Scientific article DOI:10.18287/2223-9537-2023-13-2-274-281

Improvement of the quality management system of industrial enterprises based on the use of corporate knowledge

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Abstract

This article analyzes the procedures for improving quality management using the example of solving problems of compliance with product quality requirements at industrial enterprises. The quality of the products largely depends on the use of modern methods and tools of quality management, as well as on improving the competence of personnel in the field of quality systems. In this regard, it is proposed to apply the corporate knowledge of the enterprise, including models and algorithms of artificial intelligence. Corporate knowledge is formed on the basis of the formation and processing of documentation, interviewing qualified specialists and intellectual data analysis on the implementation of business processes. During the research, an ontology of quality management was developed, decision-making rules were created and the results of improving the quality management system using a neuro-fuzzy network were predicted. The use of these artificial intelligence tools will make it possible to form a unified terminology to ensure an unambiguous perception of information by all participants in the process and the use of a knowledge base to support decision-making. It is proposed to use quality management tools to improve the efficiency of decisions made by intelligent tools, i.e. production rules and neural networks.

Key words: *decision support system, quality management, ontology, fuzzy inference system, neuro-fuzzy modeling.*

For citation: *Chernyakhovskaya LR, Mukhametyanova RI, Sirotina AA.* Improvement of the quality management system of industrial enterprises based on the use of corporate knowledge. *Ontology of designing.* 2023; 13(2): 274-281. DOI:10.18287/2223-9537-2023-13-2-274-281.

Financial Support: This work was supported by grant from the Russian Foundation for Basic Research No. 19-08-00937 «Methods and models of intellectual support for decision-making in the management of software projects implemented in the environment of industrial enterprises».

Conflict of interest*:* The authors declare no conflict of interest.

Introduction

The procedures for managing quality assurance and improvement processes are part of the management system for the entire organization and are determined by the requirements of ISO international standards: the 9000 series in the field of quality management [1] and risk analysis [2], as well as the recommendations of the ISO 14000 series of standards, focused on improving the environmental performance of the enterprise [3]. The directions of the organization's development are determined by the policy in the field of occupational safety and health management, quality management, and HR (Human Resources) management. According to the general theory of systems, the elements of the quality management system, HR management system, occupational safety, and health management should interact with each other in order to achieve the goals of the organization [4].

The quality management problems sometimes turn out to be so complex that the problem of decision-making exceeds the psychophysiological capabilities of a person, and a need for intellectual support for decision-making arises [5]. It is also relevant to create a single informational space for exchanging views and experience between various actors - specialists in different subject areas involved in the management process. As a result of the work, collaboration with key departments of

the enterprise will obtained, the correct organization of which has the most significant impact on the quality of the finished product.

1 Ontological analysis of the quality management system

The main goal of intelligent decision support is to improve the quality of decisions made through closer cooperation and knowledge exchange between managers of interacting business processes based on ontology. The use of decision support systems (DSS) increases the efficiency of decision-making, improves their quality through analytical methods for the formation and selection of alternatives and the use of formalized expert knowledge, as well as significantly reduces the risk of making erroneous decisions.

Ontology is the knowledge formally presented on the basis of conceptualization, under which a description of a set of objects and concepts, knowledge, and connections between them is assumed [6]. An important function of the ontology is also to increase the efficiency of information retrieval of relevant decisions in quality management systems on the example of the enterprise Timber LLC.

The structure of the ontology consists of the axioms of the hierarchy of classes (a set of T-axioms), axioms describing the relations of association, axioms imposed on properties (a set of A-axioms), Axioms of a conceptual scheme (a set of T-axioms), show descriptions of class taxonomies, generalization relations, representative examples of classes. Axioms explaining specific situations of the subject area and rules characterizing causal relations (a set of A-axioms), reproduce the rules formulated in ontology defining.

The ontology was developed using the Protégé editor and the Ontology Web Language (OWL). The ontology shows such subsystems of enterprise activity as organizational management, quality management, decision support, as well as methods and tools for product quality control.

One of the possible areas of ontology application is information search with using the following types of queries: implementation of queries for information retrieval in OWL based on the logical ontology model and implementation of queries in the SPARQL query language. Ontology creates a single information space in order to manage quality, the parties exchanging knowledge could currently understand each other. For a detailed look at the production system made use the ontological analysis, which formalizes the field of knowledge and the relationship between concepts. This allows to have a common understanding of the structure and provides the ability to reuse knowledge in the subject area. The main advantage of using ontologies in organizational management is a holistic approach to managed processes. At the same time, the following are achieved: consistency (ontology represents a holistic view of the subject area), uniformity (material presented in a single form is much better perceived), complexity (ontology construction allows you to restore the missing logical connections).

Decision support in strategic enterprise management based on knowledge engineering [7]. The results of ontological analysis are supposed to be used to describe problem situations containing signs of deviation from the required quality, find the best solutions for improving quality, and select corrective measures in order to reduce risk.

2 Neuro-fuzzy modeling

In improving quality management processes, it is necessary to take into account the uncertainty of the quality assessment, manifested in the deviation of the quality of the product from the specified parameters. The causes of general deviations are: moral wear, physical and moral aging of products (that is, the loss of the original properties of products during its operation and storage) [8].

For forecasting, an adaptive neuro-fuzzy network Adaptive Neuro-Fuzzy Inference System (ANFIS) is synthesized, which implements a forecasting method using experimental data. The fuzzy inference system is developed using the MATLAB software system.

The experimental study consisted in collecting, evaluating and analyzing the main factors of the internal environment during 2019, 2020 and 2021, which characterize the process of organizational management of a manufacturing enterprise. The factors characterizing the processes of quality management, risk management and personnel management are presented in figure 1, shows that, unlike the values of quality management and personnel management factors, the values of risk management factors decrease every year due to the identification of dangerous and harmful production factors and the corresponding risks associated with production processes. The scale was brought to the form 0-1, each value in this range, where 0 is a low value and 1 is a high value. The less risk management, the better, and the higher the quality indicator, the better. The data can be obtained by expert means, the expert obtains the knowledge of a certain value by evaluating the indicator.

The problem of assessing the generalized quality indicator of the manufactured sawn timber is solved using a fuzzy inference system (FIS) based on the Takagi-Sugeno-Kang fuzzy inference algorithm [9].

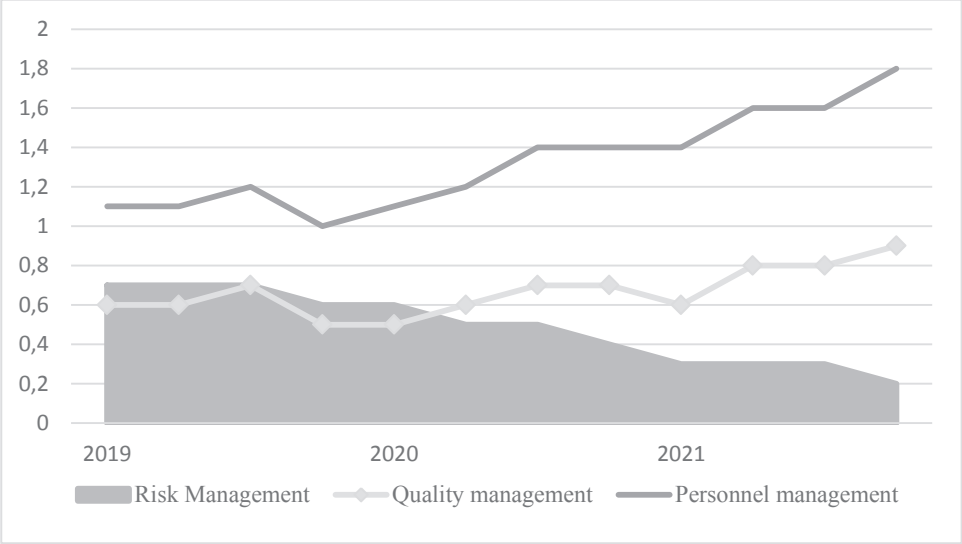


Figure 1 – Changes in the values of factors affecting quality management

The proposed assessment of the effectiveness of the functioning of the quality management system belongs to the class of forecasting problems, which are solved using methods of neuro-fuzzy modeling.

At the initial stage of creating a FIS, an analysis and selection of factors that have the greatest impact on the quality indicator of finished lumber were carried out. The choice of the most influential factors was carried out on the basis of the method of expert assessments [10, 11]. The FIS for assessing the generalized quality indicator of the manufactured sawn timber was proposed to be considered as a two-level hierarchical system, the lower level of which is represented by three fuzzy inference subsystems that solve the problems of HR management, quality management and occupational safety and health management, ecology, industrial and fire safety. The upper level of the created FIS directly solves the problem of assessing the generalized indicator of the quality of sawn timber based on the output data of the lower level subsystems, including quality indicators: X_1 – customer satisfaction in terms of quality indicators; X_2 – assessment of incoming raw materials; X_3 – the specific weight of rejected products; X_4 – the state of industrial injuries and occupational diseases; X_5 – financing of activities to improve labor conditions and safety; X_6 – delivery time management,

X_7 – professional level of the enterprise HR; X_8 – motivation, and remuneration; X_9 – the degree of information support for work with people.

At the top level of the hierarchical fuzzy inference system, three factors are presented to assess the effectiveness of the functioning of the quality management system: Quality Management (QM), Risk Management (RM), Personnel Management (PM); the output variable is Effectiveness (Effect).

On the basis of expert knowledge within the framework of the proposed hierarchical model of FIS, a base of fuzzy production rules in the form of conditional statements of the "IF-THEN" type, representing a fuzzy implication, was developed [12]:

$$\text{IF PM } is\ A_{i1} \text{AND QM } is\ A_{i2} \text{ AND RM } is\ A_{i3} \text{THEN Effect } is\ B_i,$$

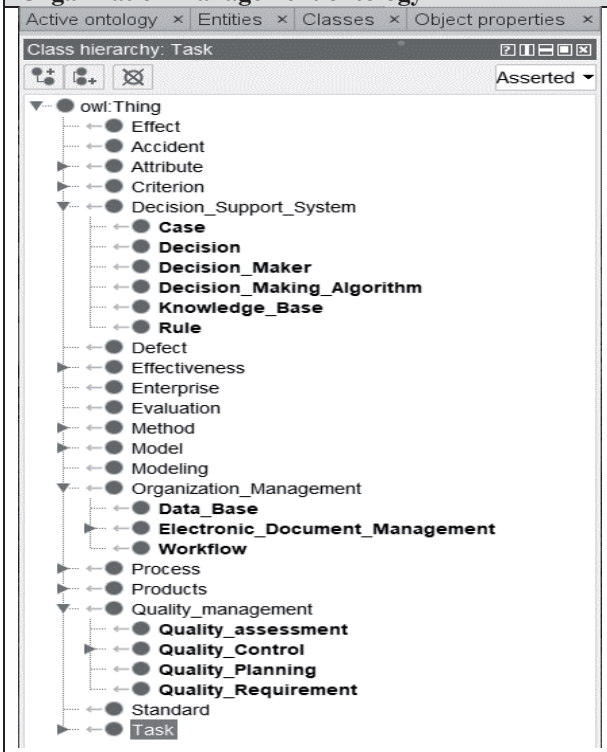
where A_{ij}, B_i are linguistic values identified using a fuzzy method through the corresponding membership functions $\mu A(x_i)$ и $\mu B(y)$ for variables.

Examples of rules for FIS can be presented in the table 1.

When developing point scales, the gradation of the scale is determined depending on the nature of the task, the quality of experts, the necessary accuracy of the results and the possibility of a verbal description of the characteristics of quality levels. The example shows the above scale with four quality levels. A group of experts was involved in the work, among the employees of the enterprise, which is involved in the organizational management of technological processes. Four qualitative values were used on the scale: low, medium, high and very high.

In Table 1, on the left, seens the ontology of organizational management, where in the decision support system class there is a subclass of the rule, and on the right side, the rules themselves are shown contained there.

Table 1 – Examples of rules for FIS

Organization management ontology	**Rules**
	If (PM is low) and (QM is low) and (RM is high) then Effect is low
	If (PM is middle) and (QM is middle) and (RM middle) then Effect is middle
	If (PM is high) and (QM is middle) and (RM is high) then Effect is high
	If (PM is very high) and (QM is high) and (RM is low) then Effect is high
	If (PM is middle) and (QM is high) and (RM is low) then Effect is high
	(PM is low) and (QM is middle) and (RM is high) then Effect is low
	(PM is low) and (QM is low) and (RM is high) then Effect is middle
	(PM is middle) and (QM is middle) and (RM middle) then Effect is middle

A model describing the impact of concepts on work efficiency enterprises was built through peer review. Values and the mutual influence of factors was assessed on an ordered scale with four linguistic meanings - from the value (influence) "very high" to the value (influence) "low ". The indicators are evaluated on a 100-point scale, and if a group of experts evaluates the level of the indicator

from 0 to 24, then the indicator is classified as a low value, if from 25 to 49, then the indicator is classified as an average value, if from 50 to 74, then as a high value and very high knowledge in the case of an indicator value of more than 75.

A FIS is a process of obtaining fuzzy conclusions about the required quality management based on fuzzy conditions or prerequisites, which present as information about the current state of the object [13]. The process of fuzzy inference itself is an algorithm for obtaining fuzzy conclusions based on fuzzy premises using the basic operations of fuzzy logic.

3 Results

Fuzzy neural set allows you to determine the quality using the theory of fuzzy sets. At the same time, neural networks are being trained.

Thus, as a result of the study, a model was proposed for the interaction of departments that have the greatest influence on the process of high-quality lumber production, implemented within the framework of a systematic approach and based on the use of triads. Within the framework of the considered task, the problem of predicting the effectiveness of the lumber production process in the aspect of the interconnected management «Personnel Management (PM)» - «Quality Management (QM)» - «Risk Management (RM)» is investigated. Figure 2 shows interaction PM and RM.

The prediction method was implemented using an ANFIS based on previous data.

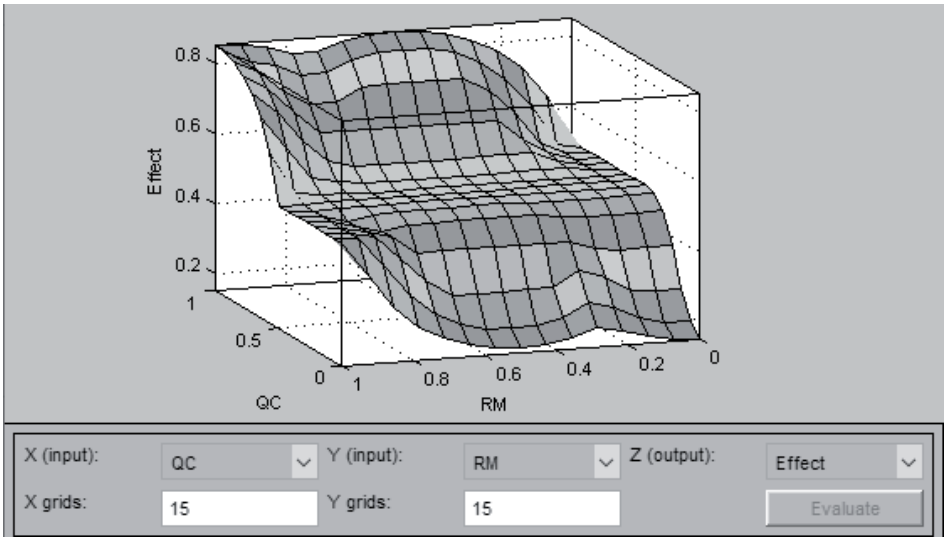


Figure 2 – Visualization of the fuzzy inference surface of the model under consideration for the PM and RM

And as a result of data analysis, there is rule-based forecasting, which indicates that risk reduction measures in production are closely related to the enterprise personnel and the overall effect of the enterprise, expressed in product development, gives a high value. Among the factors influencing the quality of products, there may be the following personnel management factors: professional selection of employees of certain professions, the degree of information and technical support for employees, the degree of team cohesion and the absence of internal conflicts, the style of work of enterprise managers with personnel, employee satisfaction with the existing system of corporate organization. In turn, this entails changes in product quality through customer satisfaction in terms of quality indicators and delivery times, assessment of incoming raw materials and materials, turnover of working capital, the proportion of defective products and profitability of sales.

As a result of the of the data analysis, forecasts of the rules for the effectiveness of quality improvement were made based on possible changes in risk management and personnel management.

Conclusion

In the context of the need to use modern quality management tools, new tools are offered. Thus, in the course of the research, an ontology of quality management was developed, decision-making rules were created and the forecasting of the results of improving the quality management system using was carried out. The use of these artificial intelligence tools will allow the use of a common terminology by all participants in the process to ensure unambiguous perception of information; apply precedents of problem situations to develop decision-making rules; create a knowledge base in the DSS. The use of such models and methods of artificial intelligence as ontological analysis and neuro-fuzzy modeling allows employees of the enterprise to carry out activities to improve product quality indicators using intelligent decision support. Recommendations should be concentrated in the analysis of several methods belonging to business processes to identify strengths on the example of production enterprises.

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Received September 8, 2022. Revised February 22, 2023. Accepted April 3, 2023.

УДК 004.8 *Научная статья* DOI:10.18287/2223-9537-2023-13-2-274-281

Улучшение системы менеджмента качества промышленных предприятий на основе использования корпоративных знаний

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Аннотация

Анализируются процедуры совершенствования управления качеством на примере решения проблем соблюдения требований к качеству продукции на промышленных предприятиях. Качество выпускаемой продукции во многом зависит от использования современных методов и инструментов управления качеством, а также повышения компетентности персонала в области систем качества. Предлагается применять корпоративные знания предприятия, в том числе модели и алгоритмы искусственного интеллекта. Корпоративные знания формируются на основе формирования и обработки документации, опроса квалифицированных специалистов и интеллектуального анализа данных о реализации бизнес-процессов. Разработана онтология управления качеством, созданы правила принятия решений и спрогнозированы результаты совершенствования системы управления качеством с использованием нейро-нечёткой сети. Использование этих инструментов искусственного интеллекта позволит сформировать единую терминологию для обеспечения однозначного восприятия информации всеми участниками процесса и использования базы знаний для поддержки принятия решений. Предлагается использование инструментов управления качеством для повышения эффективности принимаемых решений – продукционных правил и нейронных сетей.

Ключевые слова: *поддержка принятия решений, управление качеством, онтология, система нечёткого вывода, нейро-нечёткое моделирование.*

Цитирование: *Черняховская Л.Р., Мухаметьянова Р.И., Сиротина А.А.* Улучшение системы менеджмента качества промышленных предприятий с помощью использования корпоративных знаний // *Онтология проектирования*. 2023. Т.13, №2(48). С.274-281. DOI:10.18287/2223-9537-2023-13-8-274-281.

Финансирование: работа выполнена при поддержке гранта РФФИ № 19-08-00937 «Методы и модели интеллектуальной поддержки принятия решений в управлении программными проектами, реализуемыми в среде промышленных предприятий».

Конфликт интересов: авторы заявляют об отсутствии конфликта интересов.

Рисунки и таблицы

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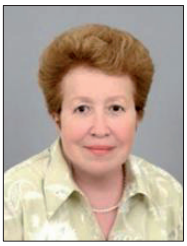
Сведения об авторах



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Поступила в редакцию 08.09.2022, после рецензирования 22.02.2023. Принята к публикации 3.04.2023.