The Actualized Complex of Indicators of Quality Monitoring of New Cars in Operation

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Abstract. The article devotes to the analysis and development of a modern analytical complex of quantitative indicators of the quality of new cars in operation.

1. Introduction

High-tech engineering, in general, and the automotive industry, in particular, are one of the key sectors of the global economy. It is here that a significant share of growing points is formed in the field of innovation, including in the field of competitiveness, quality, modernization, and development of quality management systems (QMS).

The analysis of the existing quality management systems (QMS) of national automakers at present, in comparison with the QMS landscapes of world leaders, showed the lack of comprehensiveness in solving analytical problems related to measuring product quality in operation, revealing key quality problems. It turns out that in practice, all of the most important tasks listed above, as before, are essentially solved in stages and separately, within the established rigid functional management system at enterprises. Therefore, it is obvious that the prospects for the development of the QMS at national car assembly plants are directly related to a comprehensive, within a single system, consideration of the tasks of monitoring, analysis, and solving problems of product quality.[1-3]

In this regard, the complexity of solving problems in the field of quality should be determined by such an important, fundamental aspect of the new management system as the possibility of a comparative analysis of the achievements in the field of engineering management of a particular automobile assembly plant with the corresponding achievements of other enterprises in the competitive market. This is exactly what can be called benchmarking in technical management.

2. Key research findings

One of the key tasks of transferring the QMS of domestic car assembly enterprises to a new level of development is the implementation of a new measuring system for assessing the quality of products at the after-sales stage of the life cycle. To solve this problem is required critical analysis and development of a solution in the field of creating a new group of indices that most adequately reflect aspects of the measurement process for quality assessment of automotive equipment in operation. In terms of relevance for all participants in the process, there are the manufacturer and consumer of the product, and from the point of view ensuring the consistency and adequacy of technical benchmarking of relevant products and processes. [4]
The analysis results of the existing activities of national automakers in the field of monitoring the quality of cars in operation highlight a number of important aspects reflecting the current practice. Considering the quantitative quality indicators and tools of the corresponding analysis used at Russian car assembly plants, it should be noted that they fit quite adequately into the traditional QMS, in which the quality assessment of their products was carried out practically without comparison with the quality of competitors' products. Moreover, this is the historical paradigm of the development of technical management at enterprises, when monopolists produced both cars and trucks. In addition, the denominator was historically the guarantee fleet, to which absolute quality indicators of cars in operation were given to determine the given values. In general, such a compromise option was justified until some time. [5-7]

Let us consider the problematic aspects of monitoring the quality of vehicles in operation based on the above aspect of the warranty fleet, using an example (Fig. 1). [8]
**Figure 1.** The specified defect level for various methods of calculating the volume of the warranty fleet of cars.

Figure 1a shows the curves reflecting the total (for the entire model range) and private (for each model) number of defects for vehicles of one of the leading national automakers according to the production date, taking into account the two-year operation (warranty period). Figures 1b-d (right) show curves reflecting the change in the car warranty fleet calculated by specific methods in the same analyzed period: b - by the number of cars registered in the specialized information system of car dealers; c - by the number of vehicles shipped within two years; d - the average warranty fleet, determined taking into account the date of release of cars, and a two-year stay in the park. Figures 1b-d (left) present curves showing the corresponding reduced to the volume of the warranty fleet (according to the methods under consideration), the level of defective cars in the warranty period of operation. Corresponding recounts can also be made for cost indices for the elimination of defects in automotive equipment in operation.

The data analysis (Figure 1) shows that there are a number of methods for assessing the level of the guarantee fleet that are not correlated with each other. Because of the above variety of unrelated methods for calculating the warranty fleet, it turns out that the use of the amount of the warranty fleet, as the denominator does not create the prerequisites for obtaining a reliable and adequate result of analyzing the quality of cars in operation. [9-11]

The next aspect, which logically fits into the justification block for the need to develop a new group of quality indicators, is the modern requirement of international standards. For example, ISO 9001: 2015 is related to the analysis of changes in defectiveness indicators both in the warranty and in the after-warranty period of automotive equipment operation that is exactly impossible to do based on the ideology and understanding of the performance of the guarantee fleet. At present, an aspect should be highlighted that reflects the level of stability in sales of automotive equipment. Under a smooth change in the warranty fleet, the corresponding level of defectiveness behaves adequately. However, in the case of sharp changes in sales, the given indicator begins to behave unpredictably. For example, production volumes are sharply reduced under crisis conditions, a paradoxical situation arises that is associated with an unreasonably high level of product quality that is monitored. The denominator (warranty fleet) behaves more statically because of a significant decline in the level of defectiveness in new cars due to a decrease in output and sales (numerator). Finally, two final aspects of the justification block for the need to solve the problem under consideration are presented. This is an aspect of the reliability of the car warranty base. The problem is the lack of technical ability to fully account for all cars that are in the warranty period of operation due to there are entire systems of corporate clients in which, for example, the cars can be preserved for a rather long time. At the same time, it is natural that in dealer systems they do not go through accounting during repair work, and in general corporate accounting, cars that are under warranty at the car assembly plant, they are usually presented. [12-15]

The last aspect of the justification block is the relevance of the used indices for monitoring the quality of products in operation based on the need to solve the technical benchmarking problem. Let us consider the study results of consumer satisfaction indexes for car quality in operation (Fig. 2). [16]
The upper diagram (Figure 2) presents an assessment of the dependence of consumer complaints in the first year and the first three years of operation, reduced to 1000 (E ‰), for ten well-known automotive brands operating in the Russian market. On the basis of averaging indicators, a trend line was obtained dividing the plane into two areas: “aging is worse than average” and “aging is better than average”. The analysis of the diagram clearly defines the consumer’s preferable level of defectiveness for the first four brands working in the field of “aging is better than average”. It is obvious (lower part of Figure 2) that reliability is the foundation of an overall quality assessment. High reliability is important to consumers. The consumer understands by a high level of reliability the absence of problems that disable automotive equipment or significantly reduce the safety of its operation. In practice, such problems are called blocking, since they block the possibility of full use of products. At the same time, the deterioration in reliability is the first of the reasons for the low value of product quality perceived by consumers and leads to the exclusion of the brand from the competitive market. At the same time, a high level of reliability is not a guarantee of a high consumer assessment of product satisfaction. [17]

3. Results
Comprehensive results based on the analysis are presented in Figure 3, and they consist of the need to develop and implement the whole system of indexes for monitoring the quality of cars in operation that adequately reflect consumer opinion on product quality.
Based on the analysis of the complex conclusions (Figure 3), it is quite obvious that the system of indicators of car quality should reflect the level of defectiveness, reliability, operating costs, and the level of consumer complaints. It is also obvious that the solution to the problem of ensuring a comparative assessment of the quality indicators of own products and competitors’ products should be based on using the methodology of international practice for monitoring car quality, thereby approaching advanced quality measurement standards. Prerequisites are created to increase the level of adequacy of the relevant processes of national automakers to modern industry requirements. Moreover, the reason is quite simple. How the indicators presented above can be used when benchmarking quality with cars of other manufacturers. This is difficult to do because there is no work in the system of indicators already generally accepted in the global automotive industry. Today, in order to compare the level of quality of own products with the quality of competitors, it is necessary to do complex autonomous recounting, since in corporate specialized information systems the indicators of a new monitoring level are not standardized and put into practice. That is why new indicators are needed that are well broadcast in relation to the indicators of the leaders in the global automotive industry. However, it is also obvious that the implementation of a system of new quality indicators for automotive equipment in operation should be carried out taking into account existing industry practice and some specifics of the domestic auto industry.

The goal of this study is to improve the process of monitoring the quality of cars at the after-sales stage of the life cycle by developing and improving the methods and tools of the system for monitoring the quality of cars in use.

The objectives of the study cover the following issues: development of a system of indicators for assessing the quality of automobiles in operation, taking into account international practice of the monitoring process, and industry-specific processes and products of national automakers.

Figure 4 presents the developed scientific and practical concept of the process of monitoring the quality of cars in operation in the form of a pyramid, adequately meeting today’s challenges. Based on the obtained complex conclusions (Figure 3), the solution to the problem of monitoring quality should be carried out according to the main levels of the pyramid: basic quality; durability, and attributes of product quality; inconsistencies with consumer expectations; brand identification in terms of quality. Moreover, as mentioned above, ensuring a high level of reliability is very important, but it does not
guarantee a high level of assessment of the quality of automobiles perceived by consumers (customer satisfaction).

Turning to the international practice of monitoring the quality of vehicles in operation, the quantitative index GMF (guaranty method factory) is necessary to be highlighted, which is currently a kind of reference point for organizing the methodology of the corresponding measurement process for many enterprises in the automotive industry, including companies such as GM, Renault, Nissan, etc. This index is the level of defective cars in operation by month, group of months of operation (K ‰), per 1000 cars:

\[
K_{\%0} = \frac{\sum_{i=0}^{M} Q_j}{N} \times 1000, \tag{1}
\]

where \(Q_j\) — number of defects, breakdowns, failures for each of the \(j\)-th system, cars in general, for \(i\) months of operation; \(N\) — the total number of cars having the corresponding (analyzed) date of production (release) and \(i\) – months of operation.

The international index is not burdened by the base of the warranty fleet and is calculated only on the basis of the number of defects on vehicles with a specific release date and having a certain operating limit (3, 6, 12, 24, 48 months). An important aspect of putting the system of quantitative indicators for monitoring vehicle quality into the operation of domestic enterprises to the ideology of the K ‰ index is that international marketing institutions, such as ADAC, JD Power, Ipsos, MICA, etc., that conduct market research in the field of quality, also use appropriate methodology. Currently, taking into account the needs of the car industry in such research, this aspect is very important to ensure the sustainability of the process of strategic positioning of car brands in a competitive market.

Considering domestic work practices, several important problems are highlighted that impede the direct application of the GMF indicator.

Firstly, the principle of pushing out a production facility still works in domestic production systems. Western competitors have the principle of pulling, that is, custom-made assembly of cars. If the GMF indicator is directly applicable, then the date of the cars' release is needed to consider in the database. In this case, this cannot be done, as there will be a significant distortion of the result, due to a significant amount of production can be stored for some time on the sites before the sale (Figure 5).
It turns out that for justification of the indicator, the calculation base needs to be complicated by translating the quality assessment from the date of production to the date of cars’ sale, that is, and the calculation needs to be carried out only for sold cars at the studied production date. At the same time, a certain time limit will be fixed determining the acceptability or admissibility of the quality assessment. The quality assessment of cars, for example, after the first month of operation, with an adequacy level of 80%, is obtained only after 60 days from the date of release of the cars based on the data obtained on car sales (Figure 5). The adequacy of the indicator corresponding to the level 90% is reached only after 90 days from the date of issue. This aspect is well traced using Figure 6.

Figure 6 presents the results of a series of recalculations of the quality indicator K‰ for the vehicles of the product in question (Model 2), one of the largest automakers in Russia. The calculation was carried out in dynamics, starting from the first point of June 31, 2018, for cars produced in January 2018. The process of data accumulation, to the required completeness, is traced by the points of conversion of the considered quality indicator, performed during the next 11 reporting periods (months of analysis). The graphs show that for a three-month operation, the achievement of the level of adequacy of the indicator K‰ corresponding to 90% can be obtained only after 6 months of data analysis. Approaching 100% adequacy K‰ can be obtained after 12 months of continuous analysis of vehicle quality.
For competitors, “Western” car assembly plants, issues of product quality assessment become relevant after at least 3 months of operation. For example, Renault company targets are built on a period of at least 6 months of operation, while Nissan has at least 12, and preferably 24 months of operation. Due to the specifics, it is very important to provide quality analysis in the first weeks of operation.

Based on the foregoing, it turns out that a promising basic quality indicator that provides a solution to a number of important tasks in the existing system for monitoring the quality of automotive products have a disadvantage associated with an insufficient level of efficiency. This is unacceptable for the practice of domestic car assembly enterprises. This raises the problem associated with the development, in addition to the main indicator, of an operational index providing the ability to measure the quality of cars from the first days of operation.

The operational index of the level of alarm signals from the guarantee (ASG) is proposed as an additional statistical indicator.

Practice shows that most often bursts of defects, due to the insufficient level of assembly quality of automobiles or the production of automotive components, appear in the first few months of operation. It turns out that ASG is a set of indicators reflecting the number of failures for each of the positions of the defect codifier during the first weeks of vehicle operation. Figure 7 shows the alarm diagram. An alarm is declared in case of a sharp increase in the number of defects in the first weeks of operation of vehicles with a given release date, with a 3-fold excess of the acceptable level. In this case, the permissible and boundary levels are set by the standards taking into consideration data from the guarantee for previous periods, and targets for the quality of cars in use. Thus, the levels are determined by averaging the operational indicators for failures, for each of the positions, in the period of acceptable stability.

\[
ASG^{n-mis} = \frac{D^{n-mis}_{rep\, week}}{D^{n-mis}_{av}} \geq 3,
\]

**Figure 7.** Implementation of the first approach to determining the alarm in the warranty operation of cars.

ASG is assessed according to the number of defects registered for the reporting week (according to the date of defects registration) relative to the average value for the previous 10 weeks. The formula for its calculation is as follows:
where \( \text{ASG}^{n-mis} \) – warranty defective alarm indicator; \( D_{\text{rep.week}}^{n-mis} \) – the number of defects for the reporting week, calculated by the date of defect registration (Monday to Sunday); \( D_{av}^{n-mis} \) – the average number of defects over the previous 10 weeks; \( n-mis \) – period of warranty operation of the car, on which defects are identified. The following periods 0-3 months, 3-6 months, 6-12 months are considered.

Another important aspect that determines the specifics of the domestic automotive industry is the availability of a pre-sale preparation system, with a whole range of tools to ensure that vehicles are ready for use. Many of the competitors have a pre-sale concept no longer. In accordance with state and own regulations, this is still an important process. That is, the transition to a system of new quality monitoring indicators should be accompanied by the development of an index characterizing the quality of products at the pre-sale stage.

Proceeding from the above, let us present the new most comprehensive and appropriate set of indicators to monitor vehicle operation, which determines progressive currently methodology for measuring the quality of the process (Figure 4) and taking into account the specifics of the domestic industry.

The level of defects in the month’s group of analysis for 1000 MIS cars sold (K ‰) is calculated by the formula:

\[
K_{0-b}^{\text{MIS}} = 1000 \times \sum_{i=0}^{i=MIS} k_i ,
\]

where \( k_i \) – the coefficient reflecting the ratio of the number of failures to the number of cars sold for each of the months included in the analysis group; MIS – month in service, the number of months between the date the vehicle is placed under warranty.

The “zero” month in the guarantee (0 mis) starts from the moment the vehicle is placed under the guarantee and lasts until the end of the current calendar month. From the beginning of the next calendar month - 1 mis, etc.

The number of blocking, leading to the inability to operate the car failures per 1000 cars according to the group of months of analysis MIS (R ‰) is carried out according to the formula:

\[
R_{0-b}^{\text{MIS}} = 1000 \times \sum_{i=0}^{i=MIS} r_i ,
\]

where \( r_i \) – the coefficient reflecting the ratio of the number of blocking failures to the number of cars sold for each of the months included in the analysis group; MIS – month in service, the number of months between the date of sale of the device and the date of opening of registration of documents for repair.

The maintainability index Z ‰ determines the level of costs for the elimination of failures in vehicles with fixed service life.

The indicator of the level of costs for eliminating operational failures per 1000 cars according to the group of months of analysis cv (Z ‰) is calculated according to the formula:

\[
Z_{0-b}^{\text{MIS}} = 1000 \times \sum_{i=0}^{i=MIS} z_i ,
\]

where \( z_i \) – the coefficient reflecting the ratio of costs to eliminate failures to the number of cars sold for each of the months included in the analysis group; MIS – month in service, the number of months between the sale date of the device and the opening date of documents registration for repair.

The failure rate detected at pre-sale preparation (PSP) P is the ratio of the number of failures detected at the PSP stage, as well as all the failures detected during a car drive during maintenance before the PSP with a mark in the service book to the number of vehicles that have passed PSP (Np) having a specific release date reduced to 1000 cars (P ‰):
where \( Y \) – the number of failures on cars of a known month of production identified in pre-sale preparation.

4. Conclusion

The study resulted in identifying key problems from the practice of organizing a monitoring system of the quality of new cars during warranty operation that is typical for domestic automakers. A new set of quantitative indicators of the quality of the cars in operation is substantiated and proposed, which have no previously identified shortcomings. The proposed complex has been successfully implemented at a number of domestic enterprises of automakers.

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