Digital Technologies and QMS of Industrial Enterprise: Focus on Efficiency

D V Antipov¹, E Yu Kuznetsova² and A Aytasova³

¹Samara National Research University academician S.P. Koroleva, Samara, Russia. E-mail: con-expert@mail.ru
²Togliatti State University, Togliatti, Russia. E-mail: elenatgus@yandex.ru
³Peter the Great St. Petersburg Polytechnic University, St. Petersburg, Russian Federation

Abstract. The relevance of the problem is due to the fact that currently no aspect of the functioning and development of society can be imagined without the use of digital technologies. And if at first they were identified and associated with the use of communications, then as they developed, the scope of their application expanded due to significant competitive advantages of both the private and global order: leveling of interstate and territorial borders in the transmission, dissemination and receipt of information, including large volumes, adaptation of best practices, the possibility of faster adoption and implementation of management and technical and technological decisions. Digital technologies have become an integral part of the modern economic formation: in the household sphere, the education and health system, transport and other spheres of human life. This ultimately contributed to the natural process of diffusion of digital technologies, production systems and business in general, i.e. the so-called "digitalization of industry". It is important to note that the successful operation of the enterprise, regardless of the level of progressiveness of the industrial technologies used by it, should be ensured by the production of products or services that meet certain market needs, approved standards and specifications and, finally, the requirements of the current legislation. At the same time, the quality of products and services that meet the needs of consumers cannot be ensured through the one-off events’ introduction. It must be a systematic approach to quality management that covers all aspects and stages of the full life cycle of a product or service. This involves the development and implementation of quality management systems at the enterprises. Therefore, digital technologies in the QMS should be considered as an important tool for analysis, control and quality assurance of the final product and, accordingly, the competitiveness of the economic entity. The purpose of the article is to develop an economic and mathematical model for obtaining a regression dependence between the amount of revenue from sales and the factors of its formation. The leading method of research was the method of correlation and regression analysis. The main results of the article: the main factors of QMS and digitalization that affect the income of the enterprise through the quality of its products are identified; the dependence of the influence of various factors on revenue is determined, as well as the factors themselves characteristic of the enterprises of the automotive components industry on the example of JSC «Togliatti plant of automotive units». The materials of the article can be useful for any economic entities engaged into the production of goods, as well as focused on achieving high indicators of its quality through the introduction of digital technologies in the manufacturing process and QMS. The obtained results allow us to assess the profitability of the digitalization of production processes by taking into account the influence of factors of direct (on the amount of sales volume) and indirect (on the amount of costs for quality assurance) impact.
1. Introduction
A fait accompli can be considered a new technological revolution, a characteristic feature of which is the digital transformation. In essence, this means that analog and control technologies, where the decision-maker was a person, are gradually being replaced by artificial intelligence and machine control technologies. Digital transformation expands the spheres of influence and covers not only an increasing number of economic entities, but also the functional spheres of its application. In such circumstances, it is not an exaggeration to say that a high level of digitalization becomes synonymous with the competitiveness and prospects of companies, industries and national economies [6; 14; 15], and its neglect is a sign of insolvency in competition and satisfaction of the consumers’ needs [3; 13].

Quality management problems are no exception. Rather, on the contrary: the introduction of digital technologies is focused on improving the quality of a product or service, compliance with regulatory requirements, improving the decision-making process, increasing efficiency while reducing risk [4; 10]. Therefore, speaking about the effectiveness of digital technologies for enterprises, it is firstly necessary to note its exogenous nature, i.e. external competitiveness due to the increase in production volumes induced by the growth of labor productivity. However, at present, the endogenous, i.e. internal competitiveness of the economic entity becomes the goal of digitalization of production. Its formation is carried out on the basis of tracking the parameters of all production processes in real time and their corresponding adjustments online. This means a preventive problems’ solution, including in terms of product quality management, when instead of eliminating defects in already manufactured products, i.e., «fight against defects», enterprises immediately set up technological processes, ensuring their convergence and reproducibility, preventing or reducing almost to zero the amount of losses from defects. In other words, ensuring the external competitiveness of the company is directly related to the internal competitiveness. It is here that the connection and feasibility of using digital technologies in quality management and embedding them in the QMS of business entities is formed.

2. Research structure
Research structure included the following stages: as the object of the study was selected close corporation «Togliatti plant of auto units» (plant «TZA»), which is the official supplier of the main conveyor of JSC «AVTOVAZ» - one of the largest domestic car manufacturers in Russia; developed a system of indicators to assess the efficiency of the industrial enterprise, taking into account the functioning of its QMS and the introduction of digital technologies; identified and quantified the factors that affect the amount of revenue and costs to ensure product quality; an econometric model based on the assumption that it is possible to establish a regression relationship between sales volume and factors affecting it on the part of QMS and digitalization of production.

3. Representativeness of the object of study
Since its foundation in 1995 and up to the present time the plant «TZA» provides the needs of both the main conveyor of JSC «AVTOVAZ» (AVTOVAZ-RENAULT-NISSAN) and the spare parts market with its products.

The quality management system of the company complies with the requirements of international standards ISO 9001:2015, IATF 16949: 2016, ISO 14001, as well as the requirements of the supplier evaluation standard of the Renault-Avtovaz Alliance (ASES-Alliance Supplier Evaluation Standart). All production of the enterprise corresponds to requirements of technical regulations of the Customs Union [19].

All products supplied to the spare parts market have branded packaging with the use of anti-counterfeit products. The range of products of «TZA» is constantly updated, their nomenclature extends, the let-out production is modernized according to the clients’ requirements. Currently the plant produces the following product groups:
- cooling system;
- lubrication system;
- engine elements;
• transmission;
• steering;
• technical liquids.

In 2012, within the framework of the Russian Federation government’s program aimed at the introduction of energy-saving technologies, as well as to meet the growing demand for energy-efficient lighting devices, serial production of led lamps was launched at its own production facilities. In 2017, the production of new goods — technical liquids: antifreeze and antifreeze cooling liquids, as well as summer glass-breaking liquid and glass-breaking non-freezing liquid for the winter season for cars of domestic and imported production was started.

Close corporation «TZA» has resources for the development and production of modern automotive components [19]:
• design management and pilot production;
• machining of aluminum and cast iron alloy parts;
• assembly production of main and auxiliary units;
• modern semi-automatic Assembly centers of European production;
• automatic line of production and filling of technical liquids;
• testing laboratory;
• quality control department;
• logistics management.

The high quality of automotive components produced by close corporation «TZA» is confirmed by the presence of certificates of the international standard of the quality management system of the automotive industry [19]:
- International standard ISO 9001: 2015 No. 84503 / AA / 0001 / SM / RUS dated 16.11.2017
- International standard IETF 16949: 2016 No. 84503/A / 0001/SM/RUS dated 16.11.2017
- Renault-Avtovaz Alliance supplier Evaluation standard (ASUS-Alliance Supplier Evaluation Standart): No. R-RU T 0007-0-F1921 from 27.05.2019 g, the final result of the assessment-rank B
- SHC-Supplier Health Check score no. R-RU T-0020-0-H 1820 of 23.10.2018 (assigned category H1).
- Technical regulations of the Customs Union.

Close corporation «TZA» is the patentee of more than 20 utility models and inventions. In addition, all technological processes used at the enterprise are approved and meet all the requirements of JSC «AVTOVAZ» and the agreed specifications for the products.

Therefore, the object of research can be considered involved in the process of digitalization. However, like most of Russian enterprises, close corporation «TZA» implements separate digital technologies into the production process and its management (automatic lines that allow online transmission and processing of information about the parameters of production, the level of its stability; the consumers’ feedback collection by using a questionnaire on the website and the formation of a database on the problems; electronic document management, etc.). Partial digitalization is due to the high cost of complex solutions, including Russian developers, and the amount of costs for servicing borrowed funds in the case of their involvement due to the insufficient volume of its own resources, the lack of personnel of the necessary qualifications. In addition, «automation of production sites and business processes in Russian companies, as a rule, do not have common links, which means that it is not possible to organize information links at all levels of the production process, from design and preparation of production, ending with logistics support of the manufactured product and sales management» [1; 8; 9; 18].

All this allows us to consider close corporation «Togliatti plant of auto units» as a typical representative of Russian enterprises engaged in the production of automotive components with similar problems, and the probability of the impact of digital technologies and QMS on financial results and costs to ensure product quality is high.

The authors propose to build an economic and mathematical model to assess the effectiveness of the QMS and the introduction of digital technologies in the activities of close corporation «TZA». Econometric correlation-regression model system of interrelated characteristics of the studied aggregate is a regression equation that includes the factors influencing the variation of resultant variable in the
aggregate, possesses a high value of determination coefficient (not less than 0.5), reliable and correctly interpreted in accordance (in sign and order of magnitude) with the theory of the system under study with the regression coefficients, and these properties are suitable for the evaluation of population units and for forecasting.

In general, the linear regression equation can be represented as follows [5]:

\[ y = \beta_1 + \beta_2 \cdot x_2 + \beta_3 \cdot x_3 + \cdots + \beta_k \cdot x_k + \epsilon \]  

where \( y \) – dependent variable (the resulting feature); \( \beta_1, \beta_2, \ldots, \beta_k \) – regression coefficients showing the average value of the change in the resulting feature when changing the variables \( x_1, x_2, \ldots, x_k \) per unit of measurement; \( x_1, x_2, \ldots, x_k \) – independent variables (factors of influence); \( \epsilon \) – random errors of the multiple regression equation.

The construction of a model for assessing the effectiveness of the introduction of digital technologies in the activities of close corporation «TZA» is based on the establishment of a relationship between the amount of revenue from sales of products (the resulting indicator) and specific performance indicators of the quality management system and digitalization of production (independent variables), which requires the implementation of appropriate calculations.

Stages of construction of the specified economic and mathematical model include:
1. Development of the indicators’ system to assess the effectiveness of the QMS and digitalization of the enterprise;
2. Analysis of private indicators of the level of product quality;
3. The analysis of private indicators of the QMS’ effectiveness;
4. Analysis of product quality assurance costs;
5. Analysis of private indicators of the enterprise’s digitalization level;
6. Construction of a multiple regression model of the dependence between close corporation «TZA»’s sales volume (the resulting indicator) and private efficiency indicators of the quality management system and digitalization of production (independent variables).

Stage 1. To assess the effectiveness of the QMS and the introduction of digital technologies in the activities of the enterprise, the authors developed a system of indicators, the structure of which is presented in figure 1.
### Indicators for assessing the effectiveness of QMS and digitalization

| 1. Indicators of the level of product quality | 3. Indicators of the product quality assurance’s expenditure level |
|---------------------------------------------|---------------------------------------------------------------|
| 1.1. Product quality index                   | 3.1. Share of the quality costs in the products’ input costs |
| 1.2. Index of defective products             | 3.2. Share of costs due to internal failures                  |
| 2. Indicators for assessing the QMS         | 3.3. Share of costs due to external failures                  |
| effectiveness                                | 3.4. Share of costs for a quality assessment                  |
| 2.1. Evaluation of «TZA» as a supplier       | 3.5. Share of costs of preventive measures                    |
| 2.2. Share of returns from delivery to      | 4. Indicators for assessing the digitalization level         |
| JSC «AVTOVAZ»                                |                                                               |
| 2.3. Share of returns from service STATIONS |                                                               |
| in the total value of the warranty fleet     |                                                               |
| 2.4. Level of the internal defects          |                                                               |
| 2.5. Level of compliance with technological |                                                               |
| discipline                                   |                                                               |
| 2.6. Level of implementation of corrective |                                                               |
| and preventive measures                      |                                                               |
| 2.7. Reject rate                             |                                                               |
| 2.8. Level of implementation of the         |                                                               |
| production plan                              |                                                               |
| 2.9. Release of nonconforming products due  |                                                               |
| to the staff’s fault                         |                                                               |
| 2.10. Share of product defects due to       |                                                               |
| non-compliance with storage, handling and   |                                                               |
| transportation requirements                 |                                                               |
| 2.11. Share of statistically controlled     |                                                               |
| technological processes                      |                                                               |
| 3. Indicators for assessing the product     |                                                               |
| quality assurance’s expenditure level        |                                                               |
| 3.1. Share of the quality costs in the      |                                                               |
| products’ input costs                        |                                                               |
| 3.2. Share of costs due to internal failures |                                                               |
| 3.3. Share of costs due to external failures |                                                               |
| 3.4. Share of costs for a quality assessment|                                                               |
| 3.5. Share of costs of preventive measures  |                                                               |
| 4. Indicators for assessing the digitalization level |
| 4.1. Share of automatic equipment            |                                                               |
| 4.2. Share of goods produced with the use   |                                                               |
| of automatic equipment                       |                                                               |
| 4.3. The employees’ labor productivity      |                                                               |
| index of growth                             |                                                               |
| 4.4. Coefficient of innovative renewal of  |                                                               |
| fixed assets                                |                                                               |
| 4.5. Utilization rate of installed           |                                                               |
| equipment fleet                             |                                                               |
| 4.6. Production output per 1 machine-hour   |                                                               |
| of equipment                                |                                                               |
| 4.7. Potential of intangible assets         |                                                               |

**Figure 1.** The indicators to measure the effectiveness of the QMS and implementation of digital technologies in the company’s activities.

**Source:** developed by the authors
Stage 2. The analysis of the level of product quality is carried out using two indicators:  
1) product quality index, defined as the weighted average of relative values of quality indicators of heterogeneous products of the enterprise for a certain period;  
2) index of defective products, defined as the weighted average of the defect coefficients of heterogeneous products of the enterprise for a certain period. The defect rate in this case is calculated taking into account the dynamics of its level, i.e. takes into account the trend of change.  
Dynamics of quality and defect indices of close corporation «TZA» products for 2014-2018 is presented in figure 2. Based on their dynamics, it follows that the level of quality of the company’s products increased by 0.018 points, and the level of defects, on the contrary, decreased by 0.866 points. This trend is positive, as it indicates an improvement in the quality of the plant’s products. 
Stage 3. The analysis of private indicators of the QMS’ effectiveness. 
Most of the products of close corporation «TZA» are made for the needs of JSC «AVTOVAZ». In this regard, JSC «AVTOVAZ» included «TZA» in the list of its main suppliers and regularly conducts a point quality assessment of its deliveries [17; 19]. 
As part of this research, based on internal audit data, the analysis of close corporation «TZA» as a supplier of the main conveyor of JSC «AVTOVAZ» was carried out in accordance with the scale of table 1. The rating calculations’ results of the studied enterprise as a supplier are presented in figure 3.

**Table 1.** Evaluation criteria of close corporation «TZA» as a supplier

| Supplier evaluation       | Evaluation criterion          |
|--------------------------|-------------------------------|
| Excellent supplier       | 85 or more points             |
| Reliable supplier        | 80-84 points                  |
| Unreliable supplier      | 50-79 points                  |
| Unsatisfactory supplier  | 49 or less points             |

**Source:** developed by the authors
As can be seen from figure 3, the company maintains and controls the supply’s efficiency and therefore the rating is growing.

![Figure 3. Dynamics of rating of «TZA» as a supplier](image)

**Source:** developed by the authors

In 2001, the standardization Bureau of close corporation «TZA» and the technical control Department together with consultants of JSC «AVTOVAZ» developed a quality management system. At the same time, the first certification of the quality management system for compliance with ISO 9001 version 2000 was carried out and the certificate of the German certification body TÜV CERT was obtained.

In order to obtain timely objective evidence about the need to reduce, eliminate and prevent QMS inconsistencies, the company conducts internal (auditors of the technical control Department) and external (representatives of the German certification body TIC) audits.

According to the authors, the enterprise’s effectiveness of the quality management system can be assessed by using indicators of defects, carrying out the planned activities to improve product quality, and coverage of technological processes of the enterprise advanced (statistical) methods of quality control. The results of calculations of the QMS efficiency indicators of close corporation «Togliatti plant of auto units» are presented in Table 2.

**Table 2.** Indicators of efficiency of functioning of the QMS of close corporation «TZA» for 2014-2018.

| Indicators                                                                 | Value per year |
|----------------------------------------------------------------------------|----------------|
| 1. Evaluation of TZA as a supplier, score                                  | 71,92, 76,58, 79,12, 85,83, 87,75 |
| 2. Share of returns from delivery to JSC «AVTOVAZ», %                      | 0,19, 0,17, 0,18, 0,16, 0,16 |
| 3. Share of returns from service STATIONS in the total value of the warranty fleet, % | 0,09, 0,104, 0,093, 0,080, 0,087 |
4. Level of the internal defects (in relation to the number of machined parts), %  
|   | 1,6 | 1,6 | 1,78 | 1,53 | 0,93 |

5. Level of compliance with technological discipline, %  
|   | 98,65 | 98,74 | 99,16 | 99,24 | 99,33 |

6. Level of implementation of corrective and preventive measures, %  
|   | 97,82 | 98,61 | 100 | 93,75 | 100 |

7. Reject rate, PPM  
|   | 920 | 960 | 840 | 749 | 580 |

8. Level of implementation of the production plan, %  
|   | 82,57 | 89,96 | 91,36 | 94,49 | 98,26 |

9. Release of nonconforming products due to the staff’s fault, %  
|   | 0,63 | 0,62 | 0,84 | 0,79 | 0,63 |

10. Share of product defects due to non-compliance with storage, handling and transportation requirements, %  
|   | 0,55 | 0,56 | 0,56 | 0,85 | 0,95 |

11. Share of statistically controlled technological processes, %  
|   | 92,12 | 92,47 | 93,15 | 93,69 | 94,59 |

Source: developed by the authors

Consequently, there are minor problems in the quality management system of the enterprise, as during the analyzed period there is an increase of the product defects’ share due to non-compliance with the requirements for storage, loading and unloading and transportation. It also must be mentioned that the share of returns from service STATIONS in the total value of the warranty fleet of cars in 2018 increased by 0,007% in comparing to 2017.

Stage 4. This stage is associated with the research of the enterprise’s costs to ensure the products’ quality. In accordance with the reasons for the formation the quality assurance costs are classified into the following groups: 1) costs due to internal failures associated with the identification and possible correction of defects found before the products’ transfer to the consumer; 2) costs due to external failures due to the identification and possible correction of defects found after the products’ transfer to the consumer; 3) the costs of quality assessment associated with the determination of the degree of conformity of products with quality requirements; 4) the costs of preventive measures designed to carry them out in order to minimize losses from failures and the costs of quality assessment.

Dynamics of the quality expenses’ shares by categories in their total amount of close corporation for 2014-2018 is presented in figure 4.
Positive dynamics of the quality expenses’ shares by categories in total, presented in figure 4, we should recognize as the perfection of their structure, namely the decline in the share of expenditures for internal and external cracks, contributing to the formation of the reputation of the manufacturer, and the growth of precautionary costs, indicating the strengthening of control of the company for the level of product quality, the development and implementation of preventive measures. Thus, in general, during the period under review, the total share of non-productive expenses (expenses due to internal and external failures) decreased by 12.95%, while preventive expenses increased by 7.38%. This indicates a shift in emphasis in the field of quality management of close corporation «TZA» from solving problems due to the release of reject rate to its prevention.

In addition to the structure, an important aspect of the analysis of costs for product quality assurance is their share in the total cost of production and its dynamics (figure 5). From the data of figure 5 it follows that the share of quality costs in the production costs of close corporation «Togliatti plant of auto units» decreased by the end of the period by 0.71%. Other things being equal, this fact should be considered as a positive trend.
Stage 5. Construction of a model of multiple regression of the dependence of the efficiency of the enterprise on the particular performance indicators of QMS and the use of digital technologies. The ultimate goal of this study is to build an econometric model for assessing the effectiveness of the QMS of an economic entity through the introduction of digital technologies. Typical performance criteria are time, money, compliance with requirements (regulatory, legislative, technological) and the level of performance of planned tasks. Given that in a market economy, any activity is evaluated in terms of the ability to generate income, the effectiveness of the QMS, including through digitalization, it is advisable to analyze its value. In other words, the authors propose to consider revenue as an independent variable that serves as a criterion for the performance of the enterprise to ensure the quality of its products.

Data on the sales amount of close corporation «Togliatti plant of auto units», as well as the calculated private indicators of the level of product quality, QMS efficiency, costs for product quality and the level of digitalization of business for 2014-2018 can be presented in the form of initial data of this model (table 3) [19].

**Figure 5.** Dynamics of the share of quality costs in the production costs of close corporation «Togliatti plant of auto units» for 2014-2018, %

**Source:** developed by the authors

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**Table 3.** Table of source data for the calculation of multiple regression equation

| Indicators                                      | Letter of the designation | Value per year          |
|-------------------------------------------------|---------------------------|-------------------------|
|                                                 |                           | 2014  | 2015  | 2016  | 2017  | 2018  |
| Sales amount, million rubles                    | y                          | 539,224 | 593,412 | 627,132 | 604,705 | 684,045 |
| 1. Indicators of the level of product quality   |                            |        |        |        |        |        |
| 1.1. Product quality index                      | \(x_1\)                   | 0.916  | 0.917  | 0.919  | 0.920  | 0.934  |
| 1.2. Index of defective products                | \(x_2\)                   | 2.918  | 2.914  | 2.943  | 2.803  | 2.052  |
| 2. Indicators for assessing the QMS effectiveness |                           |        |        |        |        |        |
### Indicators

| Indicators                                                                 | Letter of the designation | Value per year |
|---------------------------------------------------------------------------|---------------------------|----------------|
| 1. Evaluation of «TZA» as a supplier, score                               | x₃                        | 71,92          |
|                                                                          |                           | 76,58          |
|                                                                          |                           | 79,12          |
|                                                                          |                           | 85,83          |
|                                                                          |                           | 87,75          |
| 2. Share of returns from delivery to JSC «AVTOVAZ», %                     | x₄                        | 0,19           |
|                                                                          |                           | 0,17           |
|                                                                          |                           | 0,18           |
|                                                                          |                           | 0,16           |
|                                                                          |                           | 0,16           |
| 3. Share of returns from service STATIONS in the total value of the warranty fleet, % | x₅                        | 0,09           |
|                                                                          |                           | 0,104          |
|                                                                          |                           | 0,093          |
|                                                                          |                           | 0,080          |
|                                                                          |                           | 0,087          |
| 4. Level of the internal defects (in relation to the number of machined parts), % | x₆                        | 1,6            |
|                                                                          |                           | 1,6            |
|                                                                          |                           | 1,78           |
|                                                                          |                           | 1,53           |
|                                                                          |                           | 0,93           |
| 5. Level of compliance with technological discipline, %                    | x₇                        | 98,65          |
|                                                                          |                           | 98,74          |
|                                                                          |                           | 99,16          |
|                                                                          |                           | 99,24          |
|                                                                          |                           | 99,33          |
| 6. Level of implementation of corrective and preventive measures, %       | x₈                        | 97,82          |
|                                                                          |                           | 98,61          |
|                                                                          |                           | 100            |
|                                                                          |                           | 93,75          |
|                                                                          |                           | 100            |
| 7. Reject rate, PPM                                                       | x₉                        | 920            |
|                                                                          |                           | 960            |
|                                                                          |                           | 840            |
|                                                                          |                           | 749            |
|                                                                          |                           | 580            |
| 8. Level of implementation of the production plan, %                      | x₁₀                       | 82,57          |
|                                                                          |                           | 89,96          |
|                                                                          |                           | 91,36          |
|                                                                          |                           | 94,49          |
|                                                                          |                           | 98,26          |
| 9. Release of nonconforming products due to the staff’s fault, %          | x₁₁                       | 0,63           |
|                                                                          |                           | 0,62           |
|                                                                          |                           | 0,84           |
|                                                                          |                           | 0,79           |
|                                                                          |                           | 0,63           |
| 10. Share of product defects due to non-compliance with storage, handling and transportation requirements, % | x₁₂                       | 0,55           |
|                                                                          |                           | 0,56           |
|                                                                          |                           | 0,56           |
|                                                                          |                           | 0,85           |
|                                                                          |                           | 0,95           |
| 11. Share of statistically controlled technological processes, %         | x₁₃                       | 92,12          |
|                                                                          |                           | 92,47          |
|                                                                          |                           | 93,15          |
|                                                                          |                           | 93,69          |
|                                                                          |                           | 94,59          |

3. Indicators of the product quality assurance’s expenditure level

| Indicators                                                                 | Letter of the designation | Value per year |
|---------------------------------------------------------------------------|---------------------------|----------------|
| 1. Share of the quality costs in the products’ input costs, %             | x₁₄                       | 2,82           |
|                                                                          |                           | 2,79           |
|                                                                          |                           | 2,73           |
|                                                                          |                           | 2,43           |
|                                                                          |                           | 2,11           |

4. Indicators for assessing the digitalization level

| Indicators                                                                 | Letter of the designation | Value per year |
|---------------------------------------------------------------------------|---------------------------|----------------|
| 1. Share of automatic equipment (index)                                    | x₁₅                       | 0,07           |
|                                                                          |                           | 0,12           |
|                                                                          |                           | 0,12           |
|                                                                          |                           | 0,19           |
|                                                                          |                           | 0,19           |
| 2. Share of goods produced with the use of automatic equipment, %          | x₁₆                       | 8,56           |
|                                                                          |                           | 9,12           |
|                                                                          |                           | 10,87          |
|                                                                          |                           | 15,23          |
|                                                                          |                           | 16,92          |
| 3. The employees’ labor productivity index of growth                       | x₁₇                       | 1,0568         |
|                                                                          |                           | 1,0677         |
|                                                                          |                           | 1,0712         |
|                                                                          |                           | 1,1255         |
|                                                                          |                           | 1,1638         |
| 4. Coefficient of innovative renewal of fixed assets                       | x₁₈                       | 1,95           |
|                                                                          |                           | 3,57           |
|                                                                          |                           | 0,94           |
|                                                                          |                           | 0,39           |
|                                                                          |                           | 0,90           |
| 5. Utilization rate of installed equipment fleet                           | x₁₉                       | 0,92           |
|                                                                          |                           | 0,93           |
|                                                                          |                           | 0,93           |
|                                                                          |                           | 0,94           |
|                                                                          |                           | 0,94           |
| 6. Production output for 1 machine-hour of equipment operation, thousand rubles | x₂₀                       | 1,37           |
|                                                                          |                           | 1,40           |
|                                                                          |                           | 1,41           |
|                                                                          |                           | 1,39           |
|                                                                          |                           | 1,40           |
| 7. Potential of intangible assets, thousand rubles                         | x₂₁                       | 154            |
|                                                                          |                           | 307            |
|                                                                          |                           | 279            |
|                                                                          |                           | 409            |
|                                                                          |                           | 361            |

Source: developed by the authors
To form an econometric model, first of all, it is necessary to establish a close relationship between the dependent variable and the expected impact factors. For this purpose was held the analysis of multiple correlation. According to this analysis the criterion of influencing factors’ selection is the closeness of communication which is expressed by coefficient more than 0,7. The results of the calculations are presented in the table 4.

The sign of the correlation coefficient indicates the direction of the factor’s influence on the resulting indicator. Thus, its values for the index of defective products, the share of returns from delivery to JSC «AVTOVAZ», the reject rate and the share of quality costs in the products’ input costs are negative, therefore, the growth of these indicators leads to a decrease of the enterprise’s amount of sales. Based on the content of these factors, the value of the correlation coefficient is calculated adequately.

**Table 4.** Correlation coefficients of indicators of efficiency of quality management system and digitization of the enterprise

| The factor                                      | Letter of the designation | Value of the correlation coefficient |
|------------------------------------------------|---------------------------|--------------------------------------|
| Product quality index                          | x₁                        | 0.8774                               |
| Index of defective products                    | x₂                        | -0.79                                |
| Share of returns from delivery to JSC «AVTOVAZ» | x₄                        | -0.702                               |
| Level of compliance with technological discipline,% | x₇                        | 0.8485                               |
| Reject rate, PPM                                | x₉                        | -0.828                               |
| The level of implementation of the production plan,% | x₁₀                       | 0.9259                               |
| Share of product defects due to non-compliance with storage, handling and transportation requirements, % | x₁₂                       | 0.7008                               |
| Share of statistically controlled technological processes, % | x₁₃                       | 0.9072                               |
| Share of the quality costs in the products’ input costs, % | x₁₄                       | -0.813                               |
| The employees’ labor productivity index of growth | x₁₇                       | 0.7956                               |
| Utilization rate of installed equipment fleet    | x₁₉                       | 0.7935                               |
| Production output for 1 machine-hour of equipment operation, thousand rubles | x₂₀                       | 0.7322                               |

**Source:** developed by the authors

Analysis of all the identified factors having the strongest relationship with the resulting indicator from the point of view of determining the enterprise’s QMS effectiveness, including at the expense of digitization. The use of the software product Excel allowed the authors to obtain the model value of revenue:

\[ y = 294,32 - 52,95 \cdot x_2 - 0,192 \cdot x_9 + 8,6931 \cdot x_{10} - 257,1 \cdot x_{12} \]  

(2)

where \( y \) – is the amount of revenue from sales, mln rubles; \( x_2 \) – an index of defective products; \( x_9 \) – the reject rate, PPM, \( x_{10} \) – the level of implementation of the plan of production, %; \( x_{12} \) – share of defective products by reason of non-compliance to storage, handling and transportation, %.

The value of R-square, which characterizes the quality of the model, in our case is 1 or 100%. So it can be made a conclusion that the model has an excellent level of quality.

The «Y-intersection» and the «Coefficients» column is «294,32». Therefore, the value of Y, i.e. the value of the company’s sales volume with all other factors equal to zero, will assume its formation at the level of 294,32 million rubles.

Interpreting the model based on revenue from sales, it is worth noting that an increase in the index of defective products by 1 point, the reject rate at 1 PPM and the proportion of defective products by reason of non-compliance to storage, handling and transportation by 1%, revenue will decline accordingly on 52.95; 0.192; 257.1 million rubles. At the same time, the increased level of implementation of the production plan by 1% will lead to revenue growth for 8,6931 million rubles.
The resulting model (formula 2) reflects the natural regression coefficients. However, to ensure the possibility of their comparison with each other and ranking of factors by the power of influence, it is necessary to obtain a multiple regression equation in a standardized form (formula 3) [11].

\[ t_y = -0.38272 \cdot t_{x2} - 0.5534 \cdot t_{x9} + 0.96496 \cdot t_{x10} - 0.9345888 \cdot t_{x12} \]  

(3)

From formula 3 it follows that the greatest influence on the resulting characteristic (revenue) is rendered by factors of the production plan’s implementation level and the reject rate due to non-compliance to the execution of logistics operations, since their module values are close and much higher than levels of defects and number of claims. However, these factors are quite strong (regression coefficients greater than 0.35) [16]. Therefore, the increase in profitability of the enterprise directly depends on reducing the level of defects and negative consumer feedback, as well as compliance with the requirements of the main and auxiliary production processes.

In this case, the established directions of the factors’ influence on revenue can be interpreted as logical and justified from the point of view of the considered indicators’ content.

It is also important to note that, despite the close connection of a number of factors of digitalization with the revenue of the studied enterprise (in accordance with the calculated correlation coefficients), they were not included in the parameters of the regression model. This allows us to conclude that the influence of these factors is indirect. At the same time, it is scientifically proved that the deployment of digital technologies in manufacturing and QMS as a system-regulator of production and technological processes leads to an increase in the productivity of personnel and equipment, and therefore, reduce the costs of the business entity and increase its income on this basis [14].

The category that unites the sphere of production, controlling its system in terms of quality assurance of products and services (QMS) and the enterprises’ financial results are the costs of quality assurance and their share in the production costs. In order to establish the impact of the company’s level of digitalization on this indicator, it is advisable to build an economic and mathematical model.

First, it was established that the share of quality assurance costs in the production costs (dependent variable) was closely related to the expected impact factors (independent variables). The results of the analysis of multiple correlation of interdependent factors are presented in table 5.

**Table 5. Correlation coefficients for the share of quality assurance costs in the production costs and digitalization of the enterprise**

| The factor                                      | Letter of the designation | Value of the correlation coefficient |
|------------------------------------------------|--------------------------|-------------------------------------|
| Share of automatic equipment (index)            | x\textsubscript{15}       | -0.87852                            |
| Share of products produced with the use of automatic equipment, % | x\textsubscript{16}       | -0.96902                            |
| The employees’ labor productivity index of growth | x\textsubscript{17}       | -0.99517                            |
| Utilization rate of installed equipment fleet   | x\textsubscript{19}       | -0.84383                            |

**Source:** developed by the authors

From the data of table 4 it follows that only 4 from 7 factors of digitalization of the production activity of close corporation «Togliatti plant of auto units» have a close feedback with the share of quality assurance costs in the production costs, since the values of the correlation coefficients are higher than 0.8 points. The opposite effect of the digital technology’s level implementation is concluded in increasing the level of automation of information processing and execution of manufacturing operations leads to lower costs of providing quality and share in cost of production. This fact should be assessed as a positive economic effect.

Having carried out calculations with the help of Excel software, the authors obtained the following model of dependence of the share of expenses for quality assurance in the production costs of close corporation «TZA» in the natural form:
where $y$ – the share of costs for quality assurance in the production costs,\%; $x_{15}$ – the share of automatic equipment (index); $x_{16}$ – the share of products manufactured with the use of automatic equipment,\%; $x_{17}$ – The employees’ labor productivity index of growth; $x_{19}$ – the utilization rate of the installed equipment. The R-squared value for this model is also 1 or 100\% and characterizes its quality as excellent.

The «$y$-intersection» and the «Coefficients» column is «34,36357», i.e. the share of quality assurance costs in the production costs with all other factors equal to zero will assume its formation at the level of 34.36357\%. The regression coefficients for the factors are negative, since, as it was noted, the growth of automation and digitalization of production leads to a decrease in the costs of the economic entity to conduct business.

The obtained model of the dependence of the share of quality assurance costs in the production costs on the factors of digitalization (formula 4) in order to ensure the possibility of their comparison with each other and ranking of factors by the power of influence should be transformed into a multiple regression equation in a standardized form (formula 5).

$$t_y = 1,099075 \cdot t_{x_{15}} - 2,37877 \cdot t_{x_{16}} - 1,13555 \cdot t_{x_{17}} - 0,71699 \cdot t_{x_{19}}$$ (5)

Formula 5 shows that the greatest impact on the resulting feature (the share of costs for ensuring product quality in the production costs) has a share of products produced with the use of automatic equipment. Automatic equipment and the employees’ labor productivity index of growth also have a strong impact on the value of the dependent variable, because their module values are close and higher than the value of the utilization rate of the installed equipment fleet.

Thus, the level of profitability of the enterprise directly depends on factors of the effectiveness of the company QMS and indicators of digitalization, namely the reduction of defects and scrap, of compliance of main and auxiliary production processes, ensure the specified level of implementation of the plan of production, automation of production processes and increase production by using automatic equipment.

4. Conclusion

The intensive development of the industry and the formation of a new economic situation on the principles of digitalization, orientation to the best satisfaction of the consumers’ needs caused the public interest to the problems of introduction of QMS and digital technologies in the activities of enterprises.

This interest has a very specific practical value: increasing the competitiveness of both private companies and national economies due to GDP indicators [2; 7; 12]. However, this raises the problem of assessing the effectiveness of these areas and their impact on the financial results of economic entities. One possible solution to this problem can be developed by the authors of the methods of evaluating the effectiveness of the QMS and digitalization based on the use of objective statistical data of industrial enterprises and the mathematical apparatus, allowing to evaluate and objectively interpret actual indicators and achievements in the field of quality and level of digital technologies’ implementation in the activities of economic entities.

The models developed by the authors to estimate the sales volume and the share of costs for quality assurance can be used in the practice of companies to analyze the effectiveness of QMS and digitalization processes. The identification of priority impacts and strength of their influence should be considered as a basis for improving the efficiency of the company by reducing the number of complaints and quality defects of products, and interrelated growth of productivity and income.

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