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QUALITY MANAGEMENT MODELS AND METHODS IMPROVEMENT FOR AN EXPANDING COMPETITIVE RANGE OF LEATHER AND FOOTWEAR PRODUCTS

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A B S T R A C T

The article shows the main problems of product quality management in a multidimensional organizational structure of industrial cooperation, organizational and production risks. It analyses the prerequisites and factors, the effectiveness of developed solutions to improve the quality management systems of the expanding competitive range of leather and footwear products. The article presents a system-situational model of quality management. The conditions for adapting the method of sequential dynamic quality assessment are formulated in order to improve the quality of production of leather and footwear products.

1. INTRODUCTION

Shoes are an essential item, a complex multilayer product consisting of various components and materials. Special requirements are placed on the quality of special footwear. Indicators and properties of footwear quality are interconnected in the «person – footwear – environment» system. Every year, according to expertise, up to 50% of footwear hazardous to health is identified in case of quality discrepancies (Fig. 1).

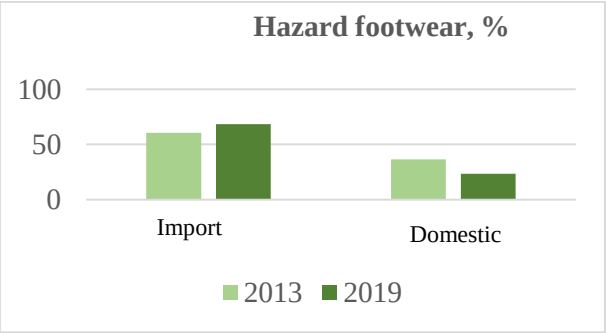

Figure 1. Expertise results of footwear quality discrepancy

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Among the main groups of prerequisites and factors for improving the quality management system of an expanding competitive range of leather and footwear products are the following:

- the highly competitive Russian footwear market is characterized by an expanding competitive range of products;
- the transformation of project quality into production quality is not of a stream line, but of a network nature - with the transfer of a number of processes to the subjects of cooperation;
- customization forms an additional consumer need in the structure of the quality profile (Evdokimov et al., 2020).

The relevance of the study is determined by the contradictions and conflicts of quality requirements of objects and processes of leather and footwear production. The problem situation is systemic. For subjects of multidimensional production cooperation the consumer becomes hidden since his requirements for product quality are unknown to the outsourcer.

2. MATERIALS AND METHODS

The study was conducted on the basis of enterprises united in a multidimensional organizational structure of industrial cooperation for the production of an expanding competitive range of leather and footwear products. The research was based on classical works and modern developments of leading domestic and foreign authors (Gazizulina et al., 2017).

The solution to the tasks was based on theoretical and empirical research using the principles and methods of standardization, system and situational modeling, qualimetric analysis, expert assessment and analysis, statistical methods, tabular and graphical methods of conceptualization and interpretation of data.

In modern socio-political conditions with the destruction of established economic ties, as well as customization and network forms of production, organizational and production risks are proven to be increased as a result of deviations from the initially established requirements. In the polysemy of concepts and terms (where, as a rule, the negative consequences of risk are highlighted), we understand that the «deviation risk» is the impact of uncertainty, qualitatively and quantitatively objectified in a situation of expedient activity, which can have positive or negative impacts on the quality of objects and processes production (Samorukov, 2022).

The classification of risks of quality discrepancy of objects and processes of leather and footwear production is presented on the basis of a matrix of systemic and non-systemic risks (Table 1).

Table 1. The matrix of systemic and non-systemic risks

Risks	**Systemic**	**Non-systemic**
Factors	politycal	financial
	economic	market
	Socio-cultural	organizational
	technologic	production

Quantitative assessment of risks (hazards) is defined as the frequency of occurrence of one event upon the occurrence of another. Quantitative analysis, expressed mathematically, allows us to determine the ratio of risk consequences in relation to a specific situation as the sum of individual risks, which can be calculated as the product of potential losses Ri and their probabilities *p(Li)*:

$$R_i = \sum_i L_i \, p(L_i) \qquad (1)$$

In order to estimate the systemic risks of the leather and footwear industry, expert assessments of the significance (*Ii*) and probability of occurrence (*Vi*) of significant risks carried out by specialists from the TOP-10 leather and footwear industries during international and local exhibitions of footwear, equipment and materials in 2020-2021 are taken as a basis (Table 2) (Klochkov et al., 2022).

Table 2. Systemic risks analysis of a leather and footwear enterprise

№	Risk	Significance of risk, Ij	Probability of risk, Vi	Weight of risk, Ri=Vi*Ij	Specific weight of risk (Vi*Ij)*100/0,396	Total in points
1	Raw materials, other materials, logistics cost	0,22	0,4	0,088	22,2	2
2	Competitor production level	0,22	0,3	0,066	16,7	3
3	Taxation	0,22	0,6	0,132	33,3	1
4	Demand variability	0,22	0,2	0,044	11,1	4
5	Introduction of an alternative product	0,055	0,5	0,0275	7,0	6
6	Dependence on the labor market	0,055	0,7	0,0385	9,7	5
7	Total	–	–	0,396	–	–

Non-systemic risks include those that can be influenced directly by the quality management system.

The analysis showed that despite the obvious effectiveness of developed solutions of quality management systems improvement in the real sector of the economy in a multidimensional organizational structure of industrial cooperation, there are elements of uncertainty, leading to the subjectivity of decisions made by industrial entities and to contradicting results in assessing the quality of the expanding competitive range of leather and footwear products.

We have proposed the following solutions to improve the quality management system:

- system modeling methods and consistent dynamic assessment of a specific situation;
- a single information space that combines information resources, automated systems and organizational and technological structures of multidimensional production cooperation, means of information interaction between users in order to maximally satisfy their needs in the production process of an expanding competitive range of leather and footwear products.

To realistically represent the processes of a single information space of cooperation subjects, a system-situational model of quality management was developed.The functional and structural composition of the model is provided by a data measurement mechanism. The data measurement mechanism (DSt.–EDA–CDA) determines compliance anomalies by setting binary labels: Yes – 0 and No – 1. Summary statistics (DSt. – Descriptivestatistics) quantitatively describes or summarizes the characteristics of objects and processes. To resolve the problems of «uncertainty identification» the model presents an exploratory analysis of the main data properties (EDA – Exploratory data analysis). Confirmation analysis of coordinated data (in Coordinated Data Analysis) focuses on confirming or refuting hypotheses in a self-learning system based on a neural network.

We consider the network-centric mechanism of the sequential dynamic quality assessment method (Ya, 2010) which allows us to adequately represent the processes and objects in the model by two levels. In managing relationships between subjects (projects) along with tools and techniques of project management (PMBoK standard), constructors of the logic of concepts and roles based on GSS (group situation analysis technologies) are used. At the level of managing qualitative and quantitative characteristics the quality functions of the subjects of cooperation are structured, which determines the accuracy of the parameters of the production process.

The model allows us to coordinate the interaction of subjects to continuously improve quality. The data obtained indicate a reduction in the proportion of defects in component materials, assemblies and parts to 25%. At the same time, the share of defects per unit of measurement among the subjects of cooperation included in a single information field is less than among external outsourcers. Integration into a single information field ensures prompt adoption by the subjects of cooperation of corrective actions to reduce the number of defects per unit of measurement (Fig. 2) (Klochkov et al., 2022).

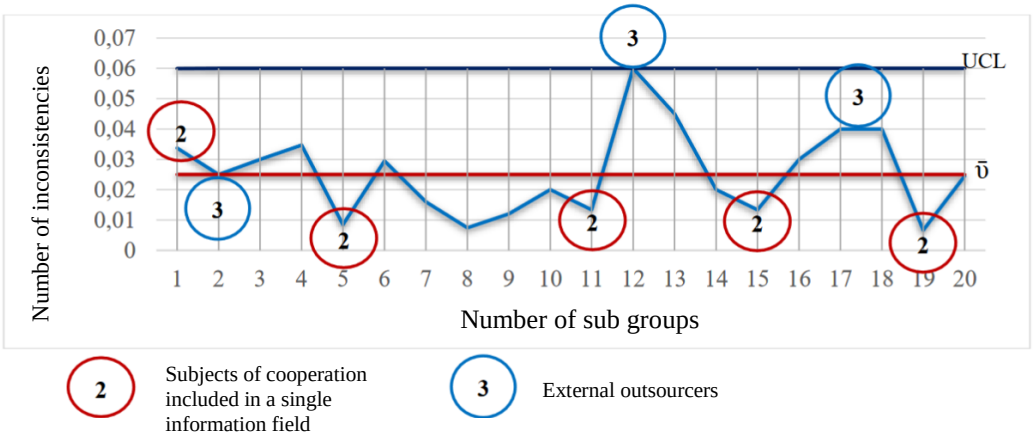

Figure 2. Defect control chart per measurement unit

Experiments with a model and methods for assessing objects and processes of leather and footwear production enterprises has shown that the successful functioning of a quality management system in conditions of multidimensional production cooperation depends on the standardization and unification of their indicators.

Based on the theory of technical system reliability the probability of defect-free products can be described by the mathematical relationship:

$$K_{system} = (1 - k_1) \cdot (1 - k_2) \cdot \ldots \cdot (1 - k_n) \quad (2)$$

where:

– K_{system} – share of quality criteria mastered during production that define the final product value;

– k_1, k_2 … k_n – shares of potential quality indicators present in the elements, but not realized in the final product - «lost qualities».

The «lost qualities» of the K_{system} combining its individual elements can be described by the dependence:

$$k_{system} = 1 - (1 - k_1) \cdot (1 - k_2) \cdot \ldots \cdot (1 - k_n) \quad (3)$$

Statistical assessment of the defect level of leather and footwear products based on this approach during the research made it possible to record the average statistical accuracy of the functional parameters of the production process in the main domestic leather and footwear industries (Table 3) (Kerimov et al., 2022).

Average statistical data on the failure structure of locally produced footwear identified by instrumental control methods is presented in Table 4.

Table 3. Functional parameters accuracy of the production process

№	Defect classification	%
1	Critical	till 5
2	Significant	15-20
3	Minor	60-80

Table 4. Footwear failure structure

№		Failure type, %		% to total
	Failure type	Manufacturing	Operational	
1	Shoe upper failure	20,7	34	27,5
1.1	Material failure	7,2	16	11,6
1.2	Fastener failure	13,5	18	15,75
2	Inner part failure	19,4	37	28,2
2.1	Lining failure	14,3	30	22,15
2.2	Reinforcing parts (backing) failure	5,1	7	6,05
3	Shoe bottom failure	29,6	9	19,3
3.1	Shoe sole failure	18,6	2	10,3
3.2	Indole failure	11	7	9
4	Findings failure	30,3	20	25,15

The set of acceptable solutions *(Pд)* in the quality management system is represented by options for organizing technological processes that allow choosing the optimal solution for manufacturing shoes with the required properties (Ok):

$$P_{opt} \in \sum P_{д}, \text{а } P_{д} \subset \sum P_{в} \quad (4)$$

where:

– ∈– adhesion sign;

– ⊂– concatenation sign.

A formalized model for reflecting the technological process in the system for assessing indicators and quality monitoring will be the following:

$$P_{opt} \in \sum P_{д} \subset \sum P_{в} \quad (5)$$

Practice shows that one of the main conditions for improving the quality of footwear products is the correct implementation of the technological process in the manufacture of shoe upper groups, performing operations during their assembly from various basic and auxiliary materials. The choice of component materials is carried out based on the analysis of the material quality indicators, the method of fastening them into a shoe upper, cost, consumption rate per unit of product, manufacturability, and compliance with aesthetic requirements.

Optimization of the solution in the performance evaluation system makes it possible to eliminate defects in the finished product using prefabrication techniques including defect visualization tools based on a set of requirements for parts and materials.

We developed the prefabrication technique as a toolkit for the architecture of the system for optimizing decisions to improve quality. «Matrixes for quality indicators comparison» were compiled according to the requirements of regulatory and technical documentation and the results of laboratory tests (Tables 5, 6).

Table 5. The matrix piece for comparing quality indicators of shoe bottoms

Indicator	Measurement unit	Materials		
		Bayflex 50S	Sorane 4500C	Extra E56102
		Indicator values		
Density	103 g/m3	0,6	0,50	0,55
Hardness	Conditional unit	63	58	61
Tensile strength	MPa	6,0	3,5	–
Elongation at break	%	420	320	–
Wearability	mm3	150	88	100

Table 6. The matrix piece for comparing quality indicators of shoe uppers

Material type, National State Standard	Average area, dm2	Type	Percentage of use %	Price 1 dm2/ rub.	Net area of the kit, dm2	Application rate per pair, dm2	Cost of the kit, dm
Nubuck 1.2-1.4	172	2,3,4,5	65%	21	19,19	32,8	678
Leather Soft N 1.2-1.4	167	1,2,3,4	67%	27	19,19	31,28	845
Grain leather 1.0-1.2	200	3,4	60%	10	4.62	6,6	66

To calculate single quality indicators the levels of single indicators are calculated by formulas:

$$yi = Pi\text{est} / Pi\text{ base}; \quad (6)$$

$$yi = Pi\text{base} / Pi\text{ est}, \quad (7)$$

where:

-yi– level of individual product quality indicators, when i = 1, 2, 3…n;

- n – number of relevant indicators adopted to estimate quality;

-Pi est – the value of the i - single indicator of the estimated object;

-Pi base – the value of the i - single indicator of the base object.

In the first case, formula (6) is used to calculate the relative values of single positive quality indicators, and in the second case (7) - for negative quality indicators. The number of such properties is limited, which facilitates the process of assessing the quality level of compared objects (Klochkov, 2018).

At the stage of introducing the methodology, the result was a reduction in materials failure for the planned period from 70,4% to 43,6 % (Table 7).

Table 7. Results of product quality control during the planned period

Model	The number of planned pairs	Number of pairs marked as production defect	Number of pairs marked as material defect	Number of pairs of the 1st grade	Number of discrepancies
1	2	3	4	5	6
80710	445	22	15	423	37
80720	200	10	5	190	15
80730	600	28	18	572	46
81230	490	19	17	471	36
81231	235	7	2	228	9
81240	305	10	9	295	19
82001	250	3	4	247	7
82006	135	2	1	133	3
82010	250	5	3	245	8
82011	100	1	2	99	3
81216	300	9	4	291	13
83150	500	21	15	479	36
83400	400	16	18	384	34
83401	100	1	2	99	3
83405	150	3	2	147	5
83406	150	4	1	146	5
83840	490	7	12	483	19
TOTAL	5100	168	130	4932	298

4. RESULTS AND DISCUSSION

Experiments with the system-situational model has shown that it generally allows taking preventive and corrective actions to eliminate the causes of discrepancies in the quality of objects and processes of leather and footwear production in the conditions of an expanding competitive range of products. The proposed model is distinguished by the fact that it allows coordinating the interaction of subjects of a multidimensional organizational structure of industrial cooperation for continuous quality improvement by the method of sequential dynamic assessment of objects and the effectiveness of leather and footwear production processes of an expanding competitive range of products.

On the one hand the analysis of decisions in quality management shows that the problems of applying qualimetric methods of quality assessment according to the presented model, as well as methods of standardization and certification (formalized description of existing activities by a certain technology) have been sufficiently developed (Klochkova et al., 2018; Subetto, 2002).

On another hand a serious problem remains the gap between the prevalence of commercial and technological information on specific areas of production (product samples) over scientific and methodological information (structured design of future activities using formalized technology) (Parfenova et al., 2021).

The method of consistent dynamic quality assessment allows managing quality of objects and production processes based on the formation and maintenance of a holistic, contextual information environment common to all subjects of cooperation. In this case the contextual type is a set of methods and techniques of production activity. Accordingly, the development of a system of indicators and methods for assessment and quality control is carried out to fill this environment with content.

Testing and practical implementation of a set of scientific, technical and documented solutions based on improving the model and methods of quality management of an expanding competitive range of leather and footwear products made it possible to reduce the production time of a product item by more than 1 month.

At the stage of implementing the prefabrication technique the result was a reduction in material defects for the planned period by 1,6 times: 43,6 % of the total number of discrepancies with the average statistical indicator for similar planned periods before the technique implementation is 70,4%.

The total economic effect is 2 204 326 rubles (in 2021 prices).

Further development of the research may be associated with the development of models and software solutions for automating quality management and control of a competitive range of products with additional consumer needs.

5. CONCLUSION

The competitiveness of leather and footwear manufacturers is directly related to the quality management of objects and processes, the dynamics of updating the expanding competitive range of products, which in turn creates the consumer assessment of its quality. The quality of objects and processes depends on what factors and the way they simultaneously and collectively appear in the real sector of the economy, including the leather and footwear industry in general and in the multidimensional organizational structure of industrial cooperation in particular.

A multidimensional production cooperation is characterized by the transfer of the process (outsource) as a result of which its subjects perform a part of the function or process in the network type of organizing leather and footwear production of an expanding competitive range of products.

To ensure consistency of regulatory requirements in the multidimensional organizational structure of industrial cooperation the unified scientific and practical approaches, the construction of models, the development of methods, procedures and algorithms, methods of management and quality control of objects and processes of leather and footwear production are required.

Improving the quality management system is aimed at improving the enterprise's performance and providing a solid basis for initiatives of business entities focused on sustainable development. Systemic, process, situational approaches, risk-oriented mind allow enterprises to identify factors that can lead to failure to achieve planned results, prevent non-compliance with quality requirements, minimize their negative consequences and make the most of existing opportunities.

In relation to the quality system the subjects of multidimensional production cooperation represent various levels of management, which have the functions of organizing, coordinating and monitoring work and services. The functions of forecasting and planning activities for managing the production quality of an expanding competitive range of products precede the implementation of all basic management processes.

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