Automation of quality management systems of agro-industrial enterprises

Galina Korableva 1, Elena Kucherova 1

1 Moscow state University of technology and management. K. G. Razumovsky (Smolensk branch), 77, Lenin str., 215100, Smolensk region, Vyazma, Russia

E-mail: gkorableva2008@yandex.ru

Abstract. The publication discusses Russian and foreign software products that automate various business processes of enterprises, including those related to quality management. The analysis is carried out and a description of the problems of the development and implementation of automated quality management systems at the Russian enterprises is presented. Theoretical principles of the methodology are formulated, the use of which will allow developing automated quality management systems both at the level of industry solutions and local solutions for individual enterprises.

1. Introduction

In the Messages of the President of the Russian Federation V.V. Putin to the Federal Assembly and in other documents, it was repeatedly emphasized that commodity producers of the Russian country have the opportunity to produce and market competitive products on the world market, which include agricultural products, products manufactured by defense and the industrial complex, the state atomic energy corporation “Rosatom”, and a number of others. Competitive products are usually high-quality products that meet Russian and international standards, technical regulations of the Customs Union and the European Union.

In addition, the Technical Regulation of the Customs Union TR TS 021/2011 “On Food Safety” and the ISO 22000:2005 standard used in many countries of the world, as well as the similar Russian standard GOST R ISO 22000-2007 “Food Safety Management Systems. Requirements for organizations participating in the food production chain” [1] formulate requirements for food products and the processes of production, storage, transportation, sale and disposal associated with it. Therefore, it is advisable for Russian producers, especially the food and processing industries, to develop and certify quality management systems at their enterprises, and to create HACCP systems at food industry enterprises [5].

All processes in quality management and HACCP systems are supported by documents created and analyzed at different stages of their functioning. The information contained in the arrays of documents is systematized and analyzed in a short time for the development and adoption of managerial decisions.

In this case, to create mathematical evidence-based management decisions it is advisable to use special tools, such as process models or data flow diagrams (DFD) [3], mathematical methods of analysis and forecasting, based on mathematical trend models, the method of correlation and
regression data analysis, models for assessing and minimizing risks; models for optimizing the investment process in quality management.

The current level of development of computer technology and software leaves no doubt that it is advisable to automate intensive and information-intensive processes related to quality management process.

2. Materials and Methods
The technical documentation describing the functions of the modules of typical automated information systems of Russian and foreign developers is considered as research materials. Automated information systems of the ERP class were considered. In addition, it was carried out an analysis of the forms of documents accompanying the processes of control and quality management at individual enterprises in various industries of the Russian Federation, as well as of methods for insertion and their processing.

Methods of analysis, synthesis, grouping, modeling, classification, system analysis were used as research methods. We used structural and object-oriented approaches to modeling and designing complex systems, the functional modeling method SADT, and data flow diagrams (DFD).

An analysis of the functions of the most common software products on the Russian market: “1C: Enterprise 8. Production Enterprise Management” (1C: ERP), “PARUS-Enterprise 8”, “Galaxy ERP”, “BEST-5” showed that typical software solutions of the reviewed automated information systems do not have a module for managing the quality of products/services. Only the Galaxy ERP-system has a special “Quality Management” solution in addition to such functional modules as “Accounting and Tax Accounting”, “Planning and Financial Management”, “Logistics”, “Planning and Production Management”, and “Personnel Management”, “Administration”.

At large enterprises in the aviation industry, the automotive industry, the military-industrial complex, the state atomic energy corporation “Rosatom”, PJSC NC “Rosneft” and some other industries, non-standard automated solutions for custom-designed or custom-built quality management systems are used. In practice, automated quality management systems are wide-spread among enterprises with stringent requirements for the quality and safety of products.

On the contrary, in the foreign software market, automated quality management systems or similar modules as part of ERP class systems are represented quite widely. Examples of automated quality management systems include SAP ERP, Master Control Quality Management Software System, EiQ Quality Management Software, Intelex Quality Management System, Novatek International Quality Management System, NICE Quality Management, IBS QSI System Software, Clarmon Quality Management System.

In the framework of the study, information support and control of quality control systems for manufactured products/services of enterprises of the Russian Federation of various industries were considered, including LLC “Ochistnye systemy” (Vyazma, Smolensk Region), OJSC KSK “Rzhevsky” (Rzhev, Tver region), LLC “Kerch Building Materials Plant” (Republic of Crimea, Kerch), OJSC “Vyazemsky khlebokombinat” (Vyazma, Smolensk region), CJSC “Technografit” (Vyazma, Smolensk region), OJSC “Avangard” (Safonovo, Smolensk region).

3. Results and discussions
Based on the analysis of the quality management systems of these enterprises and their information support, the problems that have a negative impact on the development of standard approaches to the design and implementation of such systems were identified:
1) lack of unification in the forms of documents used at various enterprises and organizations for registration of quality indicators of raw materials and finished products;
2) the complexity of the forms’ structure of primary documents used for recording quality indicators, and the need for their decomposition for implementation in the information and software of an automated information system;
3) the variability of the normative documentation that defines quality control, is determined by the presence of many constantly updated state and industry standards, international requirements, on
the basis of which the actual values of the quality indicators of raw materials and finished products are analyzed and monitored, the procedures for their evaluation is determined;

4) the problem of the multiplicity of indicators used to assess the quality of products and services, the presence of which complicates the assessment of quality, as well as the classification of products into high-quality and low-quality due to the need to use a multi-aspect classification system;

5) the need to attract experts and apply expert assessment methods to assess the quality of raw materials and finished products, to form managerial decisions on quality management issues, and to evaluate the effectiveness of corrective and preventive actions;

6) the absence of standard approaches for identifying and assessing risks in the production of products or the provision of services due to the peculiarities of technological, organizational and managerial processes of production, existing production equipment and other factors;

7) difficulties in identifying factors affecting the quality indicators of finished products or services, determining the relationships between them and assessing the degree of their influence on quality indicators due to the uniqueness of the list of factors determined by the type of product or service and the characteristics of the technological processes of their production, as well as by sources of collection of necessary statistics;

8) the difficulties of forming a list of corrective and preventive actions associated with the features of a particular production equipment or the human factor;

9) not always available resources (human, financial) necessary for the acquisition, development, and implementation of automated quality management systems and support for the HACCP system;

10) insufficient qualifications of the personnel of enterprises and organizations that monitor and control the quality of products and services.

To illustrate the above problems, we present the forms of documents used to register product quality indicators of enterprises in various industries. Figure 1 shows the form of the journal of the results of bacteriological indicators control of the drinking water quality, filled up according to the results of monitoring the quality of drinking water by the employees of the water intake laboratory at the LLC “Ochistnye systemy”.
| Date                | Date                  | Sampling time | Full name of a sampler | Exact address of sampling | Time of delivery and plating of water | Number of filtered water | The number of grown colonies in the ENDO environment | Study progress | Fermentation of lactose | Results in 1000 mm | result release date | Signature of a sampler |
|--------------------|-----------------------|---------------|------------------------|---------------------------|--------------------------------------|--------------------------|----------------------------------------------------|---------------|--------------------------|----------------------|----------------------|-----------------------|
| 04.11.2015         | 11                    | 8.00          | Alekseev A.V.          | Vyazma                    | 9.15                                 | 5                        | 7                                                  | study progress | 8                        | 12                   | 11                   | 2.3                   |
|                    |                       |               |                        |                           |                                      |                          | oxidad test                                        |               | Gregersen-test            | 37 ºС, 44 ºС       | 37 ºС, 44 ºС         | 7.8                   |
|                    |                       |               |                        |                           |                                      |                          | thermotolerant coliform bacteria                  |               |                          |                      |                      | 7.8                   |
| 18.11.2015         | 11                    | 9.15          |                        |                           |                                      |                          | 8                                                  | result release date | 7.8                      |                      | AviA                 |

**Figure 1.** Form of the journal of the results of bacteriological indicators control of the drinking water quality.

Figure 2 shows the form of the register of finished product quality indicators at OJSC “Vyazemsky khlebokombinat”.

The presented forms of documents illustrate the problem of the lack of unification in the documentation for recording the results of quality control of raw materials and finished products, especially among enterprises of various industries. In addition, in the journal presented in Figure 2, one can notice a lot of unmeasured quality indicators, such as “Form”, “crust surface”, “Flavor”, “Smell”, the values of which can be estimated by experts, and for further analysis it is necessary to use multiset theory and methods of group classification of multi-attribute objects [4].

Analysis of existing solutions in the field of automation of quality management systems and the problems of development, of implementation of such systems made it possible to formulate the theoretical principles of their design.

To create a methodological basis for the design of automated quality management systems and a theoretical justification for creating possible applied solutions in this area, a methodology for the design of automated quality management systems has been developed. The developed methodology allows integrating certain basic principles of methodologies of structural and object-oriented approaches to software development [3].
| S No. | Full name of a master | Date of baking or analysis | Item description | Weight of one piece, kg, or number of pieces | Analysis data | Technical features |
|-------|-----------------------|---------------------------|-------------------|---------------------------------------------|----------------|-------------------|
|       |                       |                           |                   |                                             | Moisture content, % | Acidity or alkalinity, ОН |
|       |                       |                           |                   |                                             | 56              | 45               |
|       |                       |                           |                   |                                             | 26              | 2.6              |
|       |                       |                           |                   |                                             | 3.4             | Round            |
|       |                       |                           |                   |                                             |                 | Smooth           |
|       |                       |                           |                   |                                             |                 | Darkly brown     |
|       |                       |                           |                   |                                             |                 | Flavor           |
|       |                       |                           |                   |                                             |                 | Smell            |
|       |                       |                           |                   |                                             |                 |                  |

Figure 2. Form of the register of bakery product quality.

4. Discussions and conclusions
Let us consider the basic principles of the developed methodology for the design of automated quality management systems. The principle of functional decomposition corresponds to the similar principle of a structural approach, which means the feasibility of decomposing the designed automated quality management system into modules that implement functions complied with the procedures that are specified in GOST R ISO 9001-2008 and performed by the organization to create, maintain and develop a quality management system.

The principle of consistency corresponds to the similar principle of the structural approach, and lies in the validity of the set of modules that make up the automated quality management system of a particular organization, and their consistency in the performance of tasks of quality control and management.

The principle of end-user access means the obligation to develop such an interface of an automated system that would allow the user to access a database that stores statistical data on the results of quality control of raw materials and finished products.

The encapsulation principle corresponds to the similar principle of the object-oriented methodology of designing automated information systems, which means hiding data and methods within the production and quality control processes that belong to the class “Processes (production and management).

The principle of data structuring using the relational data model is almost completely similar to the corresponding principle of the structural approach methodology. The data in automated quality management systems should be structured and systematized in the form of relational databases. Primary documents (mainly journal forms), which are easily converted into relational tables when designing a database of an automated system, contribute to it.

The principle of processes visualization assumes the presence of a CASE-tool in the automated quality management system that allows analyzing processes in the organization, based on the construction of multi-level diagrams of data flows. An example of a diagram of data flows of the third level, indicating the processes of control of raw materials and recording indicators in the database of an automated quality management system, is presented in Figure 3.
Figure 3. Diagram of data flows of OJSC “Vyazemsky khlebokombinat”, indicating the registration processes of quality indicators of raw materials, finished products and process parameters.

The principle of feedback (interaction with consumers) means the mandatory presence of an automated quality management system in the composition of the modules that allows conducting surveys of consumers of products or services, which fully corresponds to the model of a quality management system based on a process approach [2].

The principle of process identification requires for each production process or quality management process to have a name, to be a member in a process group defined by the GOST R ISO 9001-2008 standard. It also requires a multitude of input parameters and resulting indicators, the values of which are monitored and analyzed by the quality management system.

The principle of process control states that processes are the main objects of management in quality control systems. The standard GOST R ISO 9001-2008 is aimed at the application of the “process approach” [2].

The principle of controlling with the implementation of the 8D method implies the mandatory presence in the automated quality management system of an application or module that supports the collection, analysis of information and the formation of management decisions on the development of measures to improve the quality of products or services, or to prevent the production of low-quality products/services. When implementing software, it is advisable to focus on the Eight Disciplines Problem Solving (8D) method.

The principle of integration of electronic forms of documentation concerns the basic principles of forming a user interface in the design of automated quality control systems. As practice shows, two or more relational tables will be used to store the data of any product or service quality registration journal in the database, each of which will have its own form for entering/editing data.

The principle of adaptability of electronic forms of documentation confirms the desirability of finding a special software tool as part of an automated quality management system, which we will
arbitrarily call a designer. This tool allows creating database tables in the form of a paper document used at the enterprise or organization to register quality control of raw materials or finished products.

The principle of flexible configuration means providing the opportunity for users to select the necessary set of functional modules of an automated quality management system that support all processes or their part defined by GOST R ISO 9001-2008.

The principle of automated assessment allows us to justify the need for an application analyzing registered quality indicators of raw materials and finished products for compliance with quality standards in order to form a conclusion on the quality of products or services. Moreover, depending on the type of product and monitored indicators, this module can implement a formal procedure for analyzing numerical data for their compliance with reference values, or collect and process non-numerical data received from experts, transform them and analyze them in order to form a conclusion on quality.

The principle of group clustering determines the methodology for designing an automated assessment module in an automated quality management system. Group clustering methods and a multi-aspect system for classifying objects implemented in the software of an automated system will allow attributing specific samples or batches of products to a specific group.

Summarizing the experience of foreign developers of automated quality management systems and the material accumulated by the author made it possible to formulate the main methodological principles for developing such systems. The proposed methodology was tested in the design of automated quality management systems of OJSC “Vyazemsky khlebokombinat”, LLC “Ochistnye systemy”, OJSC KSK “Rzhevsky” and others.

The study also determined the typical structure of automated quality management systems, the main components of which are: a document management module that is necessary for recording quality indicators, an automated assessment module, an expert assessment module, a corrective and preventive action planning module, a static data analysis and risks’ evaluation module, customer feedback module, CASE-tool for visualization and analysis of processes.

Russian President V.V. Putin in his Message to the Federal Assembly on February 20, 2019 noted: “In order to reach high growth rates, we also need to solve systemic problems in the economy. I will single out four priorities. The first is the outstripping growth rate of labor productivity, primarily on the basis of new technologies and digitalization, the development of competitive industries and, as a result, an increase in non-resource exports by more than one and a half times in six years.” Automated quality management systems are a necessary tool for solving the task set by the President.

References
[1] Russian Federation Standard GOST R ISO 22000-2007
[2] Russian Federation Standard GOST R ISO 9001-2008
[3] Kalyanov G 2002 CASE-technology. Consulting in the automation of business processes (Moscow) p 320
[4] Petrovsky A 2012 Applied Mathematics, Management and Computer Science Belgorod pp 53-68
[5] HACCP http://www.kpms.ru/Standart/HACCP.htm#PR
[6] Kovalenko K, Bakhvalov S, Zekiy A, Vikulina V, Tinkov S, Tkacheva T 2019 Journal of Entrepreneurship Education 22 3 pp 1-7
[7] Lukmanova I, Golov R 2018 E3S Web of Conferences 33 02047 https://doi.org/10.1051/e3sconf/20183302047
[8] Nezhnikova E, Santos S, Egorycheva E AISC 983 DOI: 10.1007/978-3-030-19868-8_12