an impact on adequacy of the description of the model, such as the spread of the values of the geometric parameters of new parts at the time of installation on the vehicle, its writing off, etc.

4. Diagnosis of the state of components and assemblies on the basis of hidden Markov chains

For the problem of identification of components, state it is suggested a model of hidden Markov chain, which allows classifying the state by indirect evidence on the basis of the accumulated statistics. The model represents a tuple **SMM = {S, V, λ},** where:

1. **S**={S_1, S_2,…, S_n} – number of states of the model, where N – number of states, q_t – current state at the moment of time t.

2. **V**={v_1, v_2,…, v_M} – alphabet of the observed sequence.

3. **λ**=(A, B, **π**), where A=||a_{ij}|| – probability transition matrix, a_{ij} =P[q_{t+1}=S_j | q_t=S_j], 1≤*i,* j≤N; B=||$b_j(k)$|| – distribution of probability of occurrence of symbols in the j-state, where $b_j(k)$=P[v_k | q_t=S_j], 1≤*j*≤N, 1≤*k*≤M; π_i=*P*[q_1=S_i], 1≤*i*≤N.

SMM generates the observed sequence: O_1, O_2,…, *O*, where OtOV, T – length of sequence.

The sequence generation algorithm suggested by authors supposes the following steps:

Step 1. Select the initial state q_1=S_i in accordance with the distribution π=(π_1,…, π_N).

Step 2. Set t=1.

Step 3. Select O_t=v_k according to the distribution b_j(k) in S_i state.

Step 4. Transfer the model to the new state q_{t+1}=S_j in accordance with the transition matrix ||a_{ij}|| taking into account the current state of S_i.

Step 5. Set the time t: = t + 1; go back to step 3, if t <T; otherwise – the end of the algorithm.

On the basis of the model the following problem is solved: Given the sequence observed O_1, O_2,…, O_T and model λ=(A, B, **π**).. It is necessary to calculate the P(**O**|λ) – the probability that the observed sequence was constructed specifically on the basis of this model.

Let us consider the type of counting the probability of occurrence of the sequence of observations for each possible sequence of states of the model on the example of one sequence of states Q={q_1, q_2,… ,q_T, }, where q_1 – initial state of the model. The probability of sequence occurrence **O** is $P(O \mid Q,\lambda) = \prod_{t=1}^{T} P(O_t \mid q_t, \lambda)$ where there is a statistical independence of observations. Probability of matching ***O*** and ***Q***, ie possibility of their simultaneous manifestations is expressed by

$P(O,Q|\lambda)=P(O|Q,\lambda)\cdot P(Q,\lambda)$. The probability of occurrence of ***O*** – is the sum of the probabilities for all possible combinations of states of q system:

$$P(O|\lambda)=\sum_{Q}P(O|Q,\lambda)\cdot P(Q,\lambda)$$

On the Fig. 5 it is shown the sample path of the hidden Markov chain of changes of component states generated according to the designed model.

To solve this problem it is suggested to use forward and reverse algorithms. At that $\alpha_t(i)$ is defined as $\alpha_t(i)=P(O_1,O_2,...,O_t,q_t=S_i|\lambda)$. That is the possibility that the given model λ at the moment time t was observed a sequence $\boldsymbol{O}_1$, $\boldsymbol{O}_2$,…, $\boldsymbol{O}_T$ and at the time t and the system is in the state S_i.

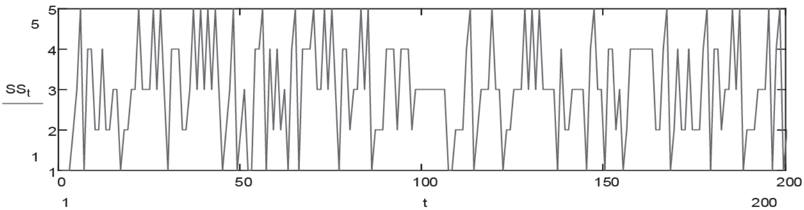


Fig. 5. Sample path of the hidden Markov chain of components states change

For searching the values of $\alpha_t(i)$ is suggested a recurrent scheme:

1) Initialization: $\alpha_1(i)=\pi_i b_i(O_1)$, $1\le i\le N$.

2) Induction: $\alpha_{t+1}(j)=\left[\sum_{i=1}^{N}\alpha_t(i)\alpha_{ij}\right]b_j(O_{t+1})$, $1\le t\le T$-1, $1\le j\le N$.

3) Completion: $P(O|\lambda)=\sum_{i=1}^{N}\alpha_Y(i)$.

During the approbation the given algorithm has shown a sufficiently high convergence and low probability of misclassification.

5. Information Support System

To accompany data concerning registration, current state and record of repairs of the serviced equipment it is suggested to use information support system (Fig. 6). The system includes subsystems of registration of equipment lists, registration of data about the performed maintenance operation and repairs, as well as formation of reports on the current status and record of repairs of the serviced equipment.

The results of performing the procedure 1 are the lists of the serviced equipment registered in the information system. Incoming documents include a list of equipment to be repaired and subject to maintenance with basic requisites: customer, list of machines, etc. [19, 20].

The results of performing the procedure 2 are data on the current status and record of repair of techniques, registered in the information system. Incoming documents include act of completion of work with basic requisites: act number, date, order number, customer, repaired equipment, the list of parts actually used in the repair, actually performed work, actually incurred labor costs.

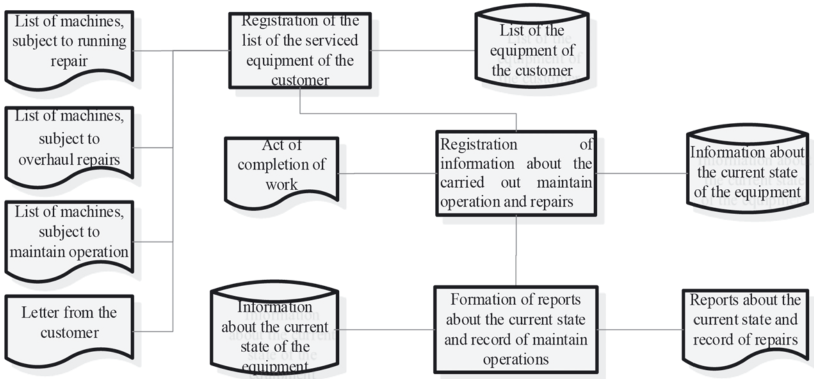


Fig. 6. Information support system

Procedure 3 of the formation of reports on the current status and repair record of the serviced equipment of regular customers include tabular and graphical forms in the information system concerning: machines, customers, dates, types of work, etc. Outbound documents include: customer, car mark, garage number, chassis number, endurance operating hours, the site made repairs, contract number, the date of execution of works, the number of act of completion, type of work (maintain operation, running repairs, overhaul repairs, etc.), the repaired system (engine, chassis, hydraulics, etc.), carried out works, performer of the works, the amount of work, installed parts, the sum on spare parts, purchased parts, parts manufactured in ATE, parts manufactured by the forces of subcontract organization.

6. Conclusion

The conducted statistical analysis of the flow of applications for parts, components and accessories of various groups and types of turnover from a number of transport enterprises allowed to reveal relationship between the different parts and groups of ATE. By the example of the platform lifting mechanism was carried out a research of the flow of failures of components and details of transport and technological machines, which allowed us to estimate the parameters of probability distributions for the models of formation of reserves in the maintenance and repair management systems. On the basis of hidden Markov processes were developed models of diagnostic and identification of the state of components and assemblies, allowing to identify the technical condition of equipment by indirect evidence. An original algorithm for generating the sequence of inspections was developed. It was suggested to use the information support system for the maintenance of data concerning registration, current status and record of repairs of the serviced equipment.

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IMPLEMENTATION OF INCIDENT DETECTION ALGORITHM BASED ON FUZZY LOGIC IN PTV VISSIM

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Traffic incident management is a major challenge in the management of movement, requiring constant attention and significant investment, as well as fast and accurate solutions in order to re-establish normal traffic conditions. Automatic control methods are becoming an important factor for the reduction of traffic congestion caused by an arising incident.

In this paper, the algorithm of automatic detection incident based on fuzzy logic is implemented in the software PTV VISSIM. 9 different types of tests were conducted on the two lane road section segment with changing traffic conditions: the location of the road accident, loading of traffic.

The main conclusion of the research is that the proposed algorithm for the incidents detection demonstrates good performance in the time of detection and false alarms

Keywords: *Traffic incident management; PTV VISSIM; Automatic methods; detection of road incident.*

1. Introduction

Application of fuzzy logic in the system of incident detection allows to make a decision under conditions of uncertainty. Process of traffic incidents detection is a process of finding difficulties in traffic, which occur on the roadway. The difficulty in the conveyor flow is a major indication that there was a road accident and its elimination requires a reaction. The difficulty in traffic is the main indication that there was a road accident and its elimination requires a reaction.

This conclusion led to the use of input data that will be relevant to the vehicles and the road, with this data must be considered together and should be compared with the corresponding values for further analysis. The main parameters of the traffic flow, which can characterize its current state, are: flow rate; flow volume.

Necessary to analyze the data received from the sensors. After that, the fuzzy rules take these data as evidence, and depending on them and imposed fuzzy rules will be taken action that will improve the situation in traffic or at least not allow it worse.

When an incident occurs, it is formed on the road a congestion. Once the incident is considered to be eliminated, the road capacity is increased and congestion is dissipated. The algorithm determines the state of the road on changing of flow rate and flow volume [11]. In proposed algorithm based on fuzzy logic, the following data are used (**Fig. 1**).

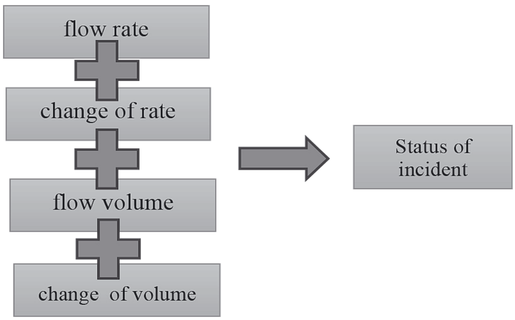

Fig. 1. The input data to determine the status of the incident

Proposed algorithm will produce one of the following results:

1. The traffic is normal.
2. Incident is probably occurred.
3. Incident is found.

The algorithm of the incident detection system is the following (**Fig. 2**).

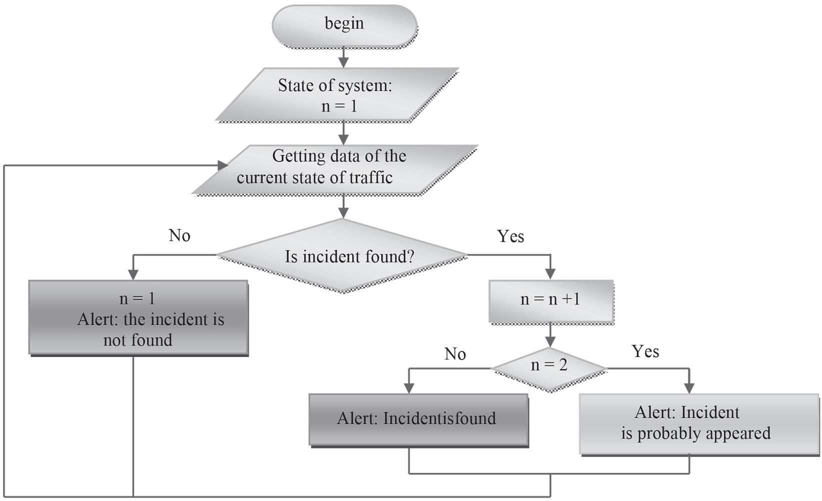

Fig. 2. The algorithm of the incident detection system

During a certain period, current state of traffic will be for occurrence of the incident. If the analysis shows that the traffic is not normal, it is considered likely that the incident occurred (situation 2), or – situation 1. If the situation is over 3 time intervals measured traffic is not normal, it is considered that a road incident occurred, then the output will be situation 3. If the situation has returned to normal flow, so that the incident has been eliminated, and the output will again situation 1. After the system has shown that the incident occurred, the incident classification stage starts.

2. Determination of efficiency measure of the algorithm

The effectiveness of traffic incident management system is related especially with the implementation phase of the detection of the incident. The following parameters characterize the effectiveness of incident detection algorithms:

- *DR (Detection Rate)* – is defined as the percentage of incident cases detected correctly by the algorithm.

$$DR = \left(\frac{N_{DI}}{N_{TI}}\right) * 100 \quad (1)$$

where N_{DI} – the number of detected incidents,

N_{TI} – the total number of incidents.

- *FAR (False Alarm Rate)* – is an index to represent the rate at which the non-incident cases are falsely classified as incident cases.

$$FAR = \left(\frac{N_{FA}}{N_{TA}}\right) * 100 \quad (2)$$

where N_{FA} – the number of false alarms,

N_{TA} – the total number of alarms.

- *MTTD (Mean Time to Detection)* – it is defined as the time from the moment when the incident occurred until it is discovered.

$$MTTD = \sum_{i=1}^{N} (t_a - t_{inc})/n \quad (3)$$

where N – the number of detected incidents,

t_a – the time when the incident was discovered,

t_{inc} – the time when the incident occurred.

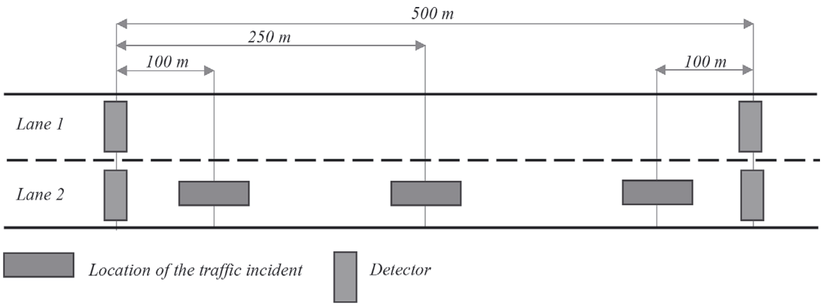

Fig. 3. Simulated study area

Detection of the incident can be considered as an essential component of the incident management process. As soon as an incident is detected and verified, and other actions must be launched for the elimination of the existing incident. In order to ensure effectiveness of any incident management process it is important that emerged incident was detected as soon as it arose. A timely and accurate incident management becomes more important when one considers the negative impact on road traffic and its safety. The delay in identifying the incident may lead to long traffic jams, which can be a major cause of secondary accidents.

3. Data Description

Simulation of the incident and collect data about it will be implemented in software PTV Vissim. Software PTV VISSIM is microscopic simulators stochastic traffic that was used to create a detailed model of I-210 West. In the past, it used mainly as a tool for the design of urban public transport systems, but later was used for the simulation of traffic on the highway.

Vissim has not tools for real model simulations of the traffic incident, so the data will be collected through the creation of on the roadway a parking space that will be considered as a traffic accident.

Installed road options in PTV Vissim (**Fig. 3**):

- Number of lanes in one direction – 2 lanes;
- Width of the roadway – 3.5 meters (based on the average value of the width of the roadway for the roads usual use (not high speed) of different categories according to GOST R 52398);
- The length of the roadway – 1000 m;
- The distance between the sensors – 500 m;
- The transport stream: motor cars – 95%, HGV – 2%, buses – 3%.

Definition of conditions of traffic incident simulation:

- In order to analyze the efficiency of the algorithm in a variety of traffic conditions, road section will be loaded with 3 different traffic load values: 2000 vehicles/h, 4000 vehicles/h, 8000 vehicles/h.
- Incidents (parking spaces) will be established in three different places:

- o At a distance of 100 meters after the first detector.
- o Exactly halfway between the detectors (at a distance of 250 meters).
- o 100 meters up to the second detector.

The data will be obtained every 30 seconds from the sensors. Incident detection algorithm will be tested at 3 different road conditions (with different traffic loads and with different location of incident).

4. Experimental Analysis

The performance of the proposed model has been evaluated by standard parameters (MTTD, DR, FAR), assessing the effects of some factors. 9 various experiments were performed with different traffic conditions in software PTV Vissim:

- Parking space located in three different locations with respect to the installed sensors (after 100 m, in the middle, before 100 m).
- Change traffic load values (2000 vehicles/h, 4000 vehicles/h, 8000 vehicles/h).

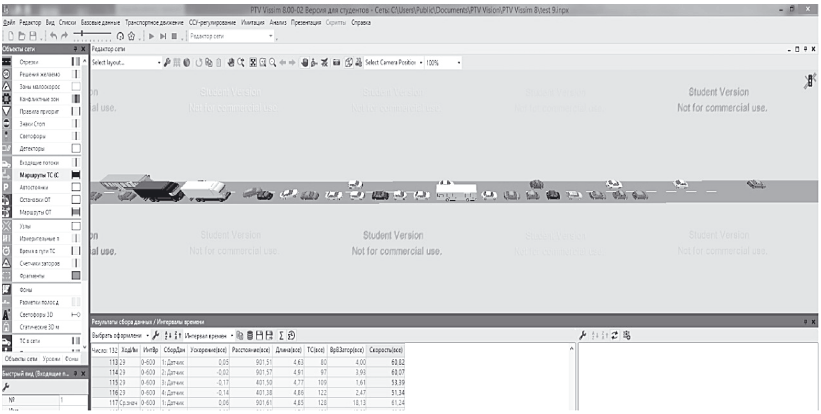

Fig. 4. Screen simulation of traffic when incident occurs

10 situations were simulated in each experiment, in which the incident occurred (**Fig. 4**). It was analyzed the data before the incident,

during (as the car took the parking space), after. Below are the average values of the results of all of the experiments (**table 1**):

Table 1.

Results of all of the experiments

№	Location of the incident	Traffic load values, vehicles/h	MTTD, s	DR, %	FAR, %
1	after 100 m	2000	63,3	100	0
2		4000	20,7	100	0
3		8000	18,3	100	0,1
4	in the middle	2000	64	100	0,1
5		4000	36,3	100	0
6		8000	39,3	100	0
7	before 100 m	2000	65,3	100	0
8		4000	31,7	100	0,1
9		8000	30,3	100	0
Total			***41,02***	***100***	***3,33***

The proposed algorithm showed poor results at low loading of traffic (2,000 vehicles) – incident detection time is maximum. Minimum detection time was observed at high loading (8000 cars) – 18.3 seconds, which is caused by the fact that the presence of incident on the road more rapidly affect the overall traffic flow than at low loading.

Several experiments showed false alarms of incidents, two of them were at a loading of 4,000 cars. At higher loading of traffic, the system showed the presence of incident after his elimination. It is caused by the during incident action on the simulated road congestion was formed, which was not disappeared immediately after the removal of incident.

It's observed the following regularities: the more loading of traffic, the less time of detection.

5. Conclusions

In this paper, the algorithm is implemented to detect incidents based on fuzzy logic in program PTV VISSIM. 9 various experiments were performed with different traffic conditions in software PTV Vissim:

- Parking space located in three different locations with respect to the installed sensors (after 100 m, in the middle, before 100 m).
- Change traffic load values (2000 vehicles/h, 4000 vehicles/h, 8000 vehicles/h).

According to a result of modeling the effectiveness of the proposed algorithm has been evaluated on three basic indicators (Mean Time to Detection (MTTD), Detection rate (DR), False Alarm Rate (FAR)).

The following conclusions can be drawn based on the results of algorithm performance:

- Mean Time to Detection (MTTD) is 41,02 seconds. This means that the system can detect the presence of incident in two phases. (each phase lasts 30 seconds), which is a very good indicator.
- Detection rate (DR) is high (100%) even at low loading of traffic.
- False Alarm Rate (FAR) has an average value. The system showed only 3 false signal at 90 test.

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RESEARCH OF EARLY STAGES OF MODELING

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In represented article the questions of estimate of accuracy of an average integral characteristics of random process in the course of imitation modeling is considered. For the purposes of analytical treatment of initial stage of modeling a conditionally nonstationary Gaussian process is analyzed as stationary Gaussian process with boundary prehistory. A model of approximant autocorrelation function is recommended. Analytical expression for variance and mathematical expectation of average integral estimation are obtained. Statistical estimation efficiency criterion, the probability of belonging to correct parameter interval is introduced. Dependences of closeness in estimation statistics clearing interval at transient behavior are researched for various types of processes.

Keywords: *simulation experiment; Gaussian process; autocorrelation function; queuing networks; the trend is a random process.*

Introduction

Experiment planning on imitation model [1, 2] supposes a range of problems solving, connected with estimated accuracy, that is: necessity for taking account of correlation data of imitation output process; necessity for taking account of transient at the initial stage of modeling; the choice of modeling interval and others. In the present paper the research of transient behavior influence is fulfilled, which includes network model of queuing [3, 4], on accuracy of middle integral estimation [5, 6]. Transient behavior of statistics nulling on one hand decreases bias of the estimate, on the other hand, it cancels out statistics collection interval and leads to the increase of dispersion [7]. Thus, the trade-off problem is arises.

That is expected that modeling of initial stable processes is performed [8]. Nonstationarity appears only by means of choice of initial conditions modeling [9]. Besides it is expected that interest is called for middle integral estimate of settling behavior in view of (under known autocorrelation function and its developments r_1 and r_2):

$$r(t)=\sigma^2\left(\alpha_1 e^{\;\; c_1 t}+\alpha_2 e^{\;\; c_2 t}\right), r_1(t)=\sigma^2 \;\; \frac{\alpha_1}{c_1} e^{\;\; c_1 t} \;\; \frac{\alpha_2}{c_2} e^{\;\; c_2 t},$$

$$r_2(t)=\sigma^2 \;\; \frac{\alpha_1}{c_1^2} e^{\;\; c_1 t} \;\; \frac{\alpha_2}{c_2^2} e^{\;\; c_2 t}$$

with parameters of variance of middle integral estimate $\langle_1$, $\langle_2$, c_1 and c_2 will be as follows:

$$D_S\,\zeta(T)=\frac{2}{T} r_1(0) \;\; \frac{2}{T^2} r_2(0)+\frac{2}{T^2} r_2(T).$$

For conditionally nonstationary process [7, 9, 10] with boundary start conditions on the basis of theorem on normal correlation for mathematical expectation the correct correlation is:

$$M\{\xi\,|\,S\}(t)=M\xi+D_{\xi\theta}(t) \;\; D_{\theta\theta}^{\;\;1} \;\; (S \;\; MS)=y+D_{\xi\theta}(t)D_{\theta\theta}^{\;\;1} \;\; (S \;\; yE), \quad (1)$$

where y is stationary process expectation and E is column vector of unity element with dimensionality (m+1), and $S=(S_0, S_{-1}, \ldots , S_{-m})^T$ determines value of basic process $\lfloor(t)$ at the moments $St{=}\langle t_0, t_{-1}, \ldots, t_{-m}\rangle$, $(t_0>t_{-1}>\ldots>t_{-m})$.

Covariance function of the process is defined by the following formula:

$$R(t,u)=r(|\,t \;\; u\,|) \;\; D_{\xi\theta}(t) \;\; D_{\theta\theta}^{\;\;1} \;\; D_{\xi\theta}^{T}(u), \;\; (t \;\; t_1, u \;\; t_1), \quad (2)$$

where $D_{\lfloor\langle}(t)=(r(t\text{-}t_0), r(t\text{-}t_{-1}),\ldots, r(t\text{-}t_{-m})$ is a row vector of co-variance and $D_{\langle\langle}=||$***cov*** $(\lfloor(t_i), \lfloor(t_j))||=||r(t_i\text{-}t_j)||$, $i,j=0..\text{-}m$ is a co-variance matrix for instant of time t_i, t_j. Herewith for conditional stable process, the variance of middle integral estimation will be defined by double integral from covariance function (2).

Methodology

In the case of statistics clearing transition period Δ mathematical expectation of middle integral estimate be $M\zeta(T,\Delta) = \frac{1}{T-\Delta}\int_{\Delta}^{T} M\xi(t\,|\,t_0, S_0)\,dt$ and the variance on the basis (2) be $D\zeta(T)=D\zeta_S(T)\text{-}D\zeta_N(T)$. With this stationary constituent of variance be $D_S\zeta(T,\Delta) = \frac{1}{(T-\Delta)^2}\int_{\Delta}^{T}\int_{\Delta}^{T} r(|\,t-u\,|)\,dtdu$ and introducing the function $W(T,\Delta) = \frac{1}{T-\Delta}\int_{\Delta}^{T} D_{\xi\theta}(t)\cdot dt$ for nonstationary constituent the proportion will be true:

$$D_N\zeta(T,\Delta) = W(T,\Delta)\quad D_{\theta\theta}^{1}\quad W^{T}(T,\Delta). \tag{3}$$

For the autocorrelation function r(t) for the stationary component of the variance of the average integral evaluation after few generations we get:

$$D_S(\Delta,T) = \frac{2}{T\quad\Delta} r_1(0)\quad \frac{2}{(T\quad\Delta)^2} r_2(0) + \frac{2}{(T\quad\Delta)^2} r_2(T\quad\Delta). \tag{4}$$

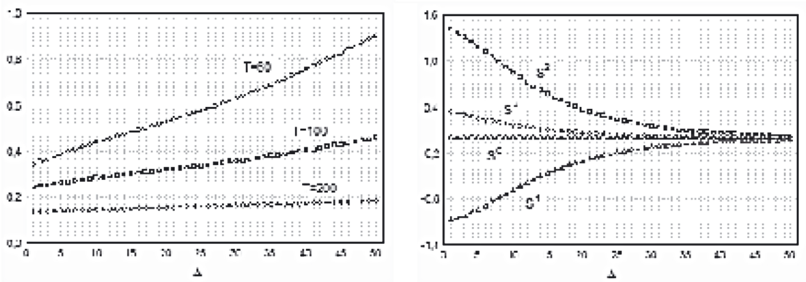
As a consequence of worked in correlations obtained the value of function W for nonstationary constituent of variance and mathematical expectation that afford to carry out an analysis of influence of clearing statistics on efficiency of estimation procedure [8, 11, 12].

Thus, mathematical expectation and variance of estimation should be considered as a function of variables Δ, *St, S, Cv*=(c_1, c_2)*, T:*

$$\boldsymbol{M}\zeta(\Delta) = \boldsymbol{M}_{\zeta}(\Delta|St, S, Cv, T),$$

$$\boldsymbol{D}\zeta(\Delta) = \boldsymbol{D}_{\zeta}(\Delta|St, Cv, T).$$

As long as variance value is independent of initial data of modeling, we shall estimate a correlation influence Cv^1=(0.2, 0.1), Cv^2=(0.4, 0.3) and total modelling time $T\in\{60, 100, 200\}$.



a) variance **b)** mathematical expectation

Fig. 1. Influence of size statistical clearing on characteristics of middle integral estimate with *Cv*=(0.2, 0.1)

From diagrams it is clear, that interval size of statistics clearing is essentially reflected on variance of estimate. Anyway clearing of annual statistics increases the estimate variance, that is it decreases closeness in estimate.

In figure 1b graphs of mathematical expectation of middle integral estimation of process in dependence of interval clearing are reported. Duration value of modeling interval is T=200, as first state were chosen: St=(0, -1); S^0=(0,0), S^1=(5,0), S^2=(5,5), S^3=(0,5).

From diagrams is clear that mathematical expectation of estimation bias also essentially depends on interval size of clearing. Interval size of statistics clearing depreciates an accuracy error estimation of an estimated mean.

In such a way, the problem of choice of anterior statistics clearing interval in view of criteria contradictories demands building of some fold of initial criteria [12–14]. As such fold it is supposed to use probability of valuation entering in specified error interval [15, 16].

Results

Let estimate the probability that, estimation value in the result of modeling will belong to ™-neighborhood of middle y-function value. This probability may be considered as the selection criterion of interval size of statistics clearing [9, 10, 17]. The higher the probability, the all the more precise is the estimated mean.

Probability of belonging of the estimation ™-neighborhood is:

$$P(\delta) = \frac{1}{\sqrt{2\ \ \pi\ \ D\zeta(\Delta)}} \int_{y\ \ \delta}^{y+\delta} \exp\ \frac{(t\ \ M\zeta(\Delta))^2}{2D\zeta(\Delta)}\ dt$$

In this connection $P(\delta)$=**P**(δ|*T, St, S, Cv*, Δ). Let's make complete 4^4 factorial experiment with values of all parameters on 4 levels for research of assigned dependence. The adjusted values of variable factors are listed in the table 1.

Table 1.

Factor score

	factor 1	**factor 2**		**factor 3**		**factor 4**	
	T	**Δ(D)**	**δ(G)**	**S*10**		**Cv*10**	
N			***100**	**s(0)**	**s(-1)**	**c1**	**c2**
1	300	0	0.2	0	0	0.2	0.1
2	350	50	0.25	0	5	0.3	0.2
3	400	100	0.3	5	5	0.4	0.3
4	450	150	0.35	5	0	0.5	0.4

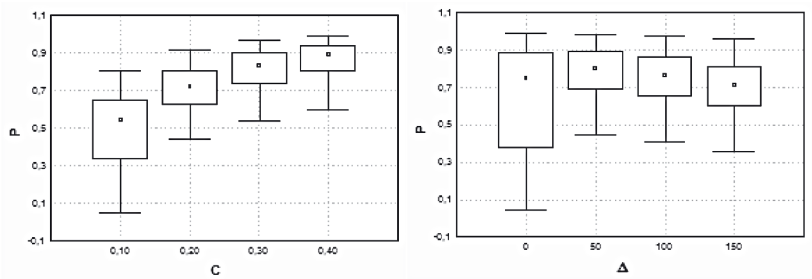
Values of interaction factors are listed in the table 2.

Table 2.

Interaction factor effects

One-factor		**Two-factor**		**Three-factor**	
1	0.159723	12	0.001759	123	0.000000
2	0.288725	13	0.000000	124	0.000250
3	0.000000	23	0.000000	134	0.000000
4	1.908926	14	0.001808	234	0.000000
		24	0.241754		
		34	0.000000		

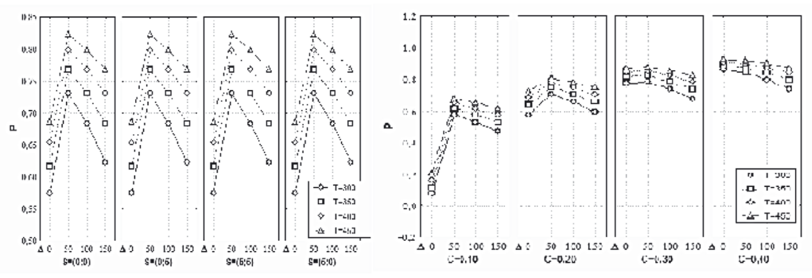
From the table 2 it is clear, that the most essential factor is the process correlation. Start conditions slightly influence on criterion value. From two-variable cooperation the essential is the combination of correlation and interval size of clearing. Diagrams of Boks-Koks of one-factorial influences for ™=0.3 are reported in figure 2. From diagrams we may see, that there are exist some optimum of clear interval size.



a) Influence Cv **b)** influence Δ

Fig. 2. One-factor analysis of interval membership probability

The optimum is represented on the picture 3 more intuitively. Here deduced graphics of neutralized in all values of probability in specified interval correlation for each start condition and modeling interval size and dependencies graphics of probability, averaged throughout for start conditions and each correlation value and each modeling interval size [18–20].



a) on initial condition **b)** on correlation

Fig. 3. Averaged impact assessment of statistics clearing

Discussion

From the graphs, it is clear, that for small values of covariation the optimum of clear interval belongs to neighborhood of zero, that is failure of taking in account of any values of transition period leads to the probability decrease. Moreover, short durations of interval modeling make an optimum clearer.

For the case of necessity in crude estimates attaining of central tendencies, computations in conditions: σ=1were made, short modeling interval (T=100), wide confidential interval (δ=0.5), slightly correlated process C*v*=(0.4; 0.5). Probability of estimation entering in the δ-neighborhood for various start conditions S^0=(1, 1), S^1=(1, 3), S^2=(3, 1), S^3=(5,5) is investigated. Was demonstrated that for state S^0 all data S_3 should be taken in account (sufficiently far initial conditions) optimal interval of nulling is equal only 4–5 units of 100.

Conclusion

The analysis of mathematical expectation of middle integral estimation of conventional nonstationary process upon condition of statistic clearing is made, which is cumulated at start modeling interval, which is Δ. Analytical expectations of mathematical expectation and middle integration estimation variance in dependence from value Δ are received. As the result of researches it is clear, that the increase Δ decreases systematical error, but increases estimation variance. Therefore it is offered to make fold of both values by means of determination of probability that the estimate value in the result of modeling and anterior statistics clear will belong to δ-neighborhood of stationary value. The set of experiments is carried on with the aim of revelation of factors, which influence this index.

Ii is testified that determining factor is the degree of process correlation: with strong correlation a clear is necessary, however with wide confidential interval and weak correlation there is no necessity in statistics clear execution. With small correlation values the optimum of interval clearing of initial-value, belonging to neighborhood of zero. Thus, statistical and analytical models of output imitation processes, offered in the article, allow essential widening the sphere of researches of various procedures of imitation modeling organization, and building of keeping under control and optimizing algorithms.

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A MODIFICATION OF THE METHOD CALLED "SUM" WITH THE TIME CONSTRAINTS OF DELIVERY OF GOODS

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The heuristic procedure considered the shift-daily planning of delivery routes method "amounts". We present the solution of the transportation problem or the routing problem in efficiency optimization of transportation.

Keywords: *optimization; modification of the method called "sum"; efficiency; small-lot cargo delivery; shift-daily planning; transport problem; routing problem.*

1. Introduction

The stage of development of the transport industry of considerable importance is the problem of increasing the efficiency of traffic optimization. The urgency of this problem is caused by the transporting cost of any product that is ultimately reflected in the price of goods.

To resolve this problem, you must properly and accurately organize transportation planning. Planning the transport of goods between supplier (GOP) and customer (GLP) location is generated in the process of solving transportation problems or routing problems.

Transportation problems, attempting to solve the problem of a large amounts, are of great interest to large firms. Making the right decisions reduces transportation costs by 10–15% [8], as well as more precisely drawn transportation schedules and routes of deliveries of goods.

One of these transportation problems is the problem of limited-time delivery of goods "just in time". Demand tasks are relevant for intra-bulk consignments of goods, since the delivery of goods or passengers is an important indicator in “megacities”.

Formulation of the problem in this project is more complicated, but at the same time reflects the real process. The aim of the proposed variant solutions of the transportation problem is the drafting of the goods delivery route, striving for the minimum distance, as well as for accurate customer service at predetermined intervals of delivery.

2. The general formulation of the transportation problem, taking into account the limitations of time of delivery

The solution of problems related to the limited time of delivery of goods from the supplier to the consumer relates to vehicle routing problems. LED, for example, the transport problem can be described by the following situation. Required to organize transportation, which is carried out on the basis of having a single vendor, homogeneous products and a variety of consumer items of similar types of cargo. The car park is leased from the motor company, which provides the necessary for the implementation of the transport rolling stock. Under each car is determined daily route of cargo delivery to the customer with the exact location of the client, with full information on the volume of cargo transported and the nomenclature of products. On each route, there are imposed restrictions that must be followed. The volume of cargo must not exceed the load capacity of the car. The client must be serviced in exactly the specified time interval. Under a specified period of time means the vehicle arrival time to the client, the unloading of cargo and the departure time from the client. In addition, each client is served by a motor vehicle once.

3. Objectives and methods of transport planning small-lot cargo

The main tasks of the distribution depending on the number of suppliers and customers, freight traffic, trucks and cargo vehicles, used supply chain and transport services to limitations on the time of delivery are as follows:

- Task "traveling salesman", time limits are not set, the number of suppliers of m = 1, the total volume of consumption of the goods in terms of (ΣQi) is less than or equal to the vehicle load capacity (qk) ΣQi≤qk;
- Decomposition + method "amounts of" time limit is specified, the number of suppliers of m = 1, the total volume of consumption of the goods in terms of (ΣQi) greater vehicle capacity (qk); ΣQi> qk;
- Method "functions benefit", specified time limit, the number of suppliers of m = 1, the total volume of consumption of the goods in terms of (ΣQi) greater vehicle capacity (qk); ΣQi> qk, or the total volume of consumption of the goods in terms of (ΣQi) is less than or equal to the vehicle load capacity (qk) ΣQi≤qkFigure 3.1. The interface of the electronic Atlas "INGIT";

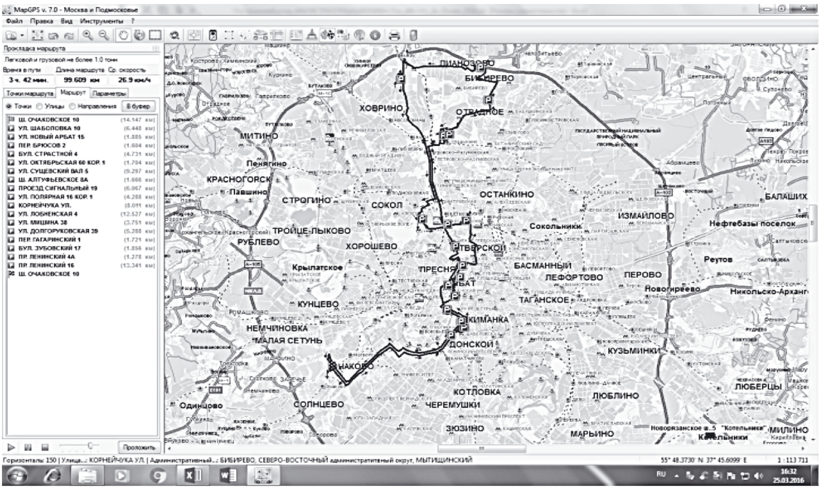

Fig. 3.1. The interface of the electronic Atlas "INGIT"

All the above objectives and methods of planning small-lot deliveries of cargo generated by an electronic atlas of highways "Streets of Moscow" INGIT (Figure 3.1) [6].

4. The algorithm of heuristic procedures for shift-day planning of routes

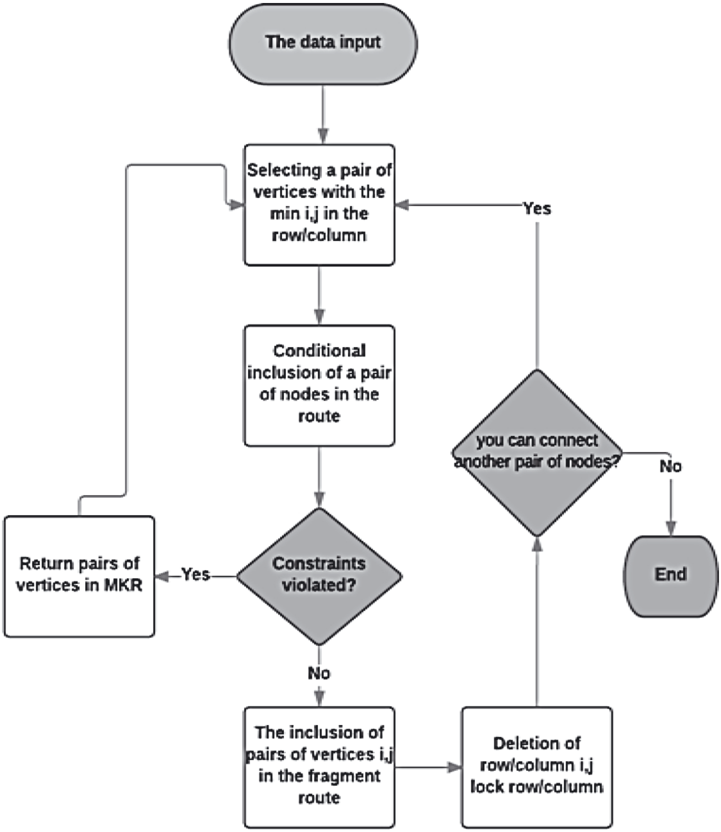

Fig. 4.1. Enlarged Block diagram

Consider the stages heuristic procedure of shift-day planning routes – the method of “sums” with regard to the delivery time slots as an example of distribution of goods from one warehouse to the set of consumers in a big city.

For clarity, planning routes presented enlarged block diagram (Figure 4.1).

The first phase addresses the warehouse and clients coded in the top of the transport network model (MTS) (Figure 4.2).

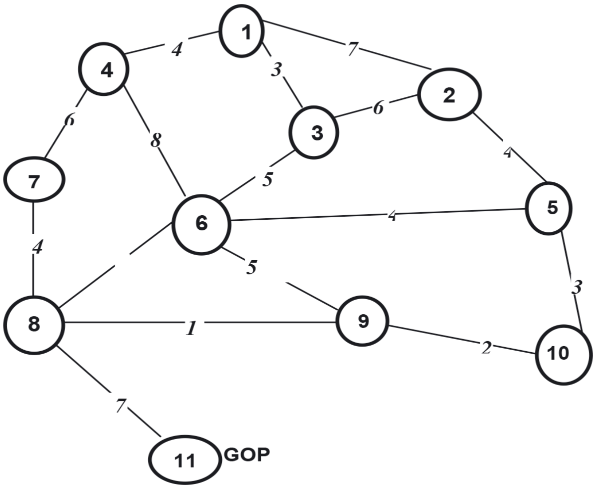

Fig. 4.2. The model of the transport network (MTS)

At the second stage construction of the routes "sums", followed by a breakdown of the general problem into several smaller tasks size. The breakdown is carried out in the following way:

1) the matrix of shortest distances (MKR) is most distant from the top of the warehouse.

2) on top of MKR determined minimum distance value in row distances from the warehouse to the consumer, or in a row / column most distant peaks, according to claim 1, if there are two nodes with the same minimum distance value, select any of them.

3) The third step is calculated evaluation Δlij, covers all links to which can be connected to the top. calculated according to the formula Δlij assessment to determine the sequence of vertices of a detour:

$$\Delta^{o}ij = li^{o}, + l^{o}, \qquad (1)$$

j – li, j where li, about – the shortest distance from the point i to the GOP;

l^o, j – shortest distance from the GOP to the point j;

li, j – the shortest distance between points i and j.

Calculate i, j to evaluate the feasibility of replacing the pendulum routes with points i, j one circular route that includes these items.

4) potential peak is included in the unit, where the assessment value

Δ^oij minimally subject to restrictions:. Cargo auto-mobile, the time spent on duty, the timing of delivery of cargo, etc. If at least one of the conditions is not satisfied, the top can not be included in the link. Consider other units or determine the next top with a minimum distance. With each subsequent step Δ^oij will increase.

Formation of the route ends at the exhaustion of the list of vertices or no connectivity next item without violating the limits. In the latter case the begin to build the next route. The procedure is repeated to include all items in the routes.

5. Conclusion

At the current stage of economic development to build new approaches to transport planning is a thematic issue, so to improve the efficiency of traffic optimization in this article is offered to consider a modification of the method of “sums” in view of the limitations of time of delivery of goods from supplier to consumers.

As a result of the modifications made, the method of “sums” transportation problem or a routing problem has been solved, which ensure maximum efficiency to optimize traffic by reducing the total mileage of road transport, reduction of transport costs. Thanks to the results of increased levels of customer service, which is an important factor in a market economy.

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GENERAL PRINCIPLES OF ASSESSMENT OF STAFF SKILLS BUILDING SPECIALTIES

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Nowadays the culture of controlling and estimating quality becoming more and more important. Estimating – is a process of gathering and processing information, which provides to members of education process opportunity to make decisions, which could help to improve quality of work. Database of estimating is bunch of governmental standards, control and estimating of efficiency systems are tests. Last 10-15 years the usage of tests is growing all over the world, that is why many companies and governmental structures appeared, which are creating new tests, promoting them, organizing mass testing and all-time mining the information, to understand the quality of education. Western countries are way far from our quality of testing of new scientific personnel, by the level of testing methods development, by the technical support of development processes, the use, handling and storage for tests. Last year's our scientists see the positive trends in this field. Strategy and tactics of controlling systems improvement. Education testing zooming and governmental standards developing are generating new problems, prerequisites and requirements, which are aimed on controlling systems perfection and trainees' preparation quality estimating, the process itself estimating and its efficiency by immediate response on the environment.

Keywords: *controlling systems; IRT theory; staff skills; test's task; markov's chain; stationary probabilities; complexity level; wrong classifications; adaptive process.*

1. Introduction

Unlikely from classic tests' theory, IRT theory is pursuing of fundamental theoretical approach, and yet – finding the right solutions for practical problems [1–3, 5]. In a practical point of view it's always goes with many problems, which testers are missing sometimes.

In IRT-model we are making a formal model of the conditional probability of right execution of test's questions with different complexity by *i*-th examinee with Θ_I level of knowledge's, considering, that Θ_i – is *i*-th option of *i*-th examinee, and β_j – is an independed variable. In this way – the conditional probability will be the function of latent variable β.

$$P_i\{x_{ij}=1|\Theta_i\}=f(\Theta_i - \beta)\ i=1..N. \quad (1)$$

In the same way we are inputing the conditional probability of execution of *j*-th task, with β_j complexity with different examinees. Θ is independed variable and β_j is a paramethr, which determines complexity of *j*-th test's task.

$$P_i\{x_{ij}=1|\beta_j\}=f(\Theta - \beta_j)\ i=1..N, \quad (2)$$

Where $x_{ij}=\{0,1\}$, 1 – if *i*-th examinee answered correct on *j*-th test's task, 0 – if *i*-th examinee answered wrong on *j*-th test's task.

The conditional probability of right execution of test with β level of complexity and Θ level of knowledge's formula could be presented, using double-parameter A. Birnbaum model, like this [1]:

$$P_j\{x_{ij}=1|\beta_j\}=[1+\boldsymbol{exp}(-1{,}7a_j(\Theta-\beta_j))]^{-1} \quad (3)$$

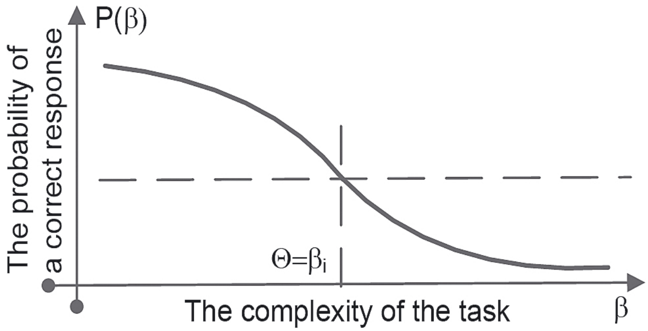


Fig. 1. Characteristic curve of test's task

With geometrical interpretation, we could determine β_j as a position characteristic of j-th task's curve relativity to Θ – axis. The a_j paramethr is related to slope of the curve in its inflection point.

2. Problem statement

2.1. Making the markov's chain of test's control adaptive process

Estimating the knowledge level by gathering the answers on test's task presents as a management task, which means, that during the next step we're getting the next task with some level of complexity. Making the "task choosing" procedure is going through the procedure of complexity choosing, by this formula:

$$\beta^{(n+1)} = \boldsymbol{F}^{(n)}(\beta^{(1)},\ldots,\beta^{(n)}) + \xi^{(n)}(\beta^{(1)},\ldots,\beta^{(n)}), \qquad (4)$$

$\beta^{(n)}$ – complexity of task on n-th step of the procedure

$\boldsymbol{F}^{(n)}$ – some functional transformation of answers

$\xi^{(n)}(\beta^{(1)},\ldots,\beta^{(n)})$ – random value, modelating the answer on n-th task.

We are going to use the finite Markov's chains apparatus, to modulate the procedure behavior [4, 6–10]. So, discrete random sequence ξ_i – is Markov's Chain, only if $P\{\xi_{k+1}= a_{k+1} \mid \xi_i ,..., \xi_k\}= P\{\xi_{k+1}= a_{k+1} \mid \xi_i\}$. In short – with fixed "present" H, "future" B and "past" F would be independed. This property of "future" and "past" independence calls Markov's property. If "future" $B=\{\xi_{k+1}=a_{k+1},..., \xi_{k+n}=a_{k+n}\}$ $n>0$, "present" $H=\{\xi_k= a_k\}$, and «past» $F=\{\xi_1= a_1 ,..., \xi_{k-1}= a_{k-1}\}$, then $P\{B|HF\} = P\{B|H\}$ или $P\{BP|H\} = P\{B|H\}\ P\{P|H\}$.

$\xi=(C,P,F)$ – determines homogeneous Markov's chain with $C=\{c_i\}$ as set of states, a row-vector with initial probabilities $F=\{p_i\}$ and matrix of transition probabilities $P=\|p_{ij}\|$.

$$p_{ij}=P\{\xi_1=j \mid \xi_0=i\}= \ldots = P\{\xi_n=j \mid \xi_{n-1}=i\}. \qquad (5)$$

From now on let's consider, that the amount of complexity levels is limited. Now we need to make a discrete numeric measure for it, for example b=1, 2,… . Every complexity level matches some state of Markov's chain. Transactions between states happens at discrete time moments, which match the i-th test answer result. Could be only 2 results – "yes" – the answer is right, or "not" – the answer is wrong. Every variant of answers matches the transaction on different state, which is different complexity level. Besides, before making the Markov's chain we need to set initial distribution of complexity. It is going to match the first task's complexity. In particular case distribution will be degenerated, if you choose the exact complexity level in the beginning. Besides, it's assumed, that answers on tasks are independed values.

For example, let's look on the state transaction graph (pic. 2) [11]. As a first state, let us choose state №1 on the pic. State №1 matches the lowest level of complexity. After giving the right answer on that task, examinee gets task with level 4 of complexity. If the answer is wrong – then 2 level. If in this procedure examinee gets task with 6 level of complexity, than he gets task with 7 level of complexity, if he's right. If wrong – №3 etc. The stop criterion is a hard math task, and it doesn't consider in this post.

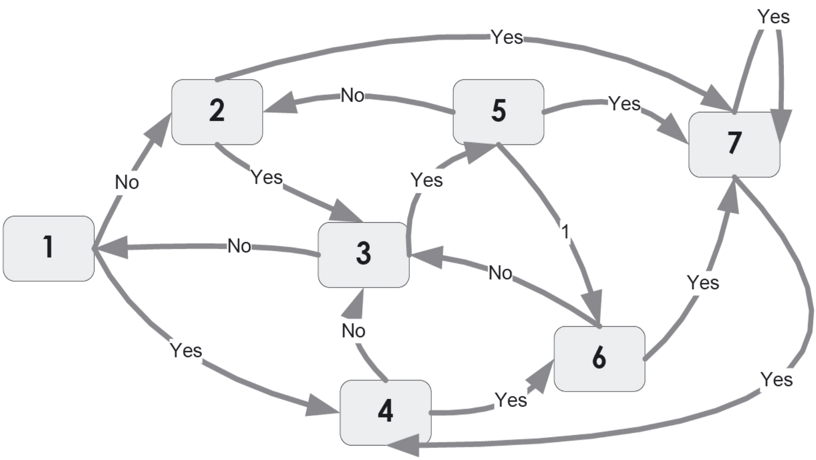


Fig. 2. Random Graph

For example – someone came up with this kind of a procedure. The question is – is it effective enough? To be sure, about effective part – let us use the adaptive control procedure (pic. 3) [12, 13]. In this model if the task has been solved correct – examinee gets level up complexity, if not – level down. Arcs on this picture are not the right answers, its possibility of answering correctly, which is determining from logic-line of IRT-model.

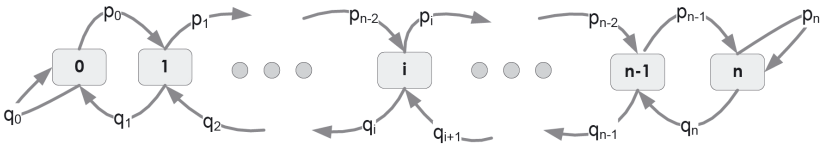


Fig. 3. Transactions of Markov's chain diagram

The result depends not only on complexity β, but on examinee's knowledge level Θ as well. After passing adaptive test, we get some trajectory, which fully matches sequence of complexity levels.

From every state of Markov's chain C_i, which matches the complexity level β_i, only two transitions are available, based on logical curve (3).

Probability of transition on higher level of complexity, if the answer is right equal:

$$p_i = \exp\frac{\alpha}{\sigma}(\theta-\beta_i)\Big/\left[1+\exp\frac{\alpha}{\sigma}(\theta-\beta_i)\right] \quad (6)$$

Probability of transition on lower level of complexity, if the answer is wrong equal:

$$q_i = 1\Big/\left[1+\exp\frac{\alpha}{\sigma}(\theta-\beta_i)\right] \quad (7)$$

So, as a pattern model of adaptive test's control procedure we get *MC* $\xi=(C, \boldsymbol{F}, \boldsymbol{P})$, where:

$\boldsymbol{C}=\{C_i\}$ – set of states of Markov's chain, which match the complexity level of tasks.

$\boldsymbol{F}=\|p_i\|$ – row vector of tasks' initial distribution.

$P=\|p_{ij}\|$ – matrix of transition probabilities, which determines by the transition diagram and probabilities determine by proportion of (5) and (6) (tab. 1).

Table 1.

Structure of transition probabilities matrix

$i \setminus j$	0			1	2	3				I-1	I
0	q_0			p_0	0	0				0	0
1	q_1			0	p_1	0				0	0
2	0			q_2	0	p_2		…		0	0
3	0			0	q_3	0				0	0
				…						…	
I-1	0			0	0	0				0	p_{I-1}^{-}
I	0			0	0	0				q_n	p_n

Because of transition diagram structure, we can see, that this is a reduced chain. That's why there is only one stationary probabilities distribution, which is not related to the initial state.

2.2. Stationary probabilities the Markov's chain

Let's mark stationary state probabilities C_i as π_i. With these notations, row vector of stationary probabilities $\overline{\pi} = (\pi_0, \pi_1, \pi_2, \dots, \pi_{I-1}, \pi_I)$ determines as a solution of this equation system:

$$\overline{\pi} = \overline{\pi} \cdot \boldsymbol{P}, \qquad \sum_i \pi_i = 1. \tag{8}$$

Now we describe this system in scalar type for several strokes of this matrix.

$$\begin{aligned} &\pi_0=\pi_0\cdot q_0+\pi_1\cdot q_1 \\ &\pi_1=\pi_0\cdot p_0+\pi_2\cdot q_2 \\ &\pi_2=\pi_1\cdot p_1+\pi_3\cdot q_3 \\ &\dots \end{aligned} \tag{9}$$

Solving this relatively on zero-state we get this:

For a first one

$$\pi_1 = \pi_0 \cdot \frac{1-q_0}{q_1} = \pi_0 \cdot \frac{p_0}{q_1} \tag{10}$$

For a second one

$$\begin{aligned}\pi_2 &= \frac{1}{q_2}(\pi_1 - \pi_0 \cdot p_0) = \frac{1}{q_2}\left(\pi_0 \cdot \frac{1-q_0}{q_1} - \pi_0 \cdot p_0\right) = \\ &= \frac{\pi_0}{q_2}\left(\frac{p_0}{q_1} - \frac{q_1 p_0}{q_1}\right) = \frac{\pi_0 p_0}{q_2 q_1}(1-q_1) = \pi_0 \cdot \frac{p_0 p_1}{q_1 q_2}\end{aligned} \tag{11}$$

For a third one

$$\begin{aligned}\pi_3 &= \frac{1}{q_3}(\pi_2 - \pi_1 \cdot p_1) = \frac{1}{q_3}\left(\pi_0 \cdot \frac{p_0 p_1}{q_1 q_2} - \pi_0 \cdot \frac{p_0}{q_1} \cdot p_1\right) = \\ &= \frac{\pi_0}{q_1 q_3}\left(\frac{p_0 p_1}{q_2} - \frac{p_0 p_1 q_2}{q_2} \cdot\right) = \frac{\pi_0 p_0 p_1}{q_1 q_2 q_3}(1-q_2) = \pi_0 \cdot \frac{p_0 p_1 p_2}{q_1 q_2 q_3}\end{aligned} \tag{12}$$

Then we say, that stationary probability for *i*-th state equal $\pi_i = \pi_0 \cdot \prod_{k=1}^{i} \frac{p_{k-1}}{q_k}$. And this proportion is correct:

$$\begin{aligned}&\pi_{i-1}p_{i-1} + \pi_{i+1}q_{n+1} = p_{i-1}\pi_0 \prod_{k=1}^{i-1}\frac{p_{k-1}}{q_k} + q_{n+1}\pi_0 \prod_{k=1}^{i+1}\frac{p_{k-1}}{q_k} = \\ &= \pi_0 \prod_{k=1}^{i-1}\frac{p_{k-1}}{q_k}\left(p_{i-1} + q_{n+1}\frac{p_{k-1}}{q_k}\frac{p_{k-1}}{q_k}\right) = \pi_0 \prod_{k=1}^{i-1}\frac{p_{k-1}}{q_k}\left(p_{i-1} + q_{n+1}\frac{p_{k-1}}{q_k}\frac{p_{k-1}}{q_k}\right)\end{aligned}$$

Therefore, the solution of stationary probability equation system is:

$$\pi_i = \pi_0 \cdot \prod_{k=1}^{i-1}\frac{p_k}{q_{k+1}}, \quad i = \overline{1, l},$$

$$\pi_0 = \left(1 + \sum_{j=0}^{l}\prod_{k=1}^{j-1}\frac{p_k}{q_{k+1}}\right)^{-1}.$$

Using transition probability equation (6) and (7), we expressed through logical function p_i=Ψ(β,Θ); (q_i=1-Ψ(β,Θ), $i = \overline{1, l}$, (Ψ(·) – random logical curve), we get:

$$\begin{aligned}\pi_i &= \pi_i^0 \prod_{k=1}^{i}\frac{\Psi\,(\Theta-\beta_k)}{1-\Psi\,(\Theta-\beta_k)} = \pi_i^0 \prod_{k=1}^{i}\frac{\boldsymbol{exp}(\Theta-\beta_k)}{1+\boldsymbol{exp}(\Theta-\beta_k)}\left[1 - \frac{\boldsymbol{exp}(\Theta-\beta_k)}{1+\boldsymbol{exp}(\Theta-\beta_k)}\right]^{-1} \\ &= \pi_i^0 \prod_{k=1}^{i}\boldsymbol{exp}(\Theta-\beta_k) = \pi_i^0\,\boldsymbol{exp}\sum_{k=0}^{i}(\Theta-\beta_k)\end{aligned} \tag{14}$$

Moreover, in the end we get $\pi_i = \pi_0 \, \boldsymbol{exp}\left(\sum_{k=1}^{i} (\Theta - \beta_k) \right), \quad i = \overline{1, l}$. Where π_i^s values are probability distribution of set of Markov's chain states. This stationary distribution has been gotten by introduction some discretization in complexity space [14, 15]. We can see graphics of stationary distribution of different level of knowledges on the picture 4.

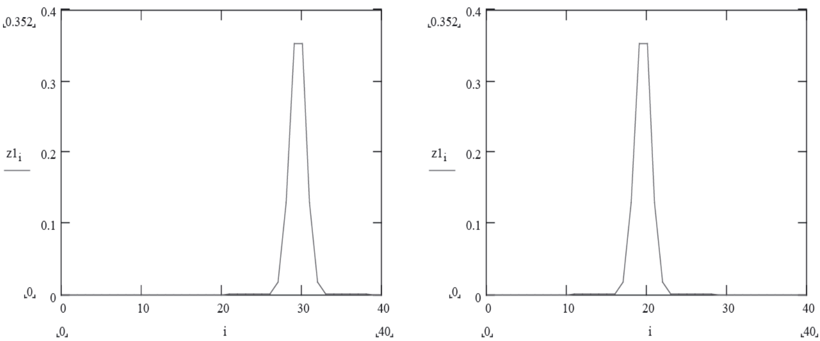


Fig. 4. Stationary distribution of probabilities

In the end we can see, that maximum of MC stationary probabilities falls on test's task complexity value, which match relevant knowledge level, which gives us a lot of information about knowledge estimation, because the answer probability is ½.

2.3. Estimating of test's control adaptive algorithm

To estimate the algorithm we need to make a procedure, which is going to classify on *K* groups, where W_1, W_2,…, W_k matches some category. First we need to create a model of a right answer, which depends on complexity level of the task (the result is matrix $m \times k$, where m – amount of test's repeats). Probability of a right answer determines by Bernoulli distribution with probability *p*:

$$\left\| z_{i,j} \right\| = P(\theta_q, \beta_j \mid \bar{p}), \; i = 1, \ldots m, \; j = 1, \ldots n, \qquad (15)$$

$\overline{p}$ – simulation model's option vector, *n* – amount of tasks in test. To prove, that answers of examinee are independed – we multiply independed events:

$$\mathbf{A} = \left\| a_{i,j} \right\| = \prod_{i=1}^{m} \begin{cases} \left\| z_{i,j} \right\|, \text{если } X = \text{U} \\ 1 - \left\| z_{i,j} \right\|, \text{если } X = \neg\text{U}' \end{cases} \quad (16)$$

U – is a reliable event.

As a second step – we will use the maximum likelihood algorithm. Consistently, we will go thruogh the *i*-th line of a matrix, and finding the maximum of column, which index will be determined as value of $\left\| \tilde{l}_i \right\| = \underset{j \in [1,k]}{\arg\max}\ (A_q^{[i]})$. We are forming $\boldsymbol{L}_q$ column-vector, which elements are value of estimating the likelihood algorithm by every iteration. $\left\| h_k \right\| = \frac{1}{m} \sum_{t=1}^{m} 1_{\left\| \tilde{l}_t \right\| = k}$ is normalized vector $\boldsymbol{L}_q$. In the end, we make a matrix $E^{[q]} = H_q^T$, which elements are value of estimating the likelihood algorithm with *k*×*n* size.

Basing on this procedure, we made a comparative analysis between the procedure we have just created and static making tasks procedure. On table 2 we can see the result of simulation experiment for seven-level complexity test, with 5 tasks on each level.

Table 2.

Static plan of test with 5 tasks each complexity level

Class	1	2	3	4	5	6	7
1	,822	,155	,002	0,000	0,000	0,000	0,000
2	,176	,700	,125	0,000	0,000	0,000	0,000
3	,002	,145	,775	,185	,002	0,000	0,000
4	0,000	0,000	,097	,636	,100	0,000	0,000
5	0,000	0,000	,001	,179	,757	,152	,002
6	0,000	0,000	0,000	0,000	,139	,686	,169
7	0,000	0,000	0,000	0,000	,002	,162	,829

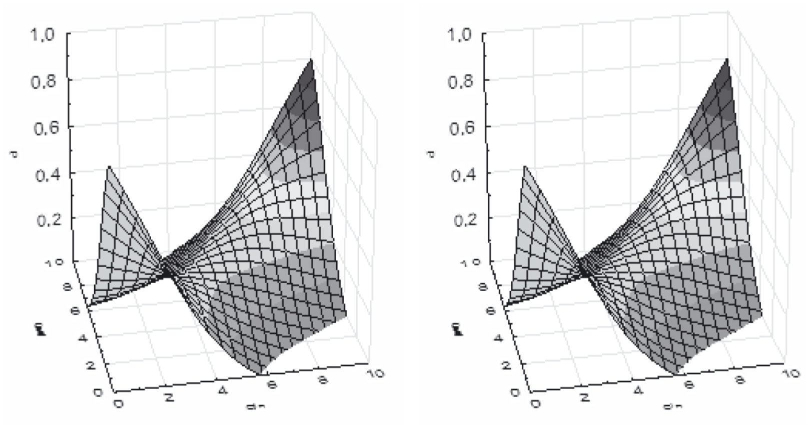
The results for adaptive algorithm with same amount of tasks and with a same model are represented on table 3.

Table 3.

Adaptive plan of test with N_T=35

Class	1	2		3	4	5	6	7
1	,906	,085		0,000	0,000	0,000	0,000	0,000
2	,094	,821		,090	0,000	0,000	0,000	0,000
3	,000	,094		,818	,098	0,000	0,000	0,000
4	0,000	0,000		,092	,803	,090	0,000	0,000
5	0,000	0,000		0,000	,099	,813	,102	0,000
6	0,000	0,000		0,000	0,000	,097	,804	,090
7	0,000	0,000		0,000	0,000	,002	,0904	,910

After analyzing these two tables we can make a decision, that classify by adaptive way gives better results for each level of examinees' knowledge level. To present the matrix of wrong classification, we'd better use the graphic form:



a) Static test **b)** Adaptive test

Fig. 5. Graphic presentation of wrong classifications matrix

Wrong classifications matrix is a pairwise probability of belonging to different knowledge levels function, which always will have a saddle-node type. Graphics of wrong classification probabilities' are uneven, because of static error of simulation experiment.

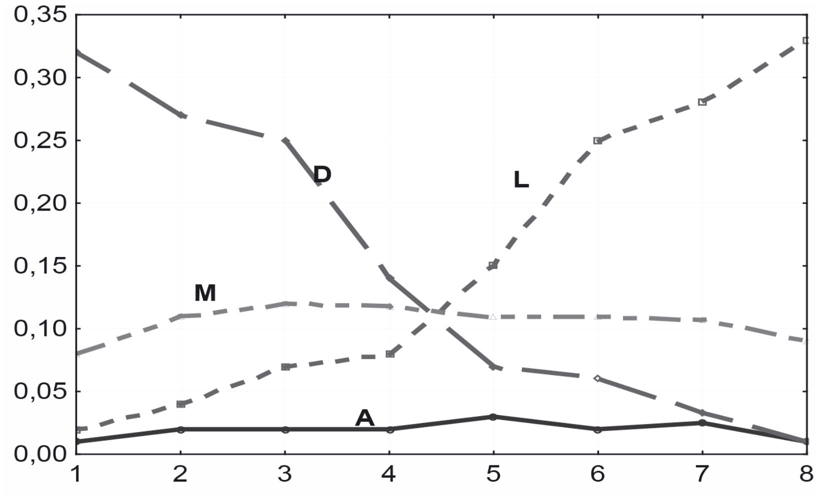


Fig. 6. A graphical representation of a matrix of incorrect classifications

Dotes of curve on the picture are estimated test's efficiency. As low the dot is as low the probability of error classify, as more efficiency test is. This model has been using to estimate tests with different complexity level. Easy tasks (L), medium tasks (M) and difficult tasks (D), and for estimating the adaptive test (A). As we see on graphics – easy test do not do good with high level of examinee's knowledge, and difficult one – do not do good with low level of knowledge. In addition, as for adaptive tests – probability of wrong classify is much less for any level of knowledge of examinee.

3. Conclusion

We made an analysis of mathematical expectation estimating by belonging to the class [16, 17]. One of the problem here is finding the right answers probability function, because on the low level they are almost not distinguishable. In 9-level knowledge model – adaptive algorithm is even doing better at wrong classify probability. Nevertheless, when model is 3–4-level – win is minor.

Because of making tests control model – we proved the efficiency of test's control procedure.

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MANAGEMENT PROCEDURE OF SUPPLIES OF UNITS, MATERIALS AND CONSTITUENT PARTS FOR REPAIR AND MAINTENANCE SUPPORT OF TRANSPORT AND PRODUCTION MACHINES

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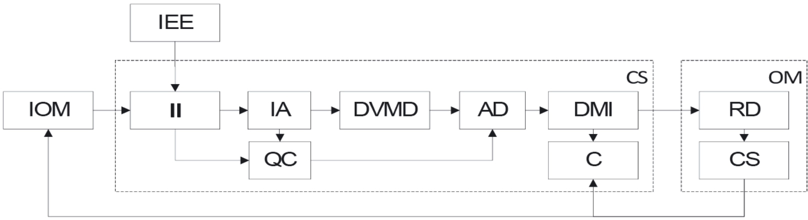
This article considers a question of creation of schemes and sequence of passing of the main stages of process of execution of repair and maintenance works order taking into account formation of stocks of necessary spare parts, materials and constituent parts. Models of an input stream are offered for inventory control system, which are rather adequately described by autoregressive models of order two.

Keywords: *Transport machines; maintenance support; repair; inventory models; random processes; autocorrelation.*

1. Introduction

Any auto-transport enterprise (ATE) represents system, i.e. set of interrelated and interacting components. In it move material, financial and information streams. Various external factors influence it. At the same time management process has cyclic character and contains a lot of stages (pic. 1). Management process – is the impact on the system and its components, which ensures its effective functioning.

The main stages are: processing of initial information (II) on object of management (IOM) and external environment (IEE), information analysis (IA) and choice of quality criteria (QC), development of variants for management decisions (DVMD), adoption of management decision (AD), development of the managing instruction (DMI). In object of management carried out realization of the adopted decision (RD), as a result of which there is a change in a state of an object of management (CS). Change in a state of the object of management (OM) is controlled in the control system (CS) in the control block (C), in which parameters of the changed state of object of management are compared with parameters reflected in the managing instruction.



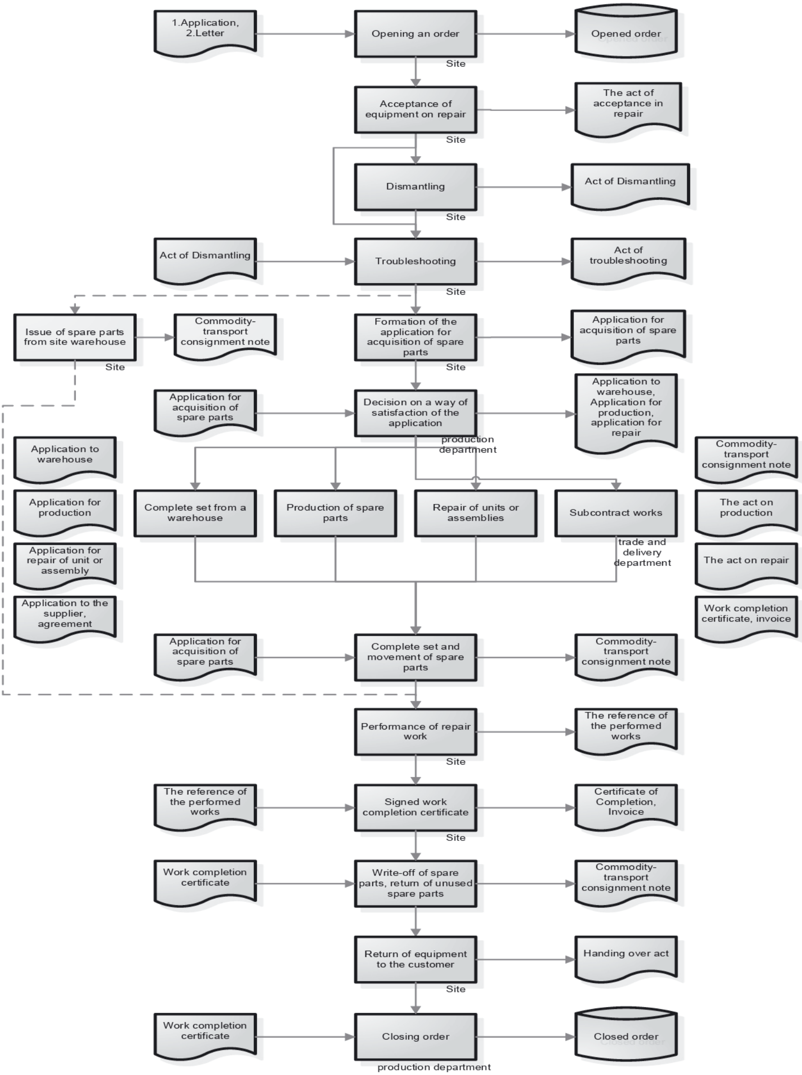
Pic. 1. Stages of management process

2. Order of execution of repair and maintenance support (MS)

In article is offered the order of execution and the scheme of technological process on repair and maintenance support of transport and technological machines (pic. 2), the main result of which is timely and qualitative execution of the order.

When opening the order the required repair is estimated and is appointed a person responsible for execution (job foreman). Then stage acceptance of equipment, which marks opening of the order number and the required repairs. Main result of a stage is dismantling - equipment of the customer sorted on units. Function is carried out only in case of capital repairs. For the current and emergency repair troubleshooting step runs immediately, which main result is the list of the knots and details demanding replacement or repair.

Stage 5 is performed only in case of availability of the necessary parts on site warehouse. In case of lack of necessary spare parts the stage formation of the application for acquisition of spare parts is carried out, which result is the application for acquisition of spare parts transferred to production department. With it stages 6, 7, 8, 9, 10, 11 and 12 are carried out only in case of lack of necessary spare parts in a site warehouse. In the case of availability of the necessary parts in a warehouse of a site the stage 5, and then 13 is carried out (conduct repairs).



Pic. 2. Order of execution and the scheme of technological process of execution of the main order on repair of equipment

As a result of the execution of 7-th stage formed application for warehouse, manufacturing, repair of units or application to the supplier on performance of subcontract works. Also preparing a list of units and assemblies that need to be repaired by the forces of MRD [mechanical repair department] (stage 9). Stage 8 – the result: spare parts issued to repair from the central warehouse. In case of lack of necessary spare parts in the central warehouse at first the "purchase of CM [commodities and materials]" procedure is carried out. As a result of performance of the 10th stage the repaired units and assemblies indulge to assembly shop. Stage 11 to repair units and assemblies involves engaging a third-party organization. The result of stage 12 is a full set of spare parts required for repairs, moved on a site. The result of stage 13 is repaired equipment of the customer, then signed work completion certificate. Procedures of write-off and return of unused spare parts to the central warehouse are also possible.

3. Inventory models

In work it is shown that both the input stream model and random inventory process is rather adequately described by autoregression models, which represents a sequence of random variables $x_1, x_2 ...$, satisfying to the stochastic differential equation at existence of a linear combination:

$$\xi_t + \beta_1 \times \xi_{t-1} + ... + \beta_p \times \xi_{t-p} = \varepsilon_t \quad t=1+p,..., \tag{1}$$

where the sequence ε_{p+1}, ε_{p+2}, ... is a sequence of the independent and equally distributed random variables.

The simplest case is a first-order equation $\xi_t = -\beta_1 \times \xi_{t-1} + \varepsilon_t$. Autocorrelated function of such process is equal $r(t) = \sigma^2 \frac{(-\beta_1)^t}{1-\beta_1^2}$. However, such process doesn't allow to realize "circuity" of autocorrelated function (ACF). In this regard in work is offered using models of second order autoregressive process $\xi_t = -\beta_1 \times \xi_{t-1} - \beta_2 \times \xi_{t-2} + \varepsilon_t$.

For aperiodic processes in the case of real roots of the characteristic equation autocovariance function has the form

$$r(t) = \frac{\sigma^2}{(x_1 - x_2)(1 - x_1 x_2)} \left(\frac{x_1^{t+1}}{1 - x_1^2} - \frac{x_2^{t+1}}{1 - x_2^2} \right), \tag{2}$$

where $0<x_1<1$ и $0<x_2<1$. Such models of 2nd order autoregressive process gives the opportunity of modeling of non-stationary processes with possibility to task an initial dynamics of process development, that is necessary for implementation of enterprise development models during the transition to new forms of management.

The carried-out analysis of input streams and the received models of orders volume allow approaching the solution of a problem of modelling inventory effectiveness. In work two models are considered: the management model with a fixed range and model monotonous policy of ordering.

In a case of model with fixed range set two threshold values: *s* and *S*, $0 \le s < S < \infty$. With destocking to s, produced an order to the effect, that level has risen to *S*. As a result, the volume of the order is calculated as

$$\eta_{n+1} = \begin{cases} 0, & s \le Z_n \le S \\ S - Z_n, & Z_n < s \end{cases}. \tag{3}$$

At the same time total stock for this model is calculated on the basis

$$Z_{n+1} = \begin{cases} Z_n - \xi_{n+1}, & s \le Z_n \le S \\ S - \xi_{n+1}, & Z_n < s \end{cases}. \tag{4}$$

In the given model, the ordered volume of accessories is delivered always, however some casual delay is possible. In the context of modelling is interesting the situation when the volume of deliveries also represents a set of random variables.

In the case of monotonous policy also determines critical value x^* and as soon as the level of a stock becomes less than this value

(Z_n<x*), procedure of the order with immediate delivery of casual volume of units and spare parts X_{n+1} is carried out. The law of distribution is considered as set, and the recurrence relation for modeling of volume of stocks is defined as

$$Z_{n+1} = \begin{cases} Z_n + X_{n+1} - \xi_{n+1}, & Z_n < x^* \\ Z_n - \xi_{n+1}, & Z_n \geq x^* \end{cases} \tag{5}$$

where ξ_{n+1} – requirement of accessories.

It is shown that both inventory and input streams models can be rather adequately presented by processes of autoregression of the 2nd order. Dependence (2) for autocorrelated function of process of autoregression by replacement of variables $x_1 = e^{-c_1}$, $x_2 = e^{-c_2}$ is given to a look

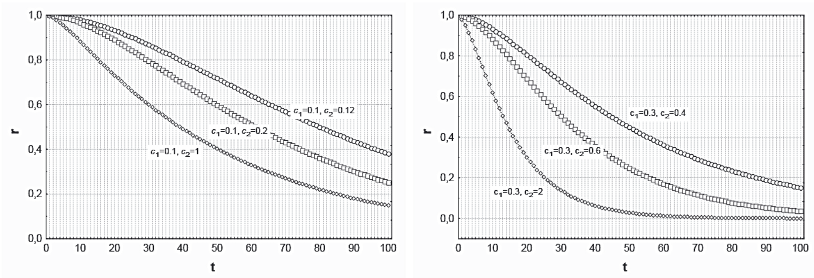
$$r(t) = \sigma^2 \left(\alpha_1 e^{-c_1 t} + \alpha_2 e^{-c_2 t} \right), \tag{6}$$

where $c_1 > 0$ and $c_2 > 0$ autocovariance parameters, $\alpha_1 = \dfrac{e^{-c_1}(1-e^{-2c_2})}{e^{-c_1}(1-e^{-2c_2}) - e^{-c_2}(1-e^{-2c_1})}$ and α_2 (defined similarly) – functions of parameters c_1 and c_2. The received approximation (6) includes exponential as a special case.

Varying the specified parameters, it is possible to model quite wide class of autocorrelations. Pic. 3. shows graphs of autocorrelation functions obtained by different combinations of the values of c_1 and c_2 parameters.

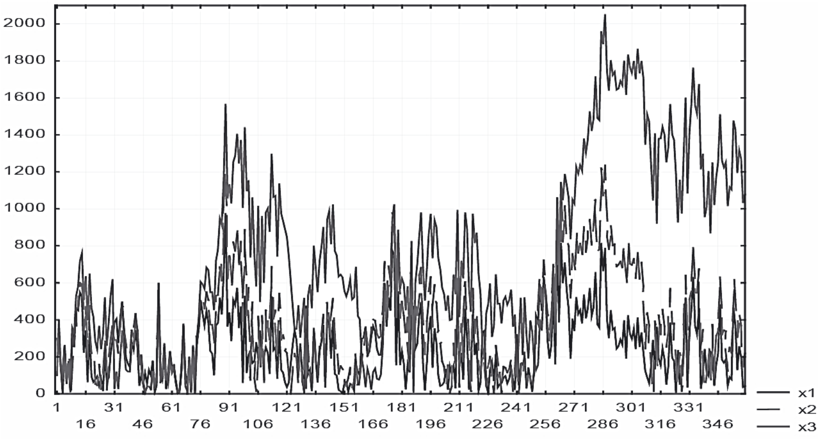
As a result of the carried-out analysis it is possible to draw the following conclusions: minimum from parameters c_1 and c_2 determines length of an interval on which correlation is essential. The difference between parameters c_1 and c_2 defines a type of ACF at small values t. The smaller the difference, the flatter the beginning autocovariance. Apparently, from graphs, varying the c_1 and c_2 parameters, it is possible to achieve a big variety in behaviour of function.

For various characteristics of processes time ranks were simulated (Pic. 4). It can be seen that the received ranks have rather various character what autocorrelated function indicates (Pic. 5).

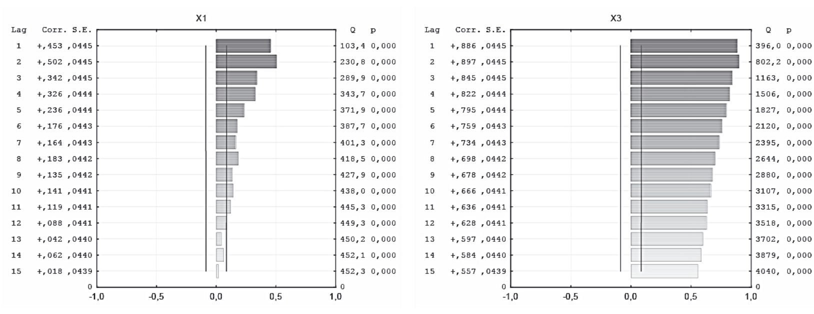


a) **b)**

Pic. 3. Approximation of ACF



Pic. 4. Selective trajectories of time ranks of autoregression



a) rank x1 **b)** rank x1

Pic. 5. Autocorrelated functions of time ranks

As a result of carrying out experiments on modelling and an assessment of characteristics of resultant processes it is shown that the received models rather adequately correspond to initial temporary ranks for the surveyed car repair enterprises.

4. Task of optimization of reservation

The optimized system is considered as set *N* types of not redundant replaceable modules, for each of which set the cost of one module (*w*), and also value of intensity of sudden refusal in disable (λ0) and enable (λ1) state. The system is characterized by the total cost (*W*) and probability of prosperity, with spare parts (*P*) at the known times of finding of system in disable (*t*0) and enable (*t*1) states.

In work two statements of an optimizing task are considered.

Task 1. To find the number of spare modules of each type (*z*) for minimization of cost of spare parts at limited probability of providing by SPA [spare parts and accessories]:

$$\begin{cases} \vec{z} = \arg\min(\vec{w} \cdot \vec{z}) \\ P \geq Pz \end{cases}, \qquad (7)$$

where *Pz* – pre-set value of probability of providing by SPA.

Task 2. To find the number of spare modules of each type (*z*), for maximizing probability of providing by SPA at the limited cost:

$$\begin{cases} \vec{z} = \arg\max(P) \\ \vec{w} \cdot \vec{z} \leq Wz \end{cases}, \qquad (8)$$

where *Wz* – pre-set value of SPA cost.

In tasks (7) and (8) probability of prosperity of the system by SPA is:

$$P = \prod_{n=0}^{N-1} \left[e^{-s_n} \left(1 + \sum_{m=1}^{z_n} (s_n)^m \Big/ m! \right) \right], \qquad (9)$$

where $s_n = (\lambda 0_n \cdot t0 + \lambda 1_n \cdot t1) \cdot x_n$; x_n – number of *n*-type modules (without taking into account SPA) in the system; λ_{0n}, λ_{1n} – failure rate of the *n*-type module.

Tasks (7) and (8) belong to the class of nonlinear integer optimum tasks with non-negative arguments and are characterized by the following features:

– with taking the logarithm of expression (9) tasks can be brought to a separable look;
– if for system in the whole P≥Pz, then this condition is fair also for each type of the modules which forming the system.

The task of optimization is brought to iterative procedure of consecutive calculation of functions

$$f(z,s,w) = w^{-1} \cdot \left\{ ln\left[1 + \sum_{m=1}^{N-1} \left(s^m \ / \ m! \right) \right] - s \right\}. \tag{10}$$

On each iteration of procedure the priority direction is defined with restrictions:

$$nopt = \arg\max\{f(z+1, s_n, w) - f(z, s_n, w)\}. \tag{11}$$

Calculations for various combinations of reservation of spare parts from the point of view of two objectives were carried out.

5. Conclusion

Is offered technique of optimization of preventive replacements allowing to put down expenses and to raise a ready state of transport and technological machines. Formed the order of passing and the scheme of technological process of execution of the main stages of the order for maintenance supply and repair that integrates models of realization of a production cycle. Developed models of input streams and recurring inventory process schemes, which for the chosen policy of formation of a package of applications for certain types of spare parts, materials and accessories allow to estimate probabilities of refusals.

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DRIVING IN EMERGENCIES WITH USE OF SYSTEM OF THE HELP TO THE DRIVER

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The purpose of this article consists in research of modern technologies in automotive industry by the analysis and carrying out technical experiment. The main attention concentrates on traffic safety, which is carried out by automation and modernization of vehicles. In article innovative solutions on implementation of the safe movement of the car are considered. The system of the help to the driver in emergencies of "System help" is offered. This system is intended for implementation of automation of certain processes of the car at those moments of the movement when the driver ignores or doesn't notice the informing signals of system.

Keywords: *automation; transport; car; "System help"; controller; sensor; iSys.*

1. Introduction

Safety on roads is a priority question around the world today. With development of infrastructure the transport system of the countries develops [1]. People became more dependent on transport and in this regard, on roads the number of cars, motorcycles, a special-purpose equipment and other transport has sharply increased [1–16]. It is one of factors which have served to increase in number of road accident on roads [2, 3].

The modern automotive industry is directed, first of all, to achievement of the maximum safety of the car, and his comfortable use [4, 5]. Vehicles are modernized and improved. Requirements for safety and comfort of equipment constantly become tougher, forcing producers to invent new systems and to introduce new technologies [6–8].

2. Innovative solutions in safety of the car

Traffic safety directly depends on quantity and quality of transport structure on roads. Every year the number of cars accelerated continues to increase the quantitative presence on roads of the different countries of the world [1–16].

Today it is necessary to improve as much as possible ways of the organization of traffic by development and deployment of the automated systems and devices [9, 10]. It is necessary to provide with information and technical support of drivers and other participants of the movement. It will allow to reduce the number of road accident that will also affect load of highways [11, 12].

Developers of cars have already made huge break in automotive industry, having created a number of auxiliary devices (sensors, a radar, chambers, etc.), and also, the automated systems [13].

Modern cars have begun to equip with system of recognition of road signs [14]. This system is intended to distinguish road signs of restriction of speed and to inform the driver on the high-speed mode on a passed site of the road. The notification of the driver happens in several ways [15]:

- the sound notification and emergence of the informing badge on the dashboard screen;
- the sound notification and projection of the informing badge on a car windshield.

System of recognition of road signs (Traffic Sign Recognition, TSR) many known car makers – Audi have in the asset, BMW, Ford, Mercedes-Benz, Opel, Volkswagen. The system of recognition of road signs on Opel cars is a part of the Opel Eye system. The Opel Eye system is noted among the best developments in the field of automobile safety of 2010. Mercedes-Benz called the Speed Limit Assist system (the monitoring system of restriction of speed), Volvo – Road Sigh Information, RSI (system of informing on road signs) [16].

This system is capable to reduce the number of road accident on roads and to increase the level of traffic safety. Besides system of recognition of road signs, the system of recognition of pedestrians began to take root widely.

The system of recognition of pedestrians is intended for identification of objects around the car and prevention of collision with them. This system as the main technical knots, as a rule, includes chambers and a radar (motion sensors). Technical knots of the car scan space on perimeter, collect information and issue it on the main controller (on-board computer). At detection of the pedestrian video cameras and additional confirmation by sensors, the system calculates probability of collision, proceeding from remoteness of object and speed of the movement of both (or more) objects and, in case of probable collision, gives the warning signal accompanied with sound on the panel screen. If after signals of system the vehicle doesn't change the movement, then the system independently reduces speed of the car and stops him completely.

For the first time the system of detection of pedestrians has been used on Volvo cars in 2010. Now the system has a number of modifications:

- Pedestrian Detection System from Volvo;
- Advanced Pedestrian Detection System from TRW;
- EyeSight from Subaru.

Also, today one of actively developing directions focused on increase of safety of processes of traffic is development and deployment of system of communication between cars. This system represents a kind of a wireless network (WLAN, Wireless Local Area Network) in which two types of knots – the vehicle (the car, the motorcycle) and infrastructure facilities (the traffic light, the center of regulation of the movement) are allocated [7]. The system of communication between cars is a component of the intellectual transport system (ITS).

The system of communication between cars is intended for the safe movement of all participants on the road. Work of system consists in an exchange of technical information between vehicles. Use of this system is necessary at journey of unregulated intersections, the complicated travel, turn on the left, about rear collision and other dangerous situations.

All above described developments in the field of automation have undergone a number of testings and are actively operated. Improvement and modernization of such systems proves that they are very effective and necessary for modern transport system.

It is very important to develop internal system of the help to drivers. The car equipped with internal system of the help is capable to provide the safe movement on roads, and also, is capable to help the driver in difficult and emergencies.

3. System of the help to the driver in emergencies

It is very important to create system which is capable to analyze independently road process and to control actions of the car. However after the detailed analysis of work of auxiliary systems of the car, a conclusion has followed that traffic safety is carried out not fully, and process of use of the vehicle can be improved. For achievement of this purpose a number of researches and testings on improvement of quality of work of the car and increase in traffic safety has been carried out.

In article the new system of the help to the driver in emergencies of "System Help" which is capable to automate work of the car is offered, having increased thereby the level of safety of process of traffic [5, 6].

Work of this system consists in an assessment of the surrounding situation by collection of information arriving from external sensors on the on-board computer of the vehicle and decision-making on impact on the hardware executive mechanisms, and also, to informing all active participants of traffic. Active participants of the movement are understood as those vehicles with which physical contact (collision, a contact etc.) is possible, it is represented in figure 1 (**fig. 1**).

The system makes the decision, analyzing all arriving data. Therefore, influences as the hardware executive mechanisms, on which she is established and on the hardware executive mechanisms of active participants (provided that all the hardware are equipped with this system), if it is necessary.

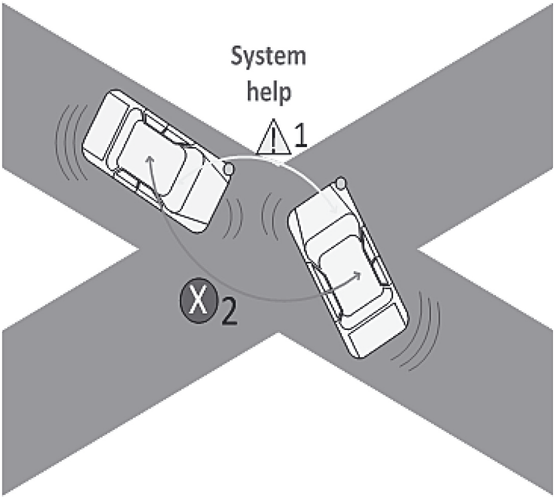

Fig. 1. An example of interaction of two cars
(1 – exchange of the informing signals of danger; 2 – giving of the operating signals)

The principle of interaction and control of environmental conditions by system in borders of one object (car) represents process of collection of information from the external equipment and data transmission on the main computer (controller), it is represented in figure 2 (**fig. 2**).

The System help system includes an automobile radar, the iSys module, a video camera, WLAN-the module and the on-board computer, which interact on one or several CAN-to tires. The automobile radar is a sensor, which uses radio waves for detection of objects around the car. Video cameras allow receiving images of a surrounding situation of the car, which are processed by system. On the basis of the analysis of the arriving signals from the radar and a video camera the complex assessment of potential danger of objects by results of which the system notifies the driver is made and if it is necessary, influences the hardware executive mechanisms. By means of module

WLAN-the system has an opportunity also to inform and influence executive mechanisms of the active hardware.

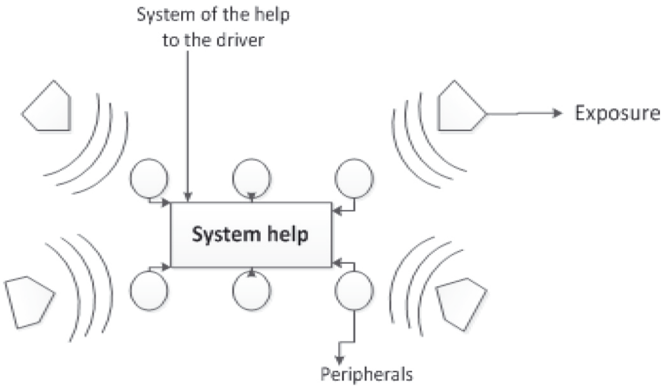

Fig. 2. The principle of interaction of system with external conditions

The arrangement of working knots can differ depending on the internal device of the car. The control unit performs the main work. This block is the on-board computer. The on-board computer interrogates the sensors and sensors established in different parts of the car, then processes collected information and gives the operating signals on devices of the car, and the informing signals on the driver's monitor. In addition, he processes entering external (from a network) signals and will transform them to the operating output signals, which, in turn, are broadcast on the automobile audio system and the information display. In emergency, the system of communication can influence governing bodies of the car, preventing accident [2].

4. Structure of the "System help"

The system of the help to the driver is complex and includes, besides specialized software, the external and internal equipment, it is represented in figure 3 (**fig. 3**). In drawing, the following knots of system are presented:

Cam – Surveillance camera.

Sens – motion sensors (radar).

Bcom – on-board computer. Is the controller, which collects, analyzes, will transform information to the operating signals. Under certain conditions, the on-board computer carries out functions of informing and the prevention of the driver and if the driver ignores the arriving signals of system, the computer assumes management of behavior of the car.

iSys – the module connected to CAN-to the tire and which is reading out necessary information from the digital tire. At an emergency, the module receives a special signal then it sends the digital program to executive mechanisms that leads to shutdown of work of one or several conditions for operation of the engine.

MOD – WLAN-the module and DSRC-the module, which provide wireless access to system of the car and communication in short, distances.

Connection of this system process individual for each installation. He depends on a complete set and technical characteristics of the car.

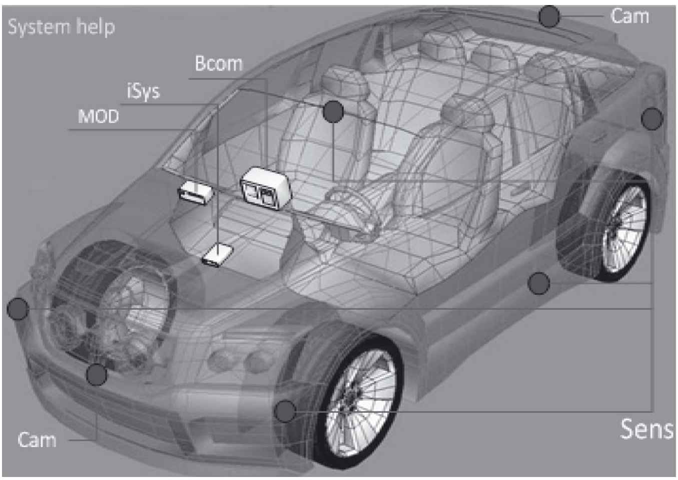

Fig. 3. The main components of the system

All sensors, chambers, executive mechanisms, the on-board computer, modules and other devices are connected to digital CAN-to the tire. This tire allows connecting among themselves a large number of knots. In addition, her feature is that it represents twisted couple that allows avoiding a large number of additional conducting and excess knots. Thanks to this tire, it is not necessary to organize transfer of the first unit of information from knot to knot on a separate wire. Such tires already exist almost in all modern cars that will make process of installation of the System help system fast and reliable.

The scheme of work of system is submitted in the following drawing and it is represented in figure 4 (**fig. 4**).

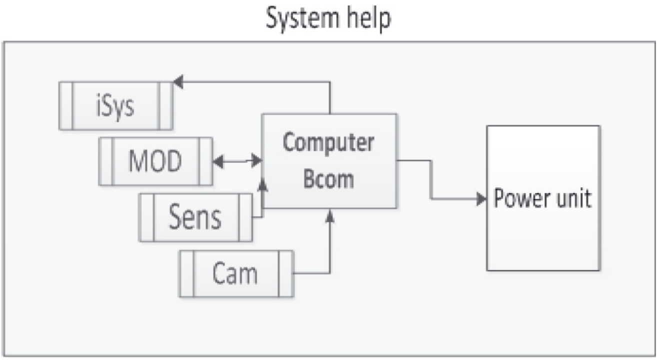

Fig. 4. The scheme of work of the system

The system performs operations on exchange of information between the working knots, collects data, processes and forms the operating signals.

The system of the help to the driver in emergencies of "System help" in the future can become an important component of the car. She is capable to analyze a surrounding situation on the road and to control behavior of the car if necessary.

Very important feature of system is ability of communication between systems that allows to increase overall performance of system and traffic safety.

It is supposed that such system will be useful at journey of difficult sites of the road, to the movement of the car under difficult weather conditions, journey of unregulated intersections and at others potentially emergencies.

5. Carrying out experiment on robotic platforms

In experiment, the following robotic devices are used: a driving platform based on the EV3 controller, a driving platform based on the NXT controller with use of additional Wi-Fi – the HumaRobotics block. Also in experiment the non-automatic model of the car and the card of a marking of the road district are used. Programming of driving platforms is carried out with use of the LEGO MINDSTORMS EV3 EDUCATION software product.

Robots are developed based on the design LEGO MINDSTORMS complex. Robots are also equipped with ultrasonic sensors, which can measure distance to objects. The ultrasonic sensor functions by distribution of sound waves and measurement of time, which is required in order that the reflected wave has returned to the sensor. The sensor is connected to the controller by means of a cable, which is connected to port of input on the controller and will play a role of an automobile radar.

The controller of the robot plays a role of the on-board computer of the car, which is connected to external and internal sensors (in our case it is the ultrasonic sensor). The ultrasonic sensor will measure distances to objects during the movement then it will send information to the controller. The purpose of experiment consists in determination of quality of work of system at interaction of two objects at which both objects are equipped with the System help system.

The number of attempts – 3. Speed of the movement of each robot: 30, 60, 90 turns of the main motors a second. Speed of the movement of not automated car is absent.

Chronology of experiment: three objects approach the unregulated intersection; on incorrect assessment of the situation at the intersection, two objects begin (robots A and B) his journey in this connection, the trajectory of their movement will be crossed in the center of the intersection and will lead to collision, it is represented in figure 5 (**fig. 5**).

As estimated criterion of overall performance of system data on final distance from the case of one robot to another after right operation of system are taken. Results of experiment are given in the table (**Table 1)**.

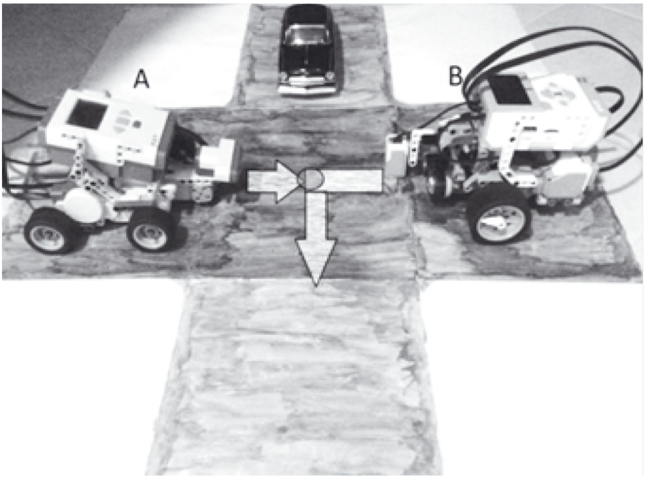

Fig. 5. Experiment

Table 1.

Results of experiment

Number of attempt (No.)	Collision	Distance (cm)
1	no	7
2	no	7
3	no	6

6. Conclusions

Automation of processes of the car is necessary and important area in automotive industry. With modernization of this area, safety of movement directly depends.

The System help system is capable to provide comfortable and safe use of the car, and to help the driver with difficult and dangerous situations on roads.

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