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system of corporate service; spare parts suppliers;
cluster analysis; vehicles on natural gas

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IMPROVING THE LOGISTICAL PROCESSES IN CORPORATE SERVICE SYSTEM

Summary. The study deals with enhancing the reliability of freight cars by improving the corporate service system. Assessing of the quality of spare parts suppliers is discussed. An algorithm for supplier selection and an evaluation method, based on cluster analysis of indicators of supplier reliability, is proposed. Alternative developments for a service network, in view of expanding of the car fleet powered by natural gas-based fuel have been considered.

СОВЕРШЕНСТВОВАНИЕ ЛОГИСТИЧЕСКИХ ПРОЦЕССОВ В СИСТЕМЕ ФИРМЕННОГО АВТОСЕРВИСА

Аннотация. В статье рассматриваются способы повышения надежности грузовых автомобилей путем совершенствования процессов в системе фирменного сервиса. Рассмотрен один из путей повышения надежности – оценка качества поставщиков запасных частей. Предложен алгоритм выбора поставщиков и метод оценки, основанный на кластерном анализе показателей надежности поставщика. Рассмотрены варианты развития сервисной сети при расширении парка автомобилей на газомоторном топливе.

1. INTRODUCTION

Due to increasing truck fleet and growing competition in the automotive market, the car manufacturers are forced both to improve the quality of their products and search for new ways to attract customers, therefore effectiveness of corporate systems is the key question [1]. No small role in this case is played by the confidence of a car buyer in trouble-free operation of the car bought. For truck owners, it is essential to be provided with timely, prompt and quality service because every hour wasted on service waiting means loss of profit.

Reliable mechanical support has become one of the main factors ensuring competitiveness. High reliability of a vehicle implies a comprehensive approach to all stages of the vehicle's life cycle: designing, manufacturing and operation.

The operational phase involves logging of information about failures of the vehicle assembly components, integral units and systems. Information is forwarded to designers to eliminate the failure causes and specify the initial data for reliability calculations. The focal point here is monitoring and diagnosing of the technical condition of a truck. Servicing time can be diminished by replacing the failed assembly components and units owing to the modular-block principle of vehicles' design.

The quality of warranty service is upgraded by improving the technological processes and by preventing sudden failures. Both improvement and prevention are based on processing and analysis of information and developing of algorithms, methods and activities of emergency response to changing of both internal system parameters and external factors. The quality of processes in the service center depends on the quality of work planning, the level of facilities' employment during a shift, and the availability of trained personnel and spare parts and consumables needed for maintenance and repair. The latter factor is closely related to the problem of preventing of sudden failures.

Determining of the spare parts demand is connected with predicting and planning of logistical processes. Servicing of truck is special because of a large number of models and modifications at a comparatively small size of the truck fleet. Moreover, the cost of spare parts and their delivery is higher than that for cars. Therefore careful planning of deliveries may essentially enhance the service system effectiveness. An important point in the planning is careful selection of suppliers. As a rule, suppliers are selected using a multi-factor quality analysis of its activity according to preliminarily selected criteria. However, we maintain that, in addition to the factors of reliability of delivery chains, analysis should involve those of the quality and reliability of supplier's products. In this case the delivery control will be largely characterized as "control of spare parts' reliability".

2. DECISION SUPPORT SYSTEM IN PERFECTING THE SPARE PARTS SUPPLY PROCESSES

2.1. Control procedures in spare parts delivery within the corporate service system

Corporate service is offered by truck manufacturers extending their markets abroad. As a rule, this system represents a dealer-service network (DSN) consisting of service centers authorized according to the manufacturer's standards. In most cases, these service centers organize their activities according to the "3S" principle, meaning provision of sales of automobile and spare parts, and servicing throughout the vehicle life cycle. This system is most relevant for trucks because their share in the total car fleet is relatively small whereas the cost of servicing equipment and maintenance efforts is higher than that for passenger cars. An integral part of the corporate service system is the logistical network of spare parts supply.

It is highly efficient, when implementing the aforementioned algorithms and models, as well as developing of adequate managerial decisions aimed at optimization of spare parts supply, to create an automated control system of spare parts supply wherein the intellectual core may be formed by a simulation model. The structure of the proposed control system is presented in fig. 1.

In order to improve the planning of the structure and schedule of spare parts deliveries, one has to take into account the fact that certain assembly components, units and systems in a truck differ in terms of resource and reliability, the latter depending on a set of stochastic factors.

Failures occur at a time point T_{fail} that can be predicted with a certain degree of probability. As demonstrated by analysis of operational indicators (t), the car failure rate λ can be divided into three operational stages [2]: the running-in period, characterized by a high failure rate due to alignment of mating parts and probably caused by manufacturing defects. During regular operation, failures are random and mostly emerge as a consequence of nonobservance of operating conditions, changed loading, adverse external factors, etc. The third period is characterized by increasing failure rate caused by ageing and other factors of long operation. Considering the aforesaid, the spare parts supply must be based on functionally differing mechanisms. Since the warranty period is the most essential in view of ensuring the customer's loyalty, this period is to provide the highest-quality service.

Although failures cannot be eliminated during the running-in period, it is possible to find out which parts fail prematurely using the failure statistics of truck service centers. To support the continuity of trouble-free service at this stage we have developed a mechanism for calculating the qualitative and quantitative structure of warranty spare-part kits (WSPK) to be available for every lot of cars released, which are to be sent to the area of the cars operation.

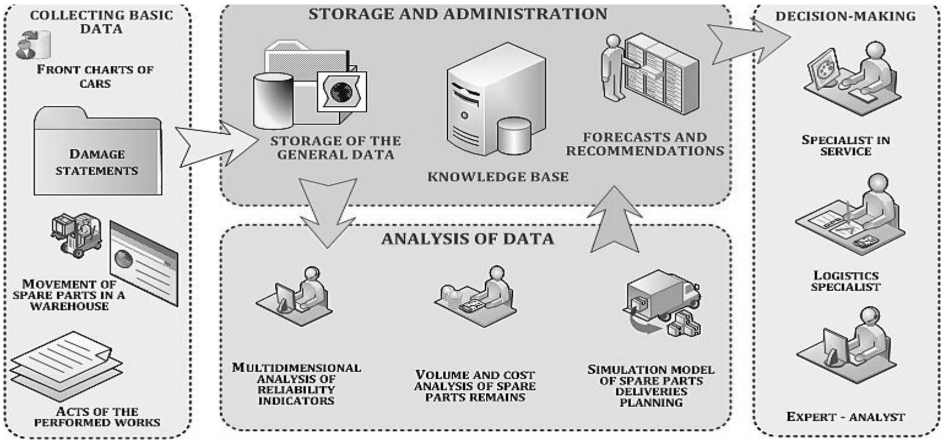


Fig. 1. Structure of a control system of spare parts supply within networks of corporate service centers in abroad
Рис. 1. Структура системы управления поставками запасных частей в сети фирменных сервисных центров за рубежом

During the warranty period, failures are largely caused by operating conditions and are stochastic in nature. Therefore predicting the needed amounts of spare parts proceeds from dependencies established when analyzing the claims accumulated in dealer- service centers (DSC).

Activities of a DSN control center of a producer company in spare parts supply can be successful if three main conditions are satisfied:

- the control center is provided with all information enabling to make operational and strategic decisions within the DSC network, including at foreign markets;
- the control center is in a position to use this information for making rational managerial decisions;
- the control center has the possibility to supervise the implementation of decisions and their outcome and promptly correct its activities on process optimization within the DSC network.

This calls for handling the following main problems:

- carrying out of electronic cataloguing and accounting of automotive equipment, availability and drawing spare parts producer's;
- timely planning of deliveries to DSCs of trucks and spare parts to meet the customer needs;
- introduction and certification of a decision support system enabling to control the deliveries and inventory, and adjusting of DSC standards.

These objectives were met by developing program modules for collecting, storing and processing of information coming from the DSC network of the "KAMAZ Foreign Trade Company". The software package was created using a *Borland Delphi 7* programming environment. Statistical processing of the data was carried out using a *Statistica* package. The data were processed at a *SQL Server 2000*. Since the information bases are formed from DSCs and contacted via the Internet, we developed a technology for exchanging the server part of the program modules with the customers' parts based on transmitting of XML files (Fig. 2).

The system of data collection incorporates inputting of data into customers' parts of the "Ledger card of a car" and "Reclamation act" program modules. The transmitted file is opened in the server part; the data are checked for adequacy and filling quality, whereupon they are transmitted to the database.

The information interchange between the customer and server modules is effected by means of *Indy* socket components (*IdTCPClient and IdTCPServer*) and original components of the Borland company (*TcpClient and TcpServer*).

2.2. Simulation modeling of the process of spare parts delivery to DSN

Since the period of no-failure operation of automotive equipment is a random variable depending on the current mileage of each vehicle, modeling of the trucks' knots and units failure may involve agent-based modeling combined with a system dynamics (Fig. 3).

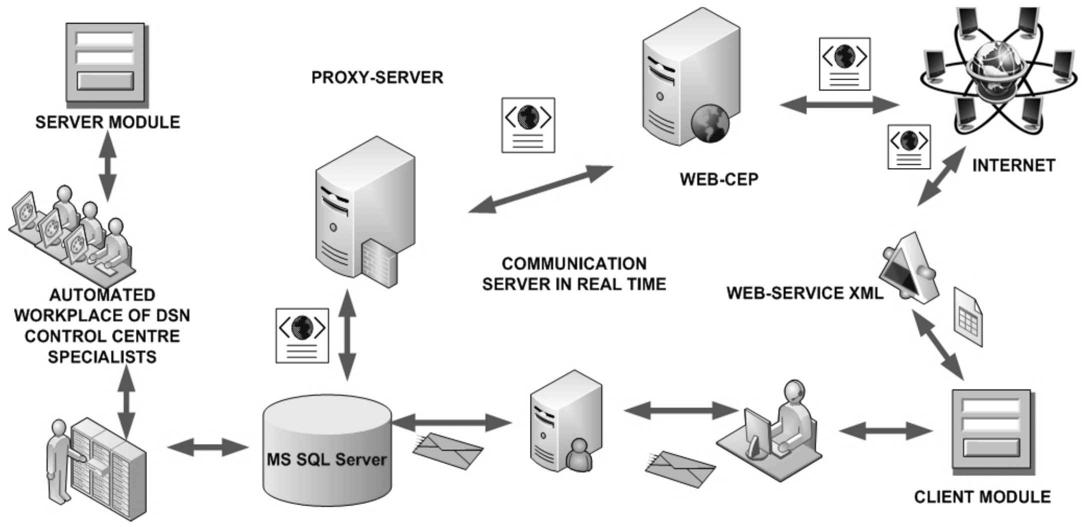


Fig. 2. Organization of communication and data transmission from DSCs to control center
Рис. 2. Организация связи и передачи данных из ДСЦ в центр управления

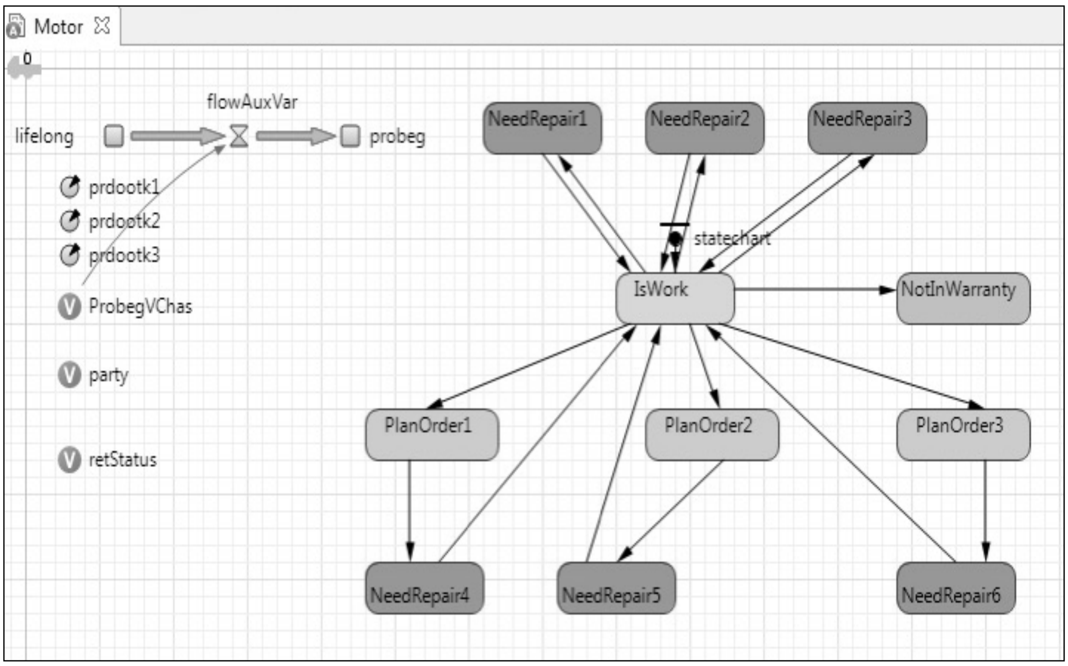


Fig. 3. Representation of an automotive vehicle as an agent
Рис. 3. Представление экземпляра автомобильной техники в виде агента

As can be seen in fig. 3, the current mileage of a truck is set as the *probeg* store, which increases in each unit of time by the value *ProbegVChas*, while the maximum mileage value is set in the *lifelong* storage. When the truck's mileage achieves the maximum value, the agent passes to the *NotInWarranty* state at which it is removed from the environment. The *NeedRepair* state simulates the failure of a certain knot or unit, listed in one of the three groups above (on achieving this state the *ProbegVChas* variable is set as equal to zero), and the *PlanOrder* state simulates the envisaged failures, arising at a certain mileage and not requiring to truck mileage.

Efficiency of spare parts delivery ***Z*** was assessed using the indicator "Minimization of expenditures on spare parts supply control in the DSN abroad". The efficiency function in this case was the total cost of organizing the delivery and storage of spare parts in DSC warehouses.

This indicator of efficiency appears to be affected by the following four factors:

X_1 – delivery time of spare parts (order point);

X_2 – ratio of spare parts in each group to the total amount (group coefficient);

X_3 – amount of minimum stock in each group;

X_4 – optimum volume of delivered lots (pieces);

Determining of the optimum control involves finding such optimal X_1, X_2, X_3, X_4 values at which the value of function Z (costs of delivery and spare parts storage in DSC warehouses) are the lowest:

$$Z = Z_1 + Z_2 + Z_3 \to \min \tag{1}$$

In this case, Z1 are expenditures on the spare parts storage in DSC warehouses:

$$Z_1 = 1/2 \cdot X_1 \cdot \sum_{i=1}^{N} \lambda_i \cdot h_i \cdot X_2 \cdot X_3 , \tag{2}$$

where: λ_i is the failure rate of i-th of a part, knot or unit; h_i is the cost of an i-th part, knot or unit storage in a DSC warehouse; n is the number of simultaneously delivered spare part items ($n = \overline{1, N}$); Z_2 is the cost of urgent delivery of spare parts unavailable in a DSC warehouse:

$$Z_2 = \frac{g \cdot X_4}{X_1} \cdot (\varphi_{\text{ur.d.}} \cdot \sum_{i=1}^{N} 1/\text{X}_2 + 1) , \tag{3}$$

where: g is the cost of the total amount of i-th positions in an urgently delivered lot; $\varphi_{\text{ur.d.}}$ is the share of extra costs due to urgent delivery;

Z_3 is the cost of a penalty for lacking spare part items in DSC warehouses (idle time of service facilities and personnel, loss of customer loyalty)

$$Z_3 = \sum_{i=1}^{N} d_i \cdot X_2 \cdot p_i , \tag{4}$$

where: d_i is the cost of penalty for lacking i-th part, knot or unit; p_i – stationary probability of the system's already having a service request for an automotive techniques with a faulty i-th part, knot or unit.

The limits at this should be the factor value ranges and the general condition of optimal stock for an i-th part, knot or unit:

$$\sum_{i=1}^{N+1} p_i \le h_i / d_i \le \sum_{i=1}^{N} p_i \tag{5}$$

Since the main principle of each corporate service system consists in focusing on customer needs, the most important indicator of efficiency, when modeling and optimizing the spare parts supply subsystem, is the average time the customers spend waiting. At the same time, this involves solving the problem of minimizing the turnover time and spare parts stock. Besides, shortening of the automotive vehicle service time at DSCs via the preventive spare part deliveries allows to diminish the profit loss of the customers. When constructing the model, one must calculate the optimum time and structure of deliveries proceeding from the fleet type and also the age and peculiarities of the operation area, as well as the cost of urgent delivery and storing of a certain range of spare parts in a warehouse.

2.3. Simulation model of controlling the spare parts delivery

Simulation modeling is one of the most effective methods in optimization of the system of spare parts delivery control. The model for the help to find the best alternative in scheduling the spare parts delivery taking into account the calculated values of probable time point of a claim and an optimum balance between the size of loss in the case of lack of spare parts and the cost of storing of surplus parts. The processes to be modeled are the planning and distribution of resources by the DSN control center of the manufacturer of automotive vehicles. The initial data for the system of delivery control and optimization are the statistical information about the operational reliability, orders and supplies stored in the DSN/ control center database.

The model was implemented using an AnyLogic application program package - a Russian professional simulation tool incorporating the Enterprise Library, which makes possible creating of discrete-and-event models by means of block diagrams [3].

Being comprised by essentially different objects, which are to be modeled differently, the model, enabling to control the spare parts delivery to DSNs, is multiple-approach, comprising a discrete- and-event model and an agent-based models. Model flows from the discrete-and-event model to the agent-based one are transmitted using a synchronization algorithm. Each model has its own algorithm affording to attain maximum efficiency from overlapping, which means that its quality is essential for the benefit obtainable from the models synchronization [4]. The results of performance of this model are shown in Fig. 4.

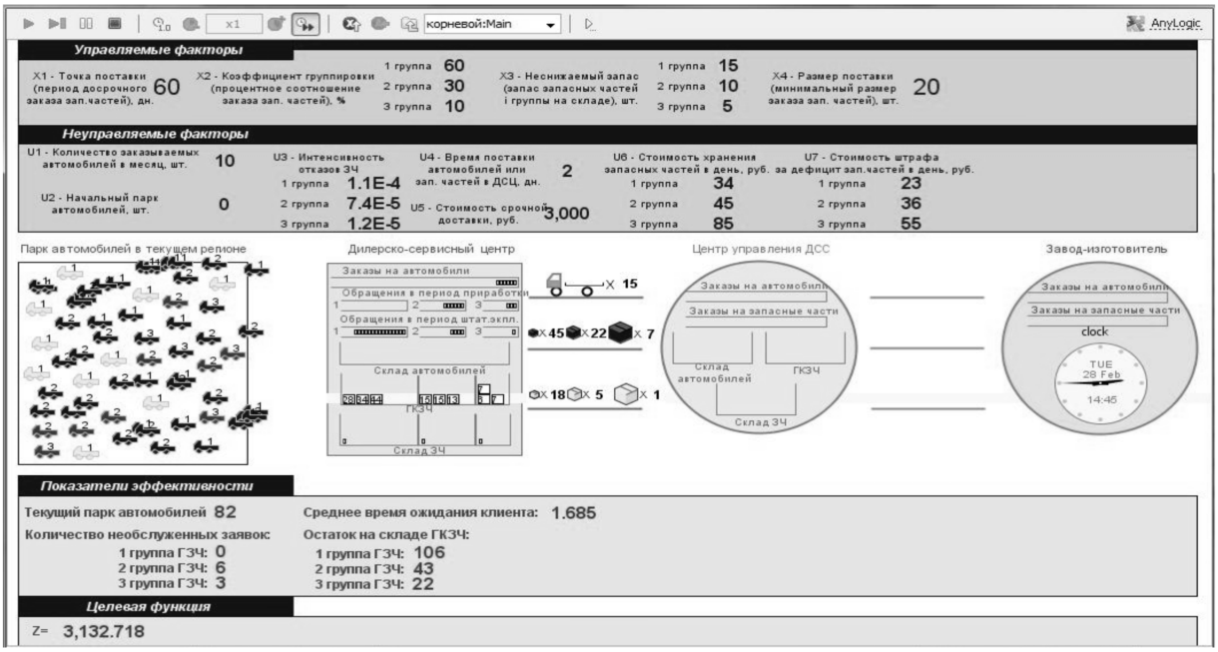


Fig. 4. The result of modelling of spare part deliveries to DSNs located abroad during the warranty period of operation

Рис. 4. Результат выполнения модели управления поставками запасных частей в ДСС за рубежом в гарантийный период эксплуатации

2.4. Optimization of the strategy of cooperation with suppliers within the corporate service system

One of the factors, affecting a truck's reliability, is the quality and reliability of its components, assemblies and systems. Therefore selecting of suppliers, in the context of economic globalization, with assembly factories emerging in different countries, is by no means unimportant. As is shown in work [3], access to reliable information about suppliers adds competitiveness to a company.

Statistical analysis of failures of different systems, units and knots in trucks has revealed that mostly they occur in power units and electrical equipment. We have examined the statistics of failures of power units that have been assembled with starters produced by three manufacturers: Eltra (city of Samara, Russia), Iskra (Slovenia), BATE (city of Borisov, Belorus). The research covered the warranty period at a mileage of 45 thousand km.

As revealed by analysis of the reliability function (Fig. 5), the most reliable starter comes from BATE (Borisov). Similar studies were conducted for power units (Fig. 6) made in Moscow and Cheboksary. Faultless performance can be achieved by replacing the parts during repairs. At the same time, the truck reliability may be negatively affected by inadequate quality of supplied spare parts. Since reliability is a crucial factor in the corporate service strategy aimed at preventing failures, it is important to carefully select the spare part suppliers. Account is taken of not only the quality of products supplied, but also of the supplier's record of timely fulfillment of contractual obligations, compliance with delivery dates and so on.

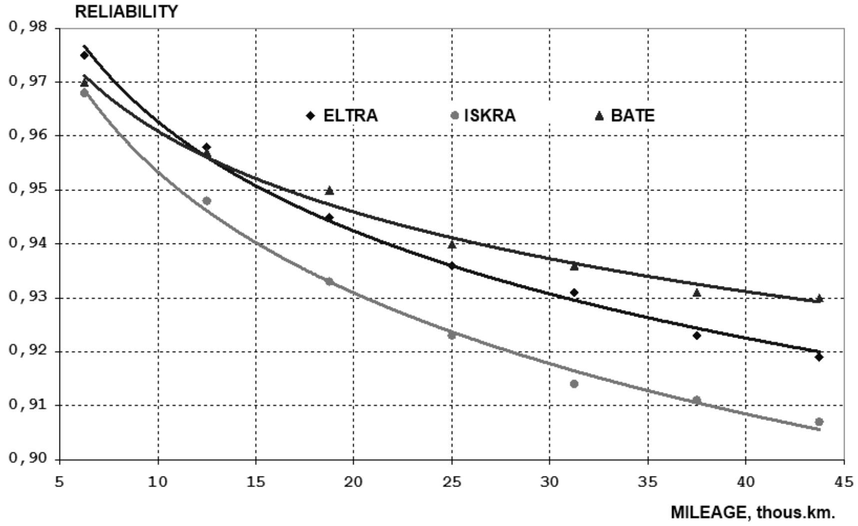


Fig. 5. Graphs of the reliability function (probability of failure-free operation) of starters
Рис. 5. Графики функции надежности (вероятности безотказной работы) стартеров

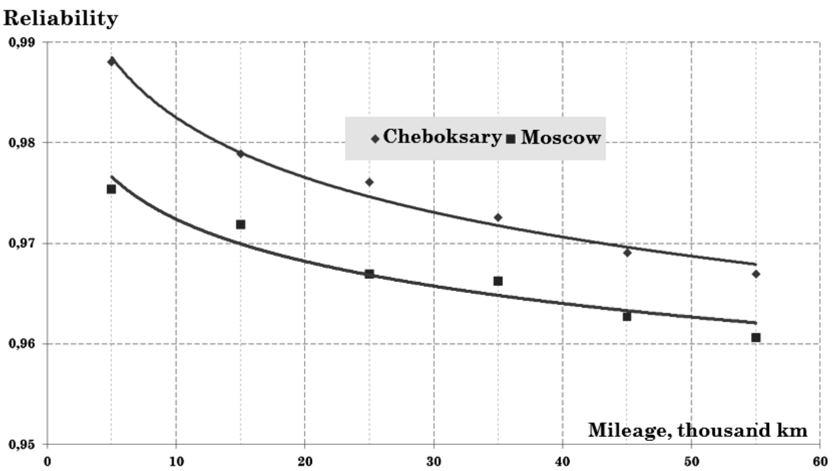


Fig. 6. Graphs of the reliability function (probability of failure-free operation) of power units
Рис. 6. Графики функции надежности (вероятности безотказной работы) генераторов

When evaluating the supplier's reliability, many of the authors highlight the factors coming to the forefront when considering alternatives in decision making. There are different methods proposed for multi-criteria analysis. Thus, the authors of work [5] point out that the extensive multi-criteria decision making approaches, proposed for supplier selection, include the analytic hierarchy process (AHP), analytic network process (ANP), case-based reasoning (CBR), data envelopment analysis (DEA), fuzzy set theory, genetic algorithm (GA), mathematical programming, simple multi-attribute rating technique (SMART), and their hybrids.

This review contains researches made between the 2000s and 2008s. These methods were furthered in later studies. Thus, the review [6] reports of works using analytical and empiric methods for selecting of strategic suppliers. In work [7] it is said that evaluating of strategic supplier performance is one of the important functions within a supply chain, with the integrated QFD-AHP method being effective but needing a customized approach to adopt it within the industry.

Strategic supplier performance evaluation is one of the important functions within supply chain. The integrated QFD-AHP method for supplier evaluation is effective, but it needs a customized approach to adopt it within the industry.

In the authors' opinion, further research should be aimed at checking the effect of other factors affecting the supplier selection, and also at developing of dynamic methods for rapid reevaluation.

The authors of work [8] have pioneered the application of hesitant fuzzy methodology in preference elicitation for strategic supplier selection. This study focuses particularly on the following circumstances: multiple strategies of companies, multiple stakeholders involved in decision processes, and multiple perspectives with uncertainties and conflictions.

The authors report [9] that expert estimation is often made difficult by insufficient volume of available expert samples.

The approach they take in evaluating and selecting of sustainable suppliers is a triple-bottom-line (profit, people and planet) one, in which both business operations, environmental impacts and social responsibilities of the suppliers are considered. The authors have introduced a new methodology for supplier selection using Bayesian theory and Monte Carlo simulation with a Gibbs sampler. The Bayesian theoretic methodology of selecting suppliers, introduced in this work, uses various dimensions of the sustainability's triple-bottom-line approach, i.e. business operations, environmental concerns, and social responsibility which effectively discerns the suppliers performance and aids in supplier selection.

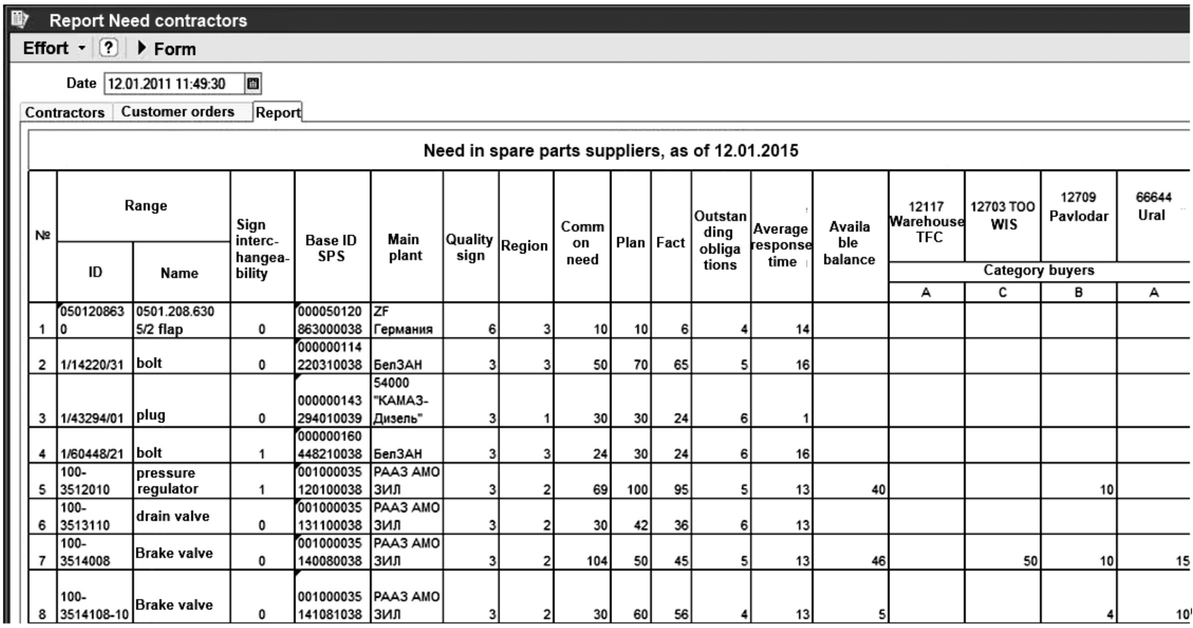
Notwithstanding the diversity of approaches, all these methods are based on expert estimates in the part of priority selection. There are drawbacks to these approaches, one being the inability of the qualitative methods to provide an objective evaluation and, second, the inevitable subjectivity of the experts. Although the business operations of a company are estimated using a multi-dimensional analysis and according to different criteria, the main factor in selecting the supplier must be that of reliability of spare parts.

In respect to vehicle models that have long been on the market and provided much information on failures for analytical treatment, selection is based on analysis of available data. Within the corporate service system, they are strategic, or "approved", suppliers. However, when new models or modifications are launched, during the warranty period there may appear "problematic" parts with recurring failures and the values of reliability parameters not complying with those declared by the manufacturer. In this case the supplier should be replaced and the dynamic methods of selection be applied.

To improve the supplier relationship management, the authors have developed a software module "Report on contractor requirement for spare parts supply" (Fig. 7). The module contains information on DSN's demand for spare parts, based on advance applications, actual deliveries to the logistics center by the manufacturer, average response time to the logistic center's application, qualitative characteristics of the delivered spare parts, the size of spare parts' clear balance in the logistic center's warehouse, and the data about the spare parts needed both by DSNs on the whole and individual DSCs. All DSCs in the report are subdivided into categories selected by the criterion of the quality of tentative requisitions. To minimize the risks of late delivery, or non-delivery of spare parts, the DSN control center must analyze the characteristics of suppliers and distribute the application flows with regard to the reliability factor obtained.

Both evaluation and selection of suppliers are based on cluster analysis. Clustering is based on information derived from the developed software module. The algorithm of solving this problem is presented in fig. 8.

The DSC control center is to make a decision to which supplier, or group of suppliers, an advance application should be sent, so it examines the spare parts array in search of those making up the "interchangeable" group. The isolated group of spare parts is subdivided, in turn, into products of foreign and domestic production, and the latter is further subdivided into those manufactured by the producer and the supplier factories. Analysis and clustering are performed separately for each of these groups.



Report Need contractors

Effort ? Form

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Contractors | Customer orders | Report

Need in spare parts suppliers, as of 12.01.2015

№	Range: ID	Range: Name	Sign interc-hangea-bility	Base ID SPS	Main plant	Quality sign	Region	Comm on need	Plan	Fact	Outstan ding obliga tions	Average response time	Availa ble balance	12117 Warehouse TFC	12703 TOO WIS	12709 Pavlodar	66644 Ural
														Category buyers: A	C	B	A
1	0501208630	0501.208.630 5/2 flap	0	000050120 863000038	ZF Германия	6	3	10	10	6	4	14					
2	1/14220/31	bolt	0	000000114 220310038	БелЗАН	3	3	50	70	65	5	16					
3	1/43294/01	plug	0	000000143 294010039	54000 "КАМАЗ-Дизель"	3	1	30	30	24	6	1					
4	1/60448/21	bolt	1	000000160 448210038	БелЗАН	3	3	24	30	24	6	16					
5	100-3512010	pressure regulator	1	001000035 120100038	РААЗ АМО ЗИЛ	3	2	69	100	95	5	13	40			10	
6	100-3513110	drain valve	0	001000035 131100038	РААЗ АМО ЗИЛ	3	2	30	42	36	6	13					
7	100-3514008	Brake valve	0	001000035 140080038	РААЗ АМО ЗИЛ	3	2	104	50	45	5	13	46		50	10	15
8	100-3514108-10	Brake valve	0	001000035 141081038	РААЗ АМО ЗИЛ	3	2	30	60	56	4	13	5			4	10'

Fig. 7. Information-report on the needs of customers in spare parts
Рис. 7. Справка-отчет о потребности покупателей в запасных частях

For qualitative evaluation of a supplier, each item is given a rating determined by the method of expert estimations. The quality rating granted to a supplier is derived as a sum of estimates by the following three indicators: price, percentage of defects, and warranty period. Besides, the difference between the planned (based on orders from the DSN control center) and actual (based on documents of goods entry) supply volumes from a particular supplier is calculated. Clustering then is made on the basis of the following four characteristics of the supplier: qualitative characteristics of spare parts, the level of demand for the particular spare parts, the level of defaults, and the delivery time.

The qualitative characteristics of a supplier's spare parts are the higher the less is deviation of the spare part's actual resource from its claimed resource. This, in turn, can be evaluated using the failure statistics during the warranty period.

Since the characteristics are specified in different units, they are pre-normalized, i.e. converted into dimensionless values.

Normalization was performed according to the formula (6).

$$x_{inorm} = \frac{x_i - \bar{x}}{\sigma} \qquad (6)$$

where: x_{inorm} is the normalized value, x_i – the original value, $\bar{x}$ – is the mean value, σ – standard deviation, i – the number of array elements.

To test the adequacy of the proposed method, we prepared a sample of interchangeable spare parts produced at subcontractor factories. The optimal number of clusters, which were split into sets of spare parts, was determined using the hierarchical agglomerative method of cluster analysis and a clustering dendrogram (Fig. 9). As the result of k-means clustering in the "STATISTICA 8" software, the interchangeable parts were split into 3 clusters [4].

The first cluster, containing 16 items of suppliers' spare parts, is characterized by low demand and long delivery times, a high quality rating of the supplier and a low non-delivery level. The second cluster, with 14 spare part items, is characterized by low demand, minimum delivery time and a low non-delivery level.

As for the third cluster, consisting of 4 spare part items, it requires careful analysis and adopting of a plan of arrangements for optimization, since it is characterized by a high level of requirement for spare parts, but a low quality rating of suppliers, failure of suppliers to meet their delivery obligations, and medium delivery times. Analysis of F-statistic values, calculated for each characteristic, has demonstrated the significance of the selected clusters. Moreover, differences in the mean values of the clusters' characteristics suggest that the selected features are good discriminators for the clusters (Fig. 10). The graph shows the average of normalized values.

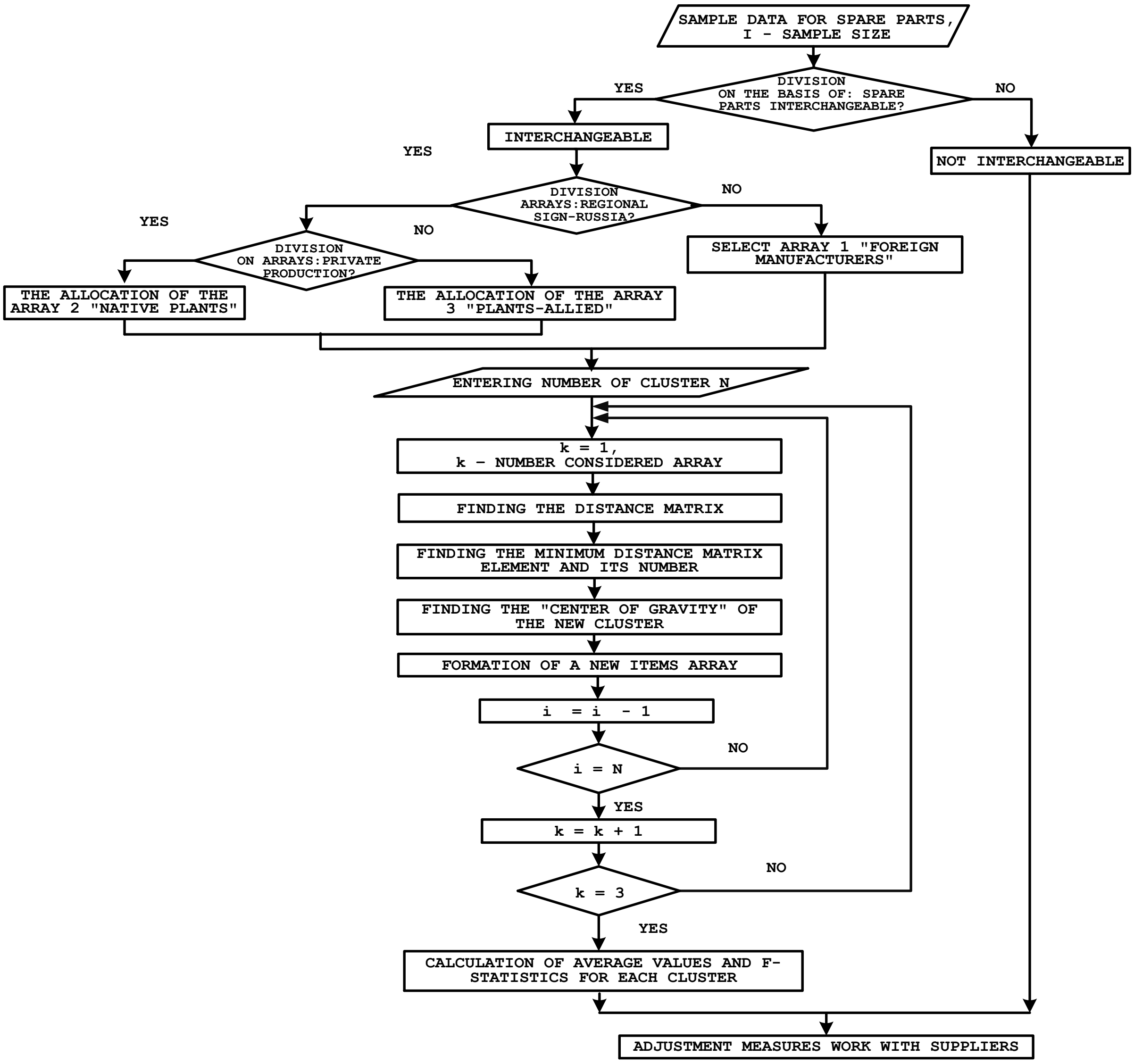

Fig. 8. The algorithm of suppliers evaluation
Рис. 8. Алгоритм оценки поставщиков

Cluster analysis affords to adopt optimal strategies in dealing with suppliers of interchangeable spare parts to improve the processes of delivery to the logistics center warehouses and to control the entire supply chain. Using the proposed alternative of adopting a strategy in dealing with suppliers within a corporate service system makes possible to improve the system of spare parts delivery and the controllability of the system's processes.

3. FEATURES OF SPARE PARTS DELIVERY ORGANIZATION ON LAUNCHING OF A NEW VEHICLE RANGE TO THE MARKET

When launching to the market of a new truck range, the problem of quality and reliability becomes especially acute due to lack of information. However, owing to decision-making support systems, incorporating modules for collecting and analyzing of information, it is possible to promptly react and make reasonable decisions in high-risk situations. Since the economy of Russia heavily relies on the gas industry, it is interested in the development of the gas motor fuel market. Nowadays there are 80 models of natural gas-powered cars, buses and other vehicles released in Russia and worldwide.

The Russian leading auto manufacturer "KAMAZ" JSC has started turning out trucks and buses running on compressed natural gas (CGV - compressed gas vehicles). Produced by advanced technologies, they significantly reduce the negative impact of vehicles on the environment.

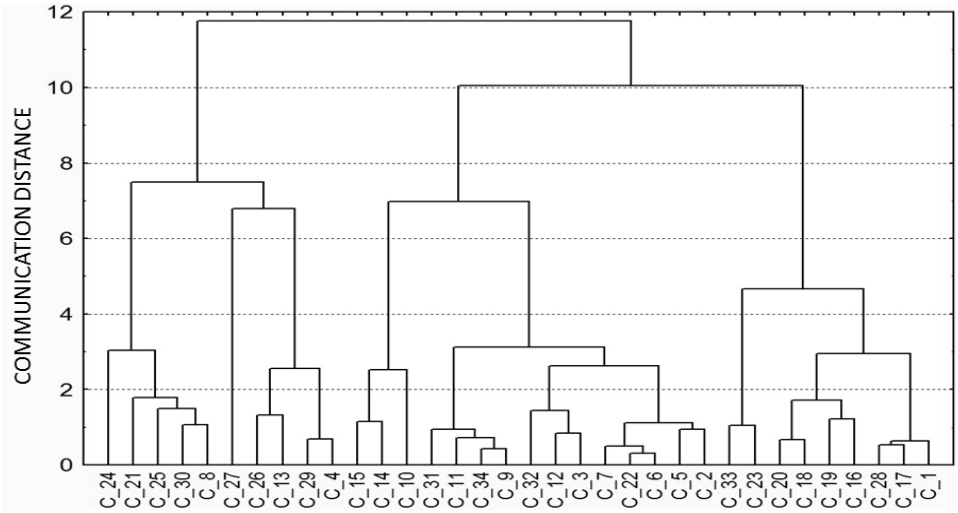

Fig. 9. Hierarchical clustering dendrogram
Рис. 9. Иерархическое дерево кластеризации

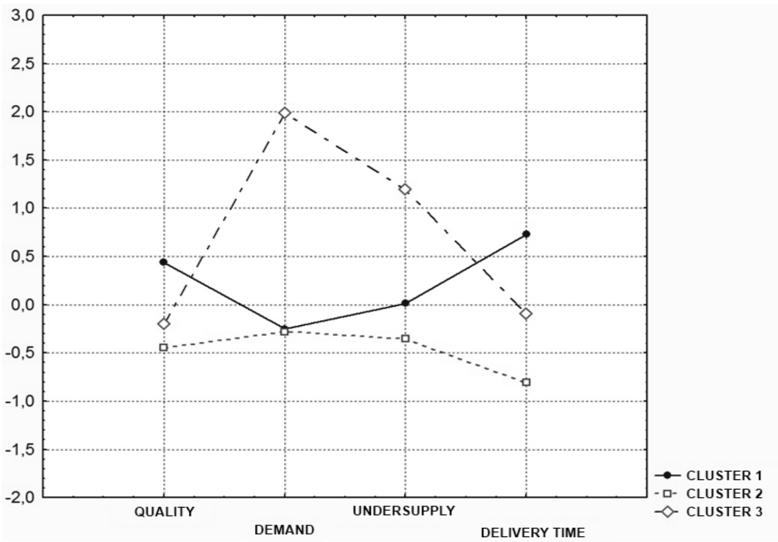

Fig. 10. Graph of the average normalized values of characteristics in clusters
Рис. 10. График средних нормализованных значений характеристик по кластерам

We have analyzed the structure of KAMAZ CGV sales in Russia by the truck body type (Fig. 11). It turns out that more than 70% of sales falls on the chassis used for mounting of superstructures to make garbage trucks, crew buses, vacuum trucks, and crane trucks.

The success of a new product depends both on engineering solutions (product reliability) and on the marketing policy (pricing, warranty). The cost of warranty service depends on the product reliability so that the manufacturer, if confident in the product reliability, may extend their warranty liabilities. This means that the issues of reliability, pricing and warranty should be considered jointly [10]. Having researched the problems of cost and duration of warranty period, the authors of works [11 - 14] suggest that modeling should be based on information about the technical failures occurring in the warranty period. In turn, the quality of decisions depends on appropriateness of information. Since failures can be caused by different heterogeneous factors, it is necessary to have a tool for processing of great bodies of data, some of which may be represented by textual files [15]. Predictions are made using various methods of intellectual data analysis, including neural network algorithms [16].

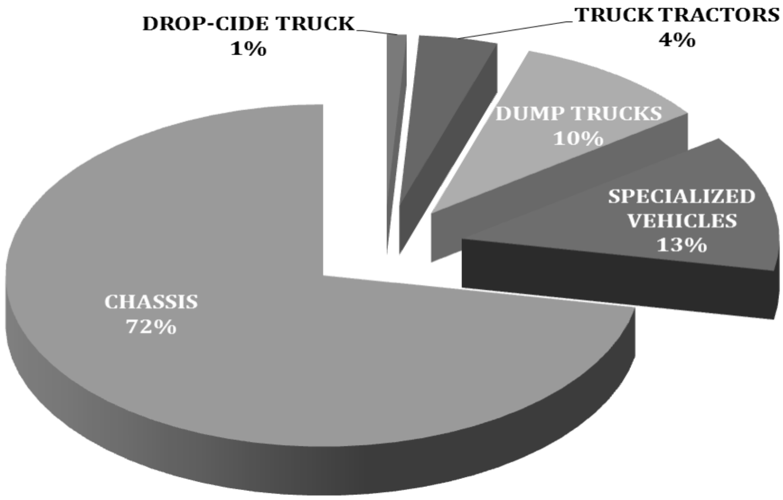

Fig. 11. Sales structure of compressed gas vehicles by the body type
Рис. 11. Структура продаж газобаллонных автомобилей по типу кузова

Analysis of the failure statistics of KAMAZ CGV during the warranty period has shown that they typically emerge within the first 10 thousand kilometers run (Fig. 12a), one of the problems being frequent failures of gas engines (Fig. 12b).

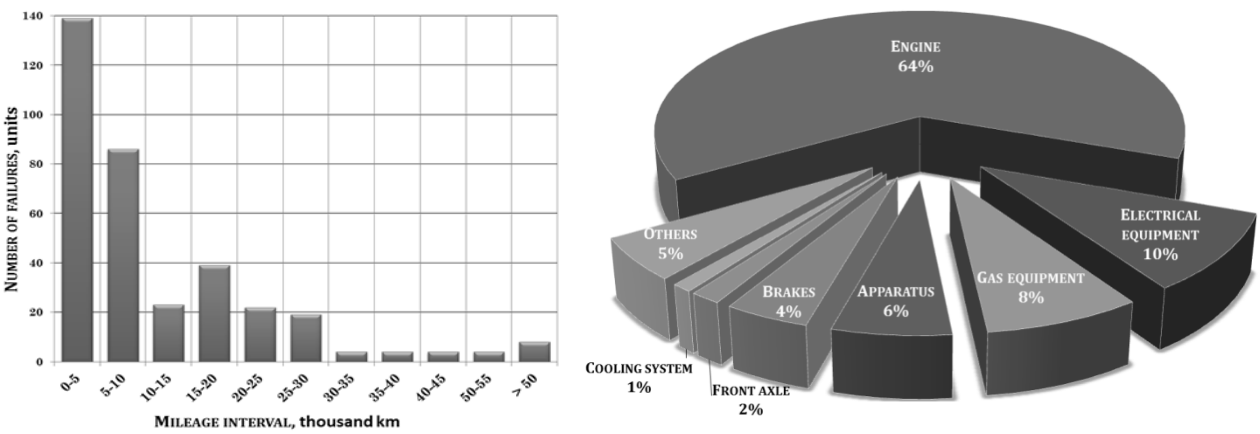

Fig. 12. Failure statistics: a) dependence on mileage; b) place of origin
Рис. 12. Статистика отказов: а) зависимость от пробега; б) по месту возникновения

Considering that the gas engine and gas equipment are radically different for compressed-gas vehicles compared to diesel ones, it was important to find the causes of failure and little reliable parts. We have revealed such parts and, if the supplier could be replaced, examined the parameters of failure distribution for similar parts from different suppliers. The failure structure was found to have changed in the short period of 2013-2014. This is due to the fact that the resource of certain parts increased as the supplier was replaced, which has resulted in diminishing of the share of faulty parts. This fact affects the general failure structure, which has become more uniform.

By operating in contact with suppliers and identifying of error-prone elements it is possible to increase the trucks reliability on the whole. Thus, it is evident that a reliable system is that comprised of equally reliable elements, or approximately so. We have examined the structure of failures of various parts of a gas engine (Fig. 13). Comparison of the failures structure in 2013 and 2014 has demonstrated that taking measures on revealing the cause of frequent failures and their elimination enhances the system's reliability due to greater uniformity of the structure.

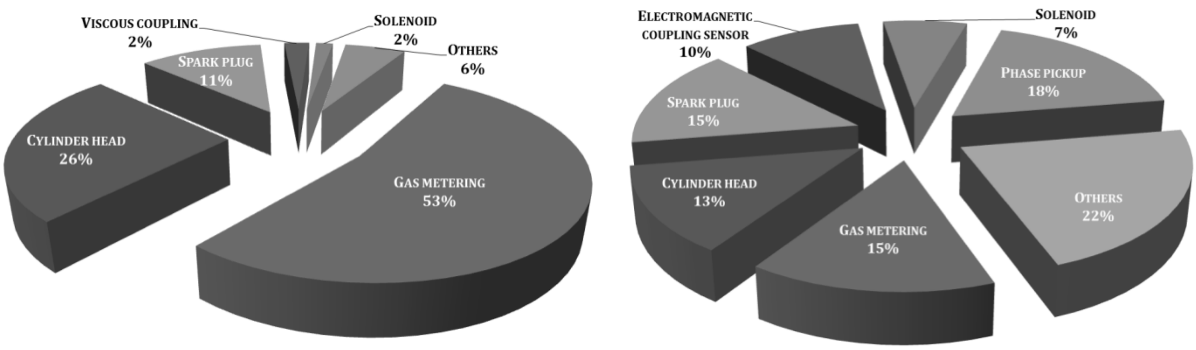

Fig. 13. Structure of failures in an emergence place: a) in 2013; b) in 2014
Рис. 13. Структура отказов по месту возникновения: а) в 2013 г.; б) в 2014 г

4. CONCLUSION

This research has shown that the reliability of automotive vehicles, i.e. their trouble-free operation can be enhanced and their marketability stepped up only through system solutions in dealing with suppliers and planning of spare parts delivery within the corporate service system. Using a scientific approach to improving the corporate service system will allow to respond promptly to challenges occurring in operation of new vehicle lines, enabling to improve the vehicle design concepts.

Improved control, achieved by developing and using of decision-making support systems, will allow to correct the activities aimed at realization of strategic objectives at each stage. Simulation models as a basic element of the systems' intelligent block will make it possible to opt most rationally for every combination of current conditions. In this case, conditions should be created for timely updating of initial information, its prompt processing and storing of decisions made.

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