reliability of trucks; forecasting of failures; the analysis of claims

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IMPROVING THE SYSTEM OF WARRANTY SERVICE OF TRUCKS IN FOREIGN MARKETS

Summary. The article is devoted to the practical methods development of improving one of the ways to ensure the health of trucks in the system warranty. Methodology is aimed at optimizing the processes of formation of warranty spare parts kits during the implementation of KAMAZ trucks in foreign markets. The example is given to demonstrate the importance of different factors in the formation of the warranty set for different regions. The algorithm was developed to assess the qualitative composition formed warranty package that will optimize the planning and organization of activity centers to improve operational reliability of commercial trucks. A basis for acceptance of the scientifically-proved decisions is the statistical data analysis of requests monitoring that allows organizing duly replacement of parts with expired service life, and also promotes customer servicing quality improvement and reliability of trucks by prevention of its failures.

СОВЕРШЕНСТВОВАНИЕ СИСТЕМЫ ГАРАНТИЙНОГО ОБСЛУЖИВАНИЯ ГРУЗОВОЙ АВТОМОБИЛЬНОЙ ТЕХНИКИ НА ЗАРУБЕЖНЫХ РЫНКАХ

Аннотация. Статья посвящена разработке практической методики совершенствования одного из направлений обеспечения поддержания работоспособности автомобильной техники в системе гарантийного обслуживания Методика направлена на оптимизацию процессов формирования гарантийных комплектов запасных частей при реализации автомобильной техники КАМАЗ на зарубежных рынках. Приводится пример, демонстрирующий важность учета различных факторов при формировании состава гарантийного комплекта для различных регионов. Разработан алгоритм, позволяющий оценить качественный состав сформированного гарантийного комплекта, что будет способствовать оптимизации планирования и организации деятельности автоцентров по повышению эксплуатационной надежности грузовой автомобильной техники. Основой для принятия научно-обоснованных решений является статистический анализ данных мониторинга обращений, что позволяет организовать своевременную замену деталей, исчерпавших свой ресурс, а также способствует повышению качества обслуживания клиентов и надежности автомобильной техники путем предотвращения ее отказов.

1. INTRODUCTION

In conditions of economy globalization, avalanche growth of information volume and fast development of engineering and technology there is an opportunity to search problem of new products and fast introduction to the markets which stands before developers of complex and high technology truck products that are competitive in this segment and satisfying consumer's expectations. Automobilization growth and an amplifying competitive struggle in the automobile market compel manufacturers of trucks to improve production quality, and also to search for new ways of customer attraction. Confidence of truck buyer plays an important role in opportunity of its problemless operation. It is especially actual for the warranty period, as manufacturers pay special attention to it because any deviations from warranty policy can negatively affect reputation of a producer and lower trust to a brand among buyers and owners. Duly, fast and qualitative service is most demanded for owners of trucks, as at commercial operation of the truck each excess idle hour of pending service is measured by the missed benefit.

As a rule, manufacturers, with the purpose of potential truck buyer attraction, increase duration of the warranty service period that is provided with opportunities of modern achievements in the field of designing and manufacturing of products, a substantiation of their reliability and quality increase ways. It is possible to provide quality of warranty service due to improvement of process quality and due to the prevention of the sudden failures arising during the warranty period. These two basic directions are connected with processing and information analysis, and also algorithm development, techniques and activities on fast reaction to changes of external and internal system parameters.

Quality of processes in the service center is defined by such factors as quality of scheduling, an equipment loading degree during a shift, trained personnel availability, spare parts and consumables availability necessary for maintenance service and repair. Last from the specified factors influencing quality of processes, is closely connected with the decision of a sudden failure prevention problem. Trucks reliability becomes one of primary factors of machinery competitiveness guaranteeing; therefore the problem of non-failure operation guaranteeing is solved at all stages of life cycle - from designing to recycling.

2. TENDENCIES OF WARRANTY SERVICE SYSTEM DEVELOPMENT

Operating a truck, it is necessary to remember, that any, even the most perfect truck, cannot carry out its functions for a long time without qualitative and duly maintenance service and observance of operation conditions. Duly parts replacement which have expired service life, allows not only to increase safety of the truck operation, but also to avoid failure of parts mating to them.

The most effective method of truck operational reliability increase is the prevention of breakdowns based on a technical condition forecasting at a certain operating time, and also planning of service time according to results of the analysis. Forecasting of the possible breakdown moment, i.e. probable defining that controllable parameter goes out acceptance limits in a definite time, allows to plan deliveries of spare parts under the nomenclature and quantity for duly replacement of unreliable elements in view of operation conditions, climatic conditions in specific region, season, type, model and a truck configuration.

Studying character effects can be based on the information on the breakdowns arising while in service, fixed in the form of claims of the consumer, after their careful processing and the analysis. The account of the information, its formalization and classification on malfunctions and the breakdowns, realized in the form of defects codifier, and also its analysis in view of various factors, allow to reveal the reasons of early breakdowns emergence and to take measures on their prevention. The system of gathering, formalization and the analysis of damage statements are necessary for this purpose which will allow the service centers experts to enter, and to employees of the producer company to look through and analyze claims.

The quality of the information about the operating conditions of the truck and its condition at the time of failure occurrence play an important role in determining the possible causes of failure, which makes it possible to improve not only the design of automotive trucks, but warranty system. These issues receive considerable attention in scientific researches. So, in [1, 2] it is noted that in many cases we have to deal with incomplete or subjective information based on the claims of owners of trucks, inaccurate data from warranty reports, or inaccurate data about the mileage. The authors analyze various tools for modeling two-dimensional warranty plan in a two-dimensional plane with one axis representing the age and another - representing the mileage and offer suitable fuzzy method for the treatment of certain uncertain data.

Since the truck is becoming more "intelligent", the possibilities for the prevention of sudden failures and malfunctions are also expanding. Unexpected malfunction occurring during the warranty period of new trucks, not only increase warranty costs for automakers, but also damage their brand reputation. Predictive maintenance strategy can reduce the number of these costly incidents, suggesting that the driver had planned a visit to the dealer, as soon as the likelihood of damage within a certain period of time exceeds a predefined threshold. The condition of each subsystem in the truck can be checked on-board telematics system of the truck, which is becoming more and more available in modern trucks. Thus, the authors of the article [3] offer multilevel algorithm of estimation for the probability to predict the probability and timing of a fault in the system warranty. Information for analysis comes from the integrated database of measurements of the sensor and claims the warranty period. For reliability modeling authors use Weibull analysis.

A similar approach to the formation of arrays of initial information is suggested in the paper [4]. The article shows that to collect information about how, when, and under what environmental parameters and the conditions in which they use the product, can be used in various sensors, which are installed on the product. The authors discusses directions for the use of data on operational reliability, and they investigated the possibility of applying modern statistical methods for management and forecasting in the field of functioning of production systems. In addition, presents some examples of recent technical developments, intended for use in such applications and solutions to such problems.

It is necessary to have a tool for big data files processing which can be textual as causes of failures can be caused by various diverse factors. Various methods of intellectual data analysis are used for forecasting. So, authors of paper [5] present a new association rule-generation algorithm for mining automotive warranty data. The algorithm uses elementary set concept and database manipulation techniques to develop useful relationships between product attributes and causes of failure. These relationships (knowledge) are represented using IF–THEN association rules, where the IF portion of the rule includes set of attributes representing product features (e.g. production date, repair date, mileage-at-repair, transmission, engine type, etc.) and the THEN portion of the rule includes set of attributes that represent decision outcome (e.g. problem related labor code). Application of the association rule-generation algorithm is presented with a data-mining case study from the automotive industry. The knowledge (rules) extracted from the automotive warranty data is used to identify root causes of a particular warranty problem or to develop useful conclusions. Features of warranty data and possibility of their use are given for revealing of emergency reasons, and also the prevention of cases when product failure leads to other product failure in later times.

Paper [6] investigates possibilities of warranty strategy perfection for warranty service cost reduction of a new product on the market. Authors apply a neural network model to forecast year-end warranty performance in the presence of the ‘maturing data’ phenomenon. They use a special type of neural network, viz. radial basis function (RBF), and optimize its parameters by minimizing training and testing errors through planned experimentation. This application shows the effectiveness of RBF neural networks to forecast warranty performance in the presence of the ‘maturing data’ phenomenon.

It is important to have strategy for a new product on the market as in the conditions of a rigid competition updating of truck lineup occurs rather often. The success of a new product depends on both engineering decisions (product reliability) and marketing decisions (price, warranty).

These two directions of strategy formation are interconnected as high reliability increases the cost price, and, hence, and the product price. Consumers are willing to pay a higher price only if they can be assured about product reliability during warranty period.

Authors in paper [7] consider that reliability, price and warranty decisions need to be considered jointly. The paper develops a model to determine the optimal product reliability, price and warranty strategy that achieve the biggest total integrated profit for a general repairable product sold under a free replacement-repair warranty strategy in a market.

Paper [8] offers an integrated model to estimate the gross profit for a new durable product. Authors make an example to illustrate the effects of some key parameters, including the product reliability, price elasticity, and warranty period elasticity, on the optimal settings of the price, warranty period, and post-warranty charge.

The important question influencing product reliability in the conditions of economy globalization, emergence of assembly manufactures and their localization is the choice of suppliers. The aim of study [9] was to increase the competitiveness of automotive companies in national and global markets by providing financial, economical and technological information regarding product design, supply chain, quality and job satisfaction. The results indicated that it is of vital importance to generate a supply-chain database management system for better selection of suppliers. Increased global competition has augmented the importance of total productive maintenance (TPM) in obtaining and maintaining a competitive advantage. Authors of article [10] assert that there is also a positive correlation between TPM and business performance. It is interrelation of six general directions: corporate planning, top management leadership, human resource focus, process focus, total quality management focus and information system focus, and the three specific constructs of TPM strategies, TPM teams and TPM process focus. Thus, according to authors of article [11], the quality system provides new channels for communication to share best practices and to coordinate the efforts of experts in quality management with those in maintenance to improve our understanding of the statistical capability and reliability of equipment.

3. IMPROVEMENT OF WARRANTY SERVICE QUALITY DUE TO SERVICE SYSTEM MANAGEMENT OPTIMIZATION

3.1. Brand service system features for trucks

Customer-oriented and effective brand service system provides services to the consumer and post sales service companies during all truck operation period. It is a principal direction of complex system strategy among large automotive corporations. Competitive advantage is provided due to demanded consumer service degree at simultaneous cost cutting for its maintenance [12]. Consumers estimate company competitiveness on the basis of its position in the market. Thus, possibility of qualitative services on production service support, particularly hi-tech and high technology which the truck relates to during all operation life becomes one of the main criteria.

The concept of expanded product is dominated as the basis of truck-service centre development in Western Europe which led to creation of company truck manufacturer dealer networks. Development of a brand dealer and service network (DSN) and its management optimization is the way to increase production competitiveness. In general, the truck-service centre can be considered as a motor transport infrastructure, in narrow sense - as a truck working capacity maintenance and restoration system throughout life cycle and as an element of the expanded product, i.e. means of truck competitiveness maintenance during their sale by manufacturers. Service support issues are studied at initial truck design stages, defining its reliability as maintainability. Possibilities and features of existing brand service system in a certain measure impose design restrictions on truck characteristics regarding complexity of its service and operation.

Service support feature of truck is complexity of independent service center management. It is caused by design features, and accordingly by repair, and also by small fleet in comparison with passenger trucks. Besides, as the truck is occupied in commercial activity, its idle times lead to the missed benefit of the customer. Therefore, qualitative and timely service substantially influences competitiveness of a brand.

From the organizational point of view brand service system represents DSN which elements are the service enterprises of various levels and formats. DSN efficient control should be based on a principle of the feedback allowing in due time to correct controlling influences on the basis of the information comparison on a current parameter condition of subject activity with their expected values and taking into account changing environment.

As the competition in the services market compels to search new forms of efficiency increase of brand service system functioning. It becomes obvious for heads of many companies that customer orienting is not an attempt to follow fashion, but the basic way of competitive advantage creation. The customer waits that the company will quickly and qualitatively complete the order. To satisfy a customer, a company should follow that [13, 14]:

- Work will be done correctly from the very first;
- There is a developed program for those cases when something goes wrong.

As the policy in the field of service in all developed countries is that a seller guarantees operative maintenance with original spare parts, so a service strategy, especially during warranty period, should be based on qualitative requirement forecasts for spare parts. To increase spare part delivery structure and time planning efficiency it is necessary to consider that various parts, units and truck systems have different resources and possess different reliability degree which, in turn, depends on set of factors having stochastic character.

3.2. The decision support system as an effective instrument of service strategy

The quality of the service strategy and the effectiveness of its implementation depend on the quality of information and the adequacy of the methods of its processing. Therefore the optimum tool allowing reacting quickly to changes of external and internal system parameters are systems of Decision Making Support Systems (DMSS) which are based on the technologies using operative databases, storehouses of data, systems of operative analytical information processing and intellectual data analysis. DMSS is a complex of the interconnected models with corresponding information research support, expert and intellectual systems including experience of management problems decision and providing participation of experts during working out of rational decisions.

As decision-making is based on real data on management object, aggregated information are applied for analysis and strategic decision making for storage of which Data Warehouse (DW) is created. The purpose of DW construction is integration, actualization and the coordination of operative data from diverse sources for formation of a uniform consistent view on an object of control as a whole. Data Warehouse contains information collected from several operative databases of OLTP-systems (OLTP (On-Line Transaction Processing) - operative processing of transactions in real time).

DMSS possesses means of granting modular data to the user for various selections from an initial set in a convenient way for perception and analysis. Modular functions form a multidimensional data set (a hypercube or a metacube), where users can formulate complex inquiries, generate reports, receive data subsets. Such technology of complex multidimensional OLAP (On-Line Analytical Processing) data analysis is analytical processing in real time which is a key component of the Data Warehouse arrangement.

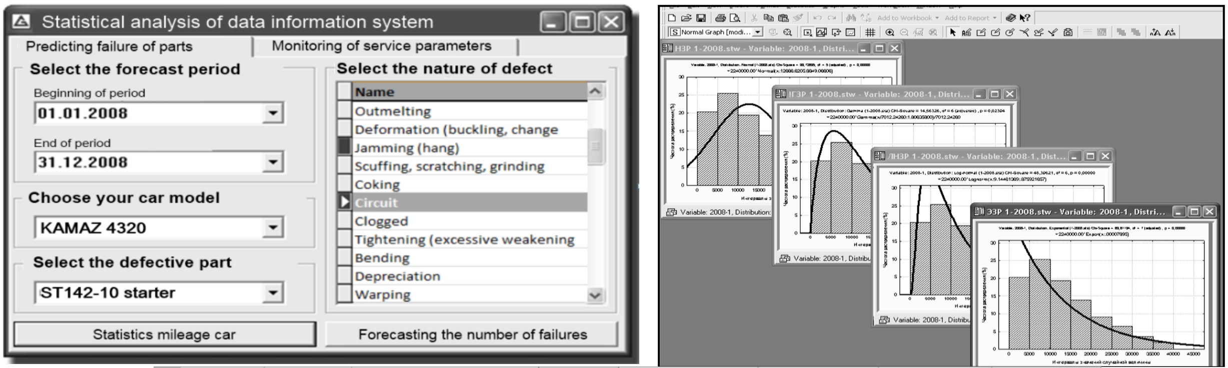
Realization method includes various patented ideas: architecture versions "customer-server", time series analysis, objective orientation, data storage optimization, parallel processes, etc. Application areas differ as well. So, in article [15] experience of an OLAP-cube application for the analysis of the product defects reasons in quality system of sewing manufacture is described, in article [16] the multidimensional analysis is applied for defect clustering at construction of bridges, in article [17] the expert system creation opportunity is described, based on knowledge and using the multidimensional data analysis for strategy construction at the logistical processes arrangement. Article [18] is devoted to the development of the computerized control system by maintenance service intended for the decision analysis, allowing revealing the reasons of failures in a system, in account of various criteria, such as time and frequency of idle times, availability of spare parts and others. The described technologies are realized in the form of DMSS for quality management [19, 20], and also for industrial systems and processes management at all stages of production life cycle [21].

While revealing reserves of automotive enterprise service centers processes efficiency increase it is necessary to consider, that various truck units, components and systems have a different resource in different conditions and possess a different degree of reliability which, in turn, depends on set of factors having a stochastic character. In particular it is typical at expansion of commodity markets and development of DSN abroad.

Data about the reasons to apply to DSN with detailed elaboration of all parameters are fixed in a database and serve as the initial information for the subsequent analysis. Thus for formation of each selection one of factors is considered, but values of the others remain fixed. Law parameters of failure distribution for each unit are defined on the generated data file by means of Statistica program [22]. Thus, according to the histogram of empirical data the schedule of distribution law is deduced and its conformity to selective data is defined at the set significance value. Results of the analysis serve for development and updating of the instructions intended both for the service centers, and for automobile owners which observance allows to provide trouble-free operation of the truck.

Continuous monitoring of system status service can improve not only the reliability of the truck, but also the effectiveness DSC. The control is performed using the implemented in the DSS module "Statistical data analysis" (Fig. 1). This module allows to solve two tasks: setting the parameters of the laws of the failure distribution and the prediction of their number for a certain period.

The analysis of the parameters of the laws of distribution of truck mileage to failure is to compare characteristics of datasets from different periods and make recommendations for the management of system maintenance. On the basis of the current data array to set parameters of the distribution are selected using the criterion of consent, which are compared with the parameters chosen as optimal in previous periods. Changing the parameters of the distribution indicates a change in system state.



	A	B	C	D	E	F	G	H
1	Year	Quarter	Distribution law	X-square test	The number of freedom degrees	Criterion X-squared	Parameter 1	Parameter 2
2	2008	1	Normal	99,73	5	11,1	**12666,62**	**8849,066**
3	2008	1	Exponential	63,61	7	14,1	**0,0000789**	
4	2008	1	Gamma	14,56	6	12,6	**7012,242**	**1,806358**
5	2008	1	Weibull	48,40	6	12,6	**9,144613**	**0,8759216**
6	2008	2	Normal	82,48	6	12,6	**14610,68**	**10435,2**
7	2008	2	Exponential	46,54	8	15,5	**0,0000684**	
8	2008	2	Gamma	6,06	6	12,6	**8113,728**	**1,800736**
9	2008	2	Lognormal	26,22	6	12,6	**9,286379**	**0,8453985**
10	2008	3	Normal	80,40	6	12,6	**14749,09**	**11168,34**
11	2008	3	Exponential	29,85	9	16,9	**0,0000678**	
12	2008	3	Gamma	4,42	6	12,6	**8975,164**	**1,643323**
13	2008	3	Lognormal	24,64	7	14,1	**9,264273**	**0,8979254**
14	2008	4	Normal	51,65	7	14,1	**16362,89**	**11276,1**
15	2008	4	Exponential	44,68	9	16,9	**0,0000611**	
16	2008	4	Gamma	13,94	7	14,1	**9684,709**	**1,689559**
17	2008	4	Lognormal	40,41	7	14,1	**9,378022**	**1,9438345**

Fig. 1. Analysis of the parameters of the distribution laws
Рис. 1. Анализ параметров законов распределения

Because the procedure is fully automated and can be performed by one person, it leads to lower financial costs associated with the reduction in headcount, as well as reducing the complexity and run-time operations.

If the parameters of the distribution laws testify to the deterioration of the system (for example, about the reduction in the average mileage to failure), the control in the previous step was not rational, and the system needed to control exposure. In this case, recommendations for control are based on the optimization of the experiment conducted on the simulation model, parameters for which are based on analysis of data about the intensity of the stream of failures in the intervening period, the average service time and so on (these indicators are also displayed in the statistical analysis module).

In the case when the values of the parameters of the distribution laws indicate better functioning of the system, we can conclude that the management in the previous period was rational, that is adequately goals. So implemented method of decision making is based on scientific data analysis information system.

To predict the number of failures time series of the number of replacements of defective parts for a period specified by the user is automatically generated, which is exported to the package Statistica, where the exponential smoothing of number is done, select the model of the seasonal component (additive or multiplicative) and a line of the time series model and the forecast line are plotted. Thus, the forecasting procedure is also fully automated (see Fig. 2).

When the results of monitoring in the system of corporate services deterioration of the system are identified relative to previous periods, subject to the adoption of certain management decisions is necessary. To solve this task a method of forecasting the state of the system and making management decisions was developed based on monitoring results, described as algorithm and implemented in the DSS. The methodology for making decisions is based on the analysis of the performance of the system: if the value of any index has changed for the worst dealer service center side, then on the basis of the analysis data of the previous period updating the parameters of the simulation model.

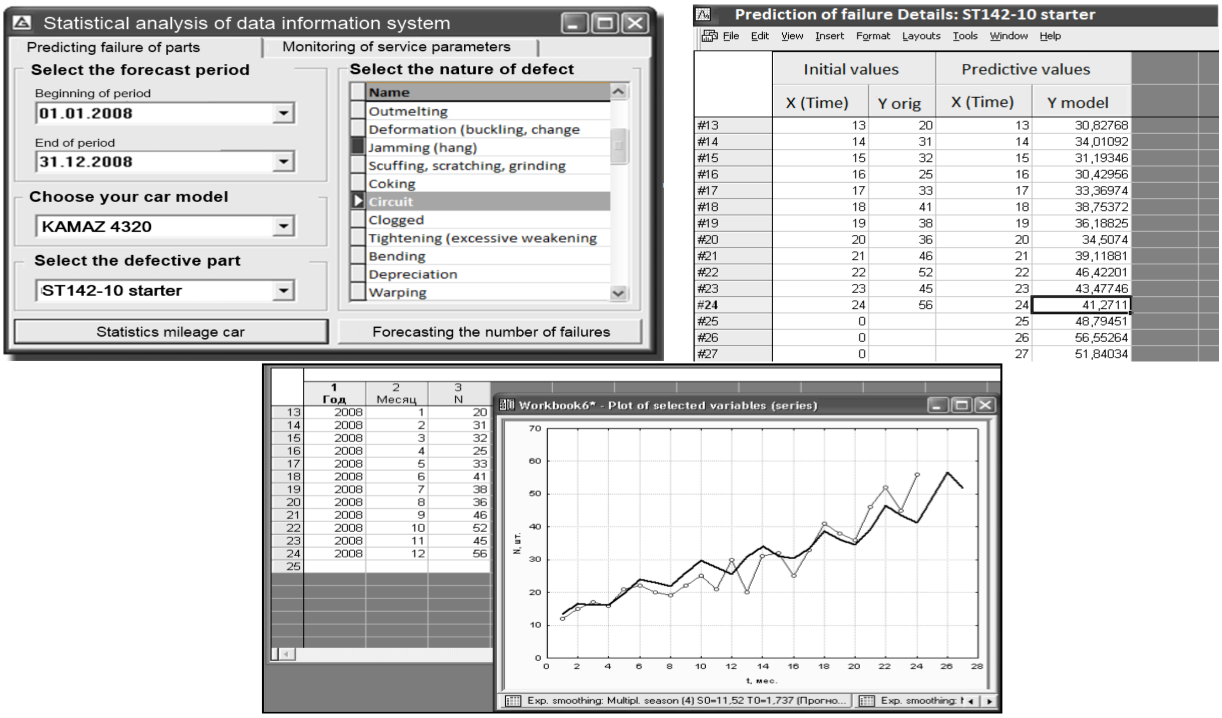


Fig. 2. The solution of the problem of predicting the number of trucks components and assemblies failures
Рис. 2. Решение задачи прогнозирования числа отказов узлов и агрегатов автомобилей

Then optimization computer experiment is carried out that allows you to find the characteristics of the processes in the service system, in which the value of the detected index is optimal. The experiment on the model is to determine such a number of resources for maintenance, in which the balance of the cost increase in the number of posts and the workers and their content to meet a larger number of service calls and lost profits resulting from the loss of the client in case of rejection of bids will be optimal.

For maintenance requests servicing, and TR, which are universal across the spectrum of work performed. The service time at the positions specified by law distribution, established on the basis of statistical data analysis information system.

3.3. Features of spare part maintenance system at the warranty service management in foreign markets

One of the main causes of downtime of trucks on the posts in anticipation of the service is the lack of spare parts. This situation is characteristic for both domestic dealer service centers (DSC) and DSC located abroad, but foreign DSC the problem is further complicated by a number of external factors affecting the organization of supply, therefore, the search for solutions has more relevance. One of the possible ways of solving this problem is the creation of such system planning needs for spare parts, which would allow to arrange timely deliveries, based on more accurate forecasts. To solve this problem in the DSS allows the analysis of the reliability of various parts, components and systems and the planning of delivery of spare parts based on the analysis of statistical information. The source data for the analysis is species-age structure of the regional Park, the statistics of calls to the dealership at automobile equipment failures during the warranty period, decorated in the form of a complaint of acts that can predict the residual resources of parts, components and systems for trucks [23].

Analysis of information on failures of trucks shows that each model under certain conditions of operation at a fixed time there are a number of details, most frequently failing, called "limiting" reliability, or critical reliability. However, as described in [24], 15-18 thousand details that make up a truck, 3-4 thousand have lifetimes of less than the truck itself, but only 400 parts are critical to reliability.

As experience in the maintenance of technical products, the change in the failure rate of the vast majority of objects described by a U - shaped curve, which can be divided in three operational stages. In the running-in period the truck has a high failure rate. It faults associated with the break-in details, usually due to a manufacturing defect. This period is associated with a warranty period of operation of automotive equipment and parts. During normal operation failures are random in nature and appear suddenly, primarily because of the non-operating conditions, load changes, adverse external factors, etc. This period corresponds to the main time of operation of the facility. The third period is characterized by an increasing failure rate, which is caused by aging and other causes associated with long-term operation. As the curve indicates the presence of three sections described various dependencies, there is the obvious difference of the reasons (or combination of factors) that cause the failure. From this it follows that the planning DSC should be performed taking into account species-age structure of the Park, as well as information on applications in DSC. While planning the supply of spare parts should have three fundamentally different mechanisms: for trucks for which the warranty period has not expired; for trucks in regular operation and for trucks with a significant lifetime, residual life for many units, assemblies and systems are approaching declared by the manufacturer.

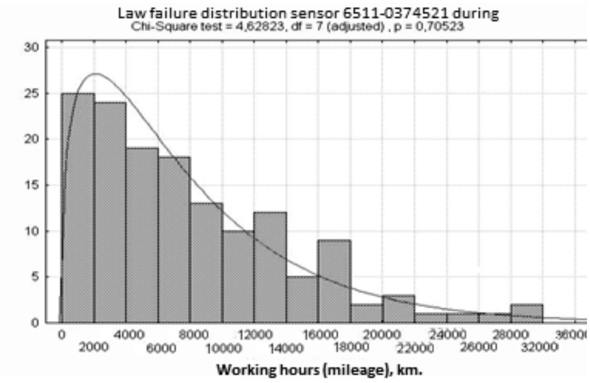
As the warranty period is the most important for maintenance of customer's loyalty, first of all, a question on maintenance of qualitative service is solved during this period. Appointing the warranty period, the producer company includes not only running-in period, but also a part of regular operation period. However, as a curve breakdown rate nature testifies, dependences of breakdown quantity on an operating time on these sites are described by two essentially different laws (Fig. 3). Therefore spare parts supply process should include two functionally various mechanisms.

So, at the service maintenance in foreign markets the regular service mechanism at running-in period Spare Parts Warranty Packages (SPWP) is sent in a region of operation together with party selling trucks, which qualitative and quantitative structure is made with account of information on failures during the previous period. Therefore SPWP qualitative and quantitative structure design procedure is necessary for a running-in period. Possible references planning method is necessary for a regular operation period owing to breakdown of this or that part in view of the statistical information analysis data under references to DSC during previous period. Such planning method serves a basis for a delivery date structure and calculation formation in control center of a dealer service network (DSN). Consignment structure in both cases is formed in view of the information on breakdowns during the warranty operation period. The great number of parameters describing operation and truck servicing conditions, and model range which is constantly updated causes a search of the means providing efficiency and accuracy of analysis carrying out.

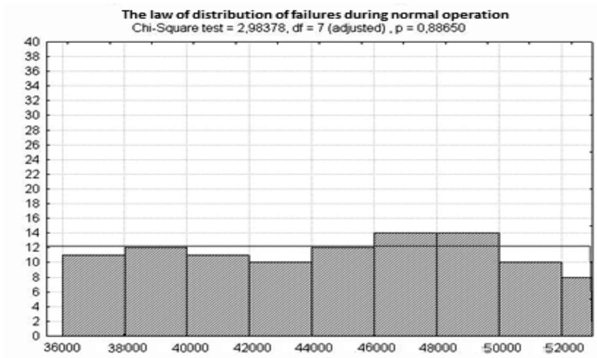
The composition of parties in both cases formed the basis of information about failures in the warranty period [25]. A large number of parameters characterizing the operating conditions and service support of the truck, as well as continuously updated range of trucks are the need to find means to ensure the timeliness and accuracy of the analysis.

3.4. Influence of warranty package formation process quality on non-failure operation of trucks during warranty period

The method of forming SPWP for a particular party hire is the determination of its composition, which would eliminate the greatest number occurring during the warranty period, the refusal rate for this party. The cost SPWP is determined by the manufacturer taking into account the risks of exceeding a certain reserve amount, which is obtained by deducting the prescribed percentage of each sold truck to cover warranty repairs. The method is based on the analysis of failure statistics - multivariate data analysis. Because many of the factors affecting the operational reliability of the truck are stochastic, with the development of a guarantee takes into account the risks of the manufacturer. If you have the required amount of adequate statistical information about the failure to use an objective method of determining the frequency of failures in a specific sample (1):



a)



b)

Fig. 3. Distribution of sensor failures 6511-0374521: a) – during the break-in; b) – during normal operation
Рис. 3. Распределение отказов датчика 6511-0374521: a) – в период приработки; b) – в период штатной эксплуатации

$$f(A)=n(A)/n \quad (1)$$

где f - incidence of failure; $n(A)$ - the number of type A failures occurrence; n - total number of cases in a statistical sample of all failures.

In case of insufficiency of information used subjective methods, expert judgement.

For enterprises engaged in the production of automobiles and their subsequent sale and warranty service, risk (R) characterize the probability and extent of potential losses as a result of excessive costs of warranty repairs to the truck park in relation to the reserve amount (Rgf), which is formed on the company as a result of deductions prescribed percentage of each sold truck and spent to cover warranty repairs. Reserve amount or "Guarantee Fund" should be developed so as to satisfy the following conditions:

• the value of enterprise risk should be minimal (min) - i.e. to lie in a risk-free region;

• guarantee Fund should be such that as little as possible the funds of the company were in the illiquid state.

$$\left| \frac{P}{C_{WF}} \right\rangle \min \quad (2)$$

These two conditions contradict each other, so as to reduce the risk it is necessary to increase the guarantee Fund, and in the reduction of the guarantee Fund, in turn, increases the risk of the enterprise - $P(C_{WS}>C_{WF})$.

The guarantee Fund of the company for the warranty of the Park is defined as (3)

$$C_{WF} = C_{\%} \times C_{TRUCK} \times N_{WP} \quad (3)$$

where: $C_{\%}$ is the percentage of contributions to the guarantee Fund of the company from the selling price of the truck; C_{TRUCK} - the average cost of a new truck; N_{WP} - water flow warranty of truck park (the average number of trucks under warranty).

To determine the warranty costs warranty park C_{WS} is to consider not only the cost of parts, broken, but also the complexity of the failure removed:

$$C_{WS} = \sum_{i=1}^{m} (C_i \cdot f_i(t) + t_i^{н} \cdot c^{н}) \cdot N_{WP} , \quad (4)$$

where: C_i i is the cost of the part of i-th species, rub.; $f_i(t)$ is the density function of the distribution of the time between failures of parts of the i-th species; $t_i^{н}$ - normative complexity of failure is removed, man-hour; $c^{н}$- rate standard hours; m is the number of groups of parts.

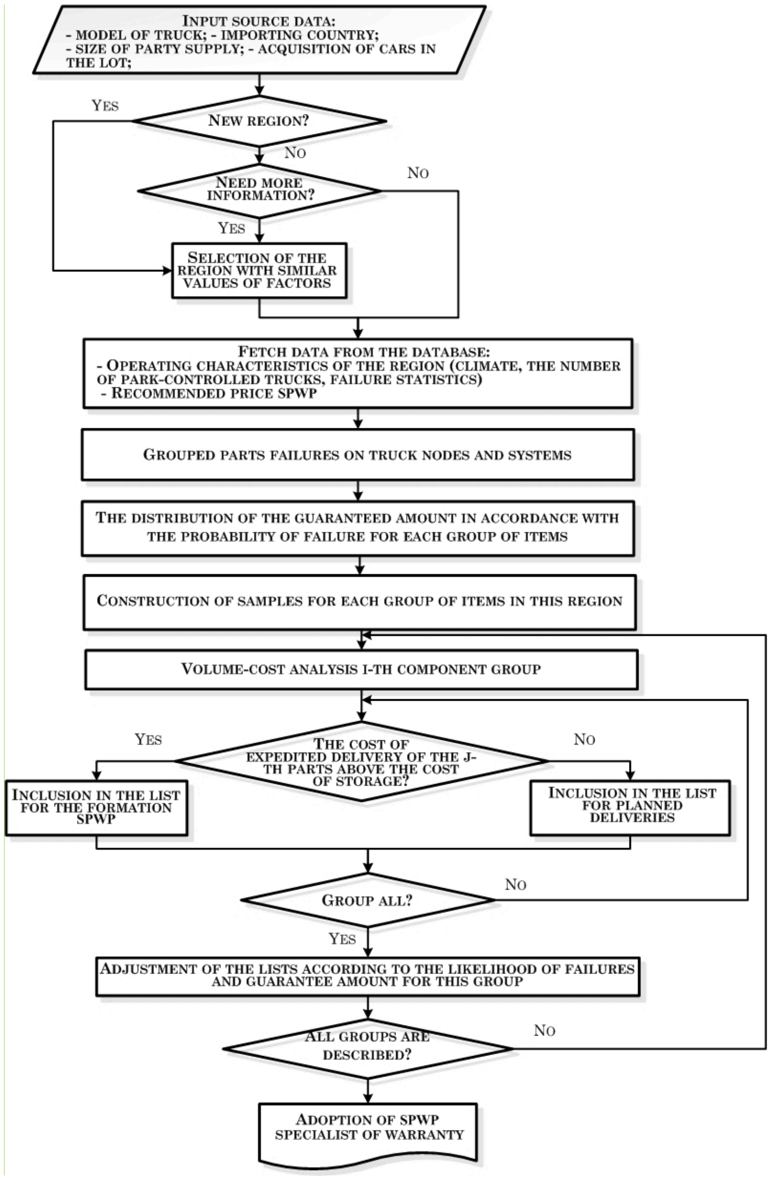


Fig. 4. Algorithm for determining the composition of SPWP
Рис. 4. Алгоритм определения состава ГКЗЧ

For the manufacturer of the truck risk-free situation must be considered as if the value of the risk of exceeding the warranty costs in relation to the reserve amount is in the range P = 0 ... 0,2. An algorithm for the solution of the question of the inclusion of details in SPWP shown in Fig. 4.

When planning for service during the warranty period, you should consider the fact that even when carefully calibrated recommended composition SPWP situations may arise at the stage of its formation, leading to unexpected costs from both DSC, and the owner of the truck. However there are situations when the risk of exceeding the guarantee Fund of the company may be repeatedly exceeded. Therefore, the quality of the process of formation of the warranty set is another factor affecting the quality of service within the warranty period.

One more factor influencing service quality during warranty period is a quality of warranty package formation process. In lineup extension conditions and one truck model versions, caused by customer satisfaction and approved interchangeability of assembly units, a situation can happen when positions in recommended SPWP do not coincide with assembly units installed in the truck. It can be reflected in reliability of the truck as quality interchangeable position of different manufacturers differs frequently. Variants of such discrepancies are reflected in the algorithm represented on Fig. 5.

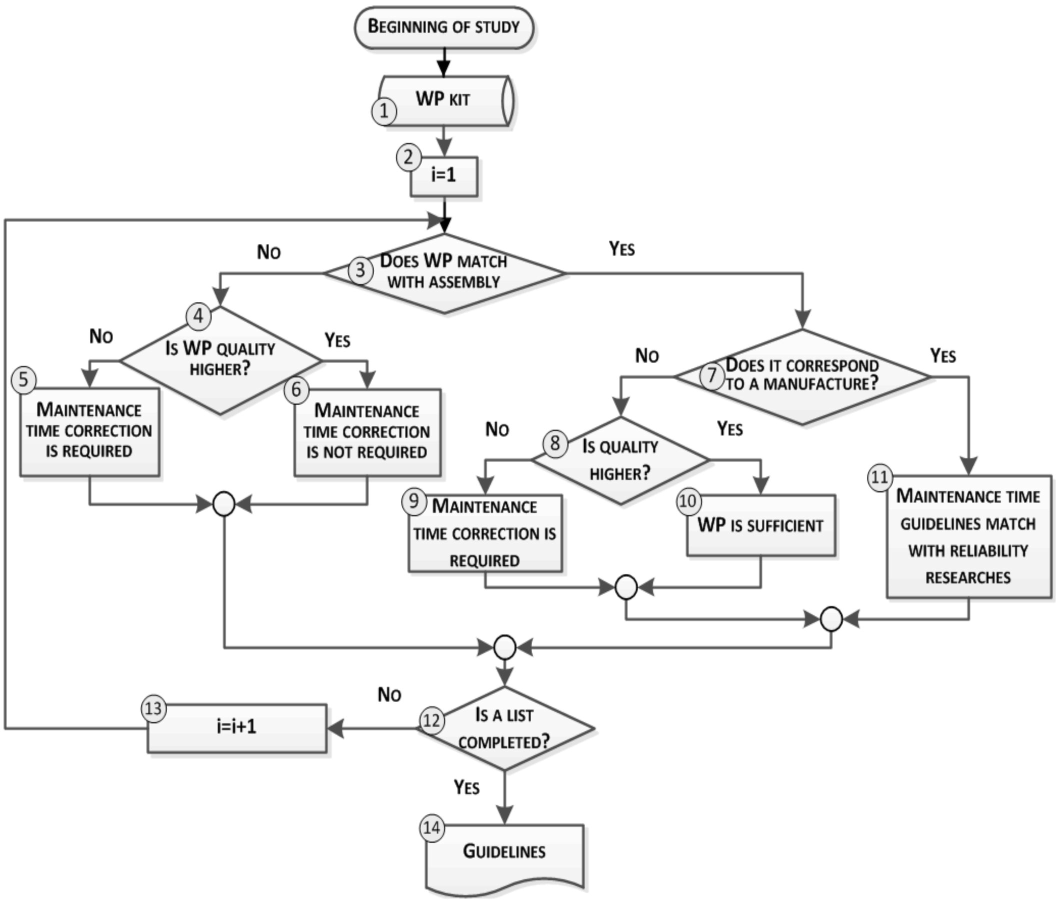


Fig. 5. Failure probability forecasting algorithm during warranty period depending on quality of SPWP formation

Рис. 5. Алгоритм прогнозирования вероятности отказа в гарантийный период в зависимости от качества формирования ГКЗЧ

4. EXAMPLE OF OPERATION REGION CLIMATIC FEATURES INFLUENCE ACCOUNT ON A WARRANTY PACKAGE KIT

As the number of failures at developed DSN represents great data volume depending on significant number of factors, the above described OLAP technology was applied to data aggregation, allowing spending failures analysis at the chosen combination of measurements. So, the three-dimensional OLAP-cube with simple measurements is displayed on Fig. 6.

The cells contain the facts pertaining to the failure of one or another part, or unit. For example, sleeve design number 740.01 in the region of operation India, in the autumn season went out 37 times in the period from 01.01.2009 on 01.01.2011. Information in multidimensional data store is a logically integrated structure in order to determine at what time and in what region has failed a particular detail. OLAP cube is implemented using the relational model, i.e. emulation of the multidimensional representation of a set of flat tables. This system is called ROLAP - Relational OLAP.

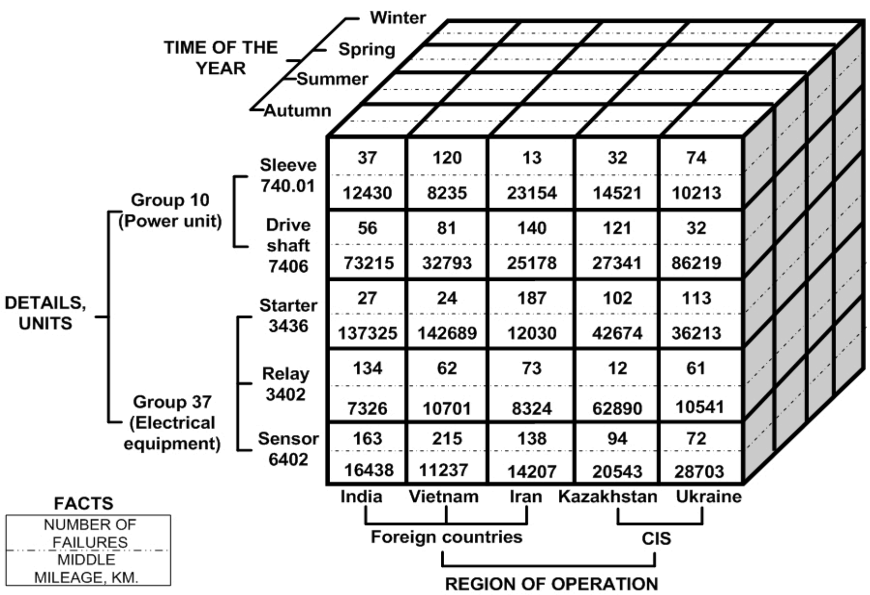


Fig. 6. The organizing principle of the multidimensional cube representation of operational reliability
Рис. 6. Принцип организации многомерного куба представления показателей эксплуатационной надежности

To provide flexibility and multidimensionality analysis queries were used to build the data arrays. the software module "analysis of the defects of the complaint acts" was developed which allows to determine the probability of failure of parts or unit as at the stage of breaking-in, and during normal operation.

The algorithm of this software module provides processing reclamation acts.

The method of ranking data in this software module is provided through the section, convolution and detail. For example, if you run the section India the measurement Region of operation, then the resulting slice will contain information about the failure of all parts, components and assemblies of trucks of all models in this region of operation, at all times of the year. By manipulating the measurement, the user can get information in the right section. Operations rollup (grouping) and detail (decomposition) are possible only in the case of hierarchical subordination of dimension values. In this case, when the bundle one or more subordinate values of the parts are replaced with the values of the subgroup of details, and those, in turn, are replaced with the values of the group details. At this level of aggregation of data is reduced.

The software module allows you to analyze the performance of the frequency of failures on various dimensions - group detail, the reason for the denial, region of operation, DSC, end customer, and models of truck, time of year, mileage, etc. This implementation are presented in Fig. 6 multi-dimensional cube, which can be manipulated by the user. For example, by varying the setting of the date of arrival of the letter of complaint, and, respectively, the date of the denial, you can determine the dependence of the number of rejected time of year. For different regions of operation of this dependence will vary, due to different climatic conditions. Analyzing customer lists, they must be separated by type of activity (construction, mining, transportation, military, and so on), which can also be attributed to one of the dimensions.

The software module allows you to establish the cause of failure, which facilitates the separation of the analysis for two different periods (break-in and normal operation). If selected for analysis the running-in period, in a software module only the failures are displayed that occurred at the stage of break-in warranty period. Causes of failures for this period are often of poor quality parts or sub-assemblies. During normal operation caused failures are either violations of the requirements of this guide, or complex conditions. In addition, the software module allows you to integrate data in Statistica for building law distribution of node failures and units depending on mileage (Fig. 7).

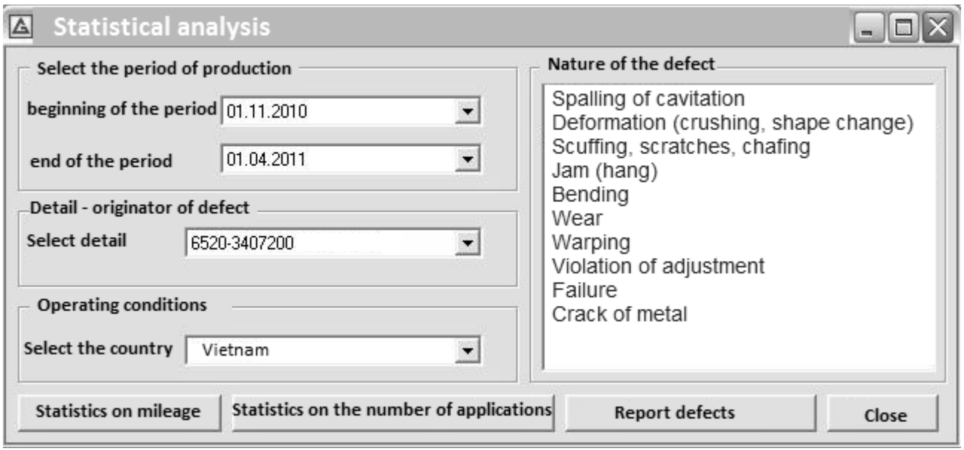
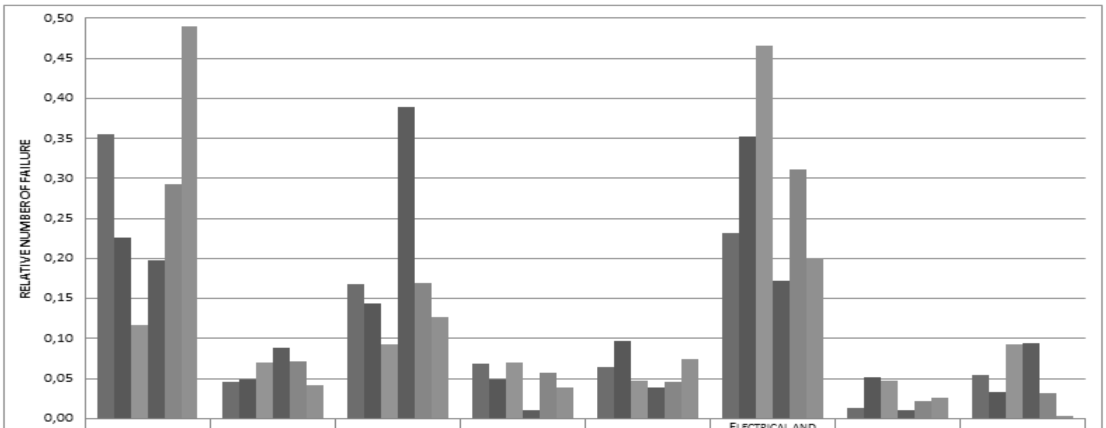


Fig. 7. The integration module reliability of trucks for statistical analysis Statistica software
Рис. 7. Модуль интеграции показателей надежности автомобильной техники для статистического анализа в программе Statistica

Based on the selected measurement the failure sample is made at a certain mileage, containing the essence of the defect. Data is exported in a package Statistica, using which the user can construct the distribution laws of the failures of parts, components and assemblies at both the running-in period, and during normal operation.

As DSN provision abroad with necessary spare parts during the warranty period is one of prominent aspects of producer company warranty observance, the essential attention is paid to formation method development of their deliveries. Methods are formed on the basis of the breakdown statistics analysis during the warranty period. However, in our opinion, the insufficient attention is given to region climatic features. So, the climate of the region directly affects the operating conditions that affect the probability of failure of various components, mechanisms and assemblies of the truck.

As can be seen from the diagram (Fig. 8), the relative number of failures in countries with different climatic groups has significant differences. In addition, for a number of countries, which have uneven climate due to the large areas and the geographical location, stat calls in the centers, located in different climatic conditions may also vary (Fig. 9).



	Engine	Transmission	Chassis	Steerage	Braking system	Electrical and Electronic Equipment	Cabin	Body and special structure
1	0,35	0,05	0,17	0,07	0,06	0,23	0,01	0,05
2	0,23	0,05	0,14	0,05	0,10	0,35	0,05	0,03
3	0,12	0,07	0,09	0,07	0,05	0,47	0,05	0,09
4	0,20	0,09	0,39	0,01	0,04	0,17	0,01	0,09
5	0,29	0,07	0,17	0,06	0,05	0,31	0,02	0,03
6	0,49	0,04	0,13	0,04	0,07	0,20	0,03	0,00

Fig. 8. The distribution of the relative number of KAMAZ trucks units failures in countries with different climatic groups according to the classification of Köppen [26]
Рис. 8. Распределение относительного числа отказов агрегатов автомобилей КАМАЗ в странах различных климатических групп в соответствии с классификацией Кеппена [26]

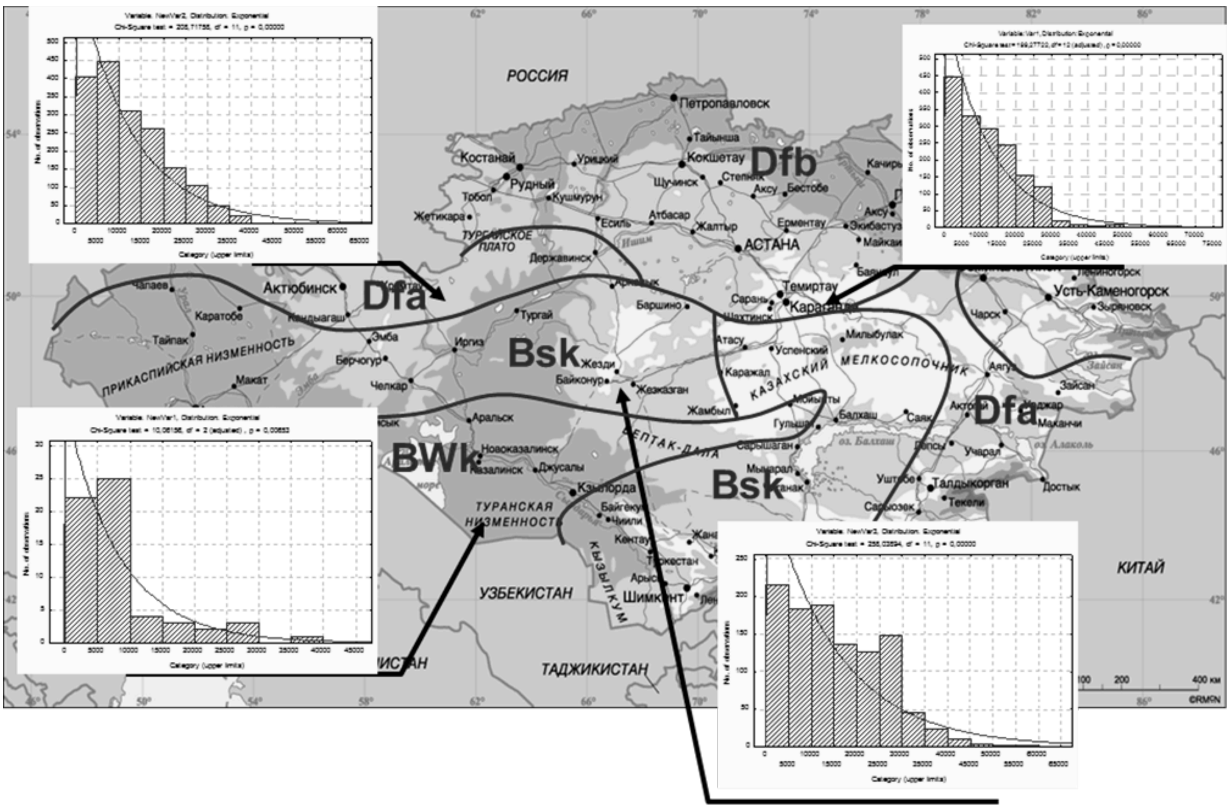


Fig. 9. The laws of distribution of hits in the dealerships in the Kazakhstan Republic
Рис. 9. Законы распределения обращений в автоцентры в республике Казахстан

The cost of fault will also be different for different groups of parts. The cost will be determined as the cost of the parts and labor cost for its replacement.

At the same time, multivariate analysis of failure statistics allows you to adjust the methods for preparing SPWP that not only improve the quality of warranty service, but also reduce costs caused by the need for urgent deliveries in the absence of stock for the right spare part.

Warranty costs for trucks operated in different conditions have considerable scatter, which is due both to climatic conditions of the region, and other factors that makes it difficult to determine how the size of the guarantee Fund and its distribution (value SPWP and payment for the repair of failures). Since it is necessary to take into account the risks that the maximum amount of contributions to the guarantee Fund of an enterprise With C% is determined from the maximum allowable mileage, average for all regions of operation taking into account the maximum allowable risk (Fig. 10).

The calculation of the optimal composition SPWP for each country must be performed taking into account the individual characteristics of the region of operation and adjusted in accordance with the developed algorithm, which will reduce the likelihood of downtime of trucks due to lack of spare parts, to improve their reliability and quality of service.

In addition, in the globalized market multidimensional analysis information and the allocation of the factors that have the greatest impact on the reliability of trucks, it is possible to form the structure SPWP for new markets by selecting regions of similar values of operational factors and using available statistical information.

5. CONCLUSIONS

Researches showed that in the conditions of economy globalization and high competition among truck manufacturers, one of effective methods of truck competitiveness increase reliability. The most steadfast attention, both scientists, and truck manufacturers, is given to problems of warranty strategy development. Quality of this strategy depends on adequacy, timeliness and completeness of the information on failures during warranty period. Besides, it is necessary to provide conditions for realization of the given strategy, improving service system. The results of researches in this paper show that forecast quality leads not only to dealer but also to manufacturer profit increase.

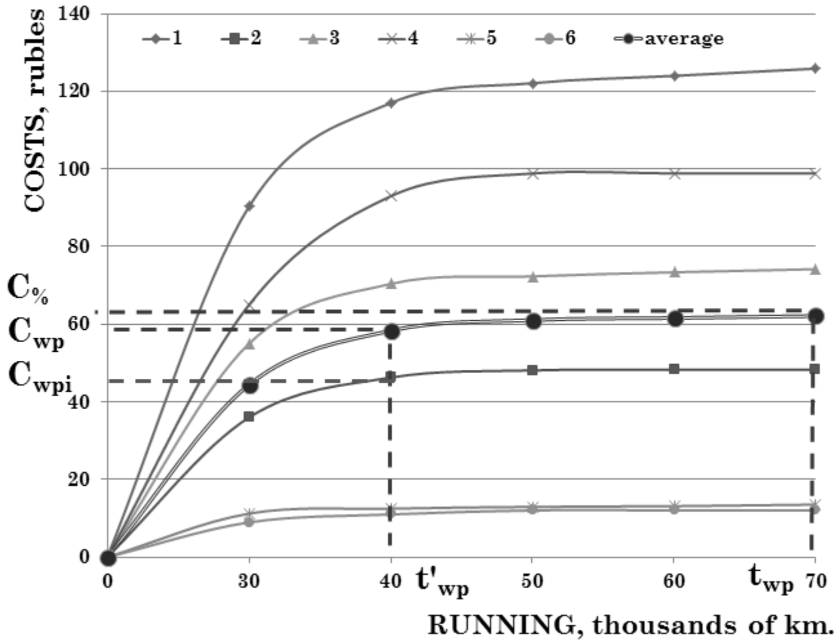


Fig. 10. A graph of the dependence of the cost of warranty repair trucks by miles. The variation of the theoretical functions of the total cost per truck for different countries: $t`_{wp}$ – limit warranty mileage; t_{wp} – mileage warranty, the permissible value of risk

Рис. 10. График зависимости затрат на гарантийный ремонт автомобилей от пробега. Вариация теоретических функций суммарных затрат в расчете на один автомобиль для разных стран: $t`_{гп}$ – предельное значение гарантийного пробега; $t_{гп}$ – гарантийный пробег, соответствующий допустимому значению риска

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