Method of quality assessment of design of complex objects in mechanical engineering

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Abstract. Methods for assessing the quality of the design processes of complex technical products are considered, taking into account the main quality indicators for a reasonable choice of the most acceptable option from among competing ones. Methods for assessing the impact of individual stages of product design are described, and methods are proposed for determining the accuracy included in the selected indicator.

Modern society is often called information, characterized, as noted in the works [1-6] by a number of new, previously not fully manifested signs. These include such as extremely high dynamism, the determining influence of information, which leads to the emergence of fundamentally new needs, the progressive development of the level of complex and complex relationships when creating new product samples.

In addition, at present, the work of any organization consists of a permanent solution of various production tasks for the development and creation of complex scientific and technical products.

Therefore, quite often the opinion is expressed that the modern crisis is a crisis of management and dictates the need to form a systematic understanding of the role and place of management in the creation and formation of opportunities to get out of it.

Modern products are characterized not only by complexity, but also a significant impact on society and the environment, the severity of the consequences of accidents due to errors in development and operation, high quality requirements and reduce the time of production of new products.

What led to the emergence of the crisis chain-"funnel" [1]: ... → reduction of management efficiency indicators → deterioration of the quality of performance → reduction of the organization's competitiveness → reduction of financial resources → reduction of susceptibility to innovation → even greater reduction of management efficiency indicators → ...

The way out of this situation seems to lie in the use of a systematic approach, the initial prerequisites of which are five principles. The main competence of management is effective orientation and behavior in difficult problem situations. Problems are a consequence of the inadequacy of management methods for the current state of the control object — the law of the necessary diversity [2]. The effectiveness of problem solving is ensured by the effectiveness (multidimensionality) of thinking and management, “keeping” the growing diversity. Efficiency or multidimensionality of thinking and management is achieved through the use of systems thinking underlying system management and fifthly, practical implementation is carried out using special technologies.
implemented in software products that are used in the environment of modern intellectual organizations. And fifth, practical implementation is carried out with the help of special technologies implemented in software products that are used in the environment of modern intellectual organizations. Compliance with these principles will provide a multidimensional systematic vision of problem situations; deep processing of existing resources, including rethinking of experience, old patterns; eliminate the insufficiency (unavailability) of standard solutions in the presence of system problems; ensure the search for new non-standard opportunities in solving problems and the choice of more viable solutions.

The implementation of these principles involves [3, 4] consistent implementation of the following steps: first, the formation of effective teams; second, the formation and development of team members practical design skills and effective orientation in complex problem situations; third, the management of team creativity in the process of solving problems in real time.

When creating such objects, they already need to be considered in the form of a system, that is, a set of interrelated internal elements with a certain structure, a wide range of properties and a variety of internal and external relations. Design should be based on a careful joint consideration of the design object and the design process, which in turn include a number of important parts (Figure 1).

![Figure 1. Block diagram of the main parts of the design.](image)

The result of the design can be the products of the organization (the results of scientific and marketing research, design and technological documentation for a new product, software, etc., developed on request) and the solution of internal production problems (improving product quality and improving the efficiency of labor organization, optimization of financial flows, etc.).

With regard to the development of design documentation [5-7], the project activity includes several stages. Management activities (project management), is achieved through the use of, inter alia, the principles and methods of project management, as part of the organization's management system. Carrying out scientific and technical developments, searching for new technical solutions, which are drawn up in the form of a set of documentation intended for the creation of the proposed facility, its operation, repair and liquidation, as well as for checking or reproducing the intermediate and final solutions on the basis of which it was developed, such scientific and technical activity is called design.

One of the aspects of improving the efficiency of the organization is the continuous improvement of quality. In Russia, as in many developing countries, this work is carried out inefficiently, which hinders the socio-economic development of the country and makes a serious discomfort in life, although these mechanisms have long been worked out. This is, first of all, the introduction of quality management standards [8-10], which reflect the "best practice" of the organization of activities in the producing systems and are the only generally recognized "code" of General management of the organization.

Design is characterized by practical orientation and personal responsibility for the results received and transferred to the customer.

Project production is a complex system of various processes of production (design and support), management, planning, support, etc.
For the purposes of quality management in design organizations, it is advisable to identify processes that affect the quality of products and rank them depending on the quality management system adopted in a particular organization.

The most effective approach to design management in modern conditions is a systematic approach, which in relation to project activities can be formulated in the form of the following principles:

• first, practical utility: the activity should be purposeful, aimed at meeting the actual needs of the real consumer or a certain social, age or other group of people, as well as to meet the actual goals of the enterprise; the activity should be appropriate. It is important to identify the obstacles to the use of existing facilities to meet new needs, to identify the key contradictions and to focus on their resolution; activities must be justified and effective. It is reasonable to use not any solution to the problem, but the search for the best option;

• secondly, the unity of the components: it is advisable to consider any object and process, whether it is complex or simple, as a system within which it is possible to distinguish logically related simpler parts — subsystems, the unity of the private properties of which forms qualitatively new properties of the system; the developed objects are intended for people, they are created and operated. Therefore, a person must also be considered as one of the interacting systems. This should take into account not only the physical interaction, but also the spiritual and aesthetic impact; external, or as it is called — the living environment, should also be considered as a system, interlinked with the projected object, and the design process - as part of the functioning of the organization;

• third, time variability: taking into account the stages of the object life cycle and the development process; taking into account the history, areas of science and technology, the achievements of which are based on the relevant developments, as well as the prospects for the development and application of the developed object.

Design processes as a complex of works on project support of all stages and stages of the "life cycle" of the object, the current legislation and relevant regulations.

This is caused, first of all, by the need to ensure the improvement of the properties and characteristics of the developed samples of new equipment in comparison with foreign and domestic counterparts while reducing the costs required for their mass production and operation. To achieve these goals, it is necessary to increase the degree of reasonableness of the adopted technical solutions, especially in the early design stages, when the cost of errors is high, to carry out thorough and comprehensive testing of all structural elements, which is feasible only on the basis of end-to-end automation of design and technological works.

So design is a purposeful activity with a certain structure for the consistent implementation of procedures based on the interaction of participants in the project process. The structure defines the control algorithm (plan) leading to the achievement of design goals, and is a model for managing the design process.

The structure of the project activity (Figure 2) shows the hierarchical management system, according to which the actions at the subsequent stages are set by the results of the previous stages.

![Figure 2. Structural scheme of project activities.](image-url)
The completion of the work at each stage serves as the main control points where the results are presented visually and in a relatively finished form. This makes it possible to give a reasoned opinion on further actions to implement the project. Due to the incompleteness of the initial knowledge about the object, the design process is iterative (Figure 2), which is reflected by the dotted arrows of reverse movements. On the other hand, feedback allows you to quickly assess the selected models and methods of decision and influence the effectiveness of management. At each design stage, the following procedures are performed: the choice of the model (that is, the fundamental principle, the type of flowchart and calculation scheme), the choice of the solution method, the decision and analysis of the results, evaluation and decision-making. The main stages of quality formation [8-10] are: planning; provision and control. Thus, the main design phases are (Figure 3): preliminary study of the necessity of creating a technical object (system).

Development of the concept of designing elements and products in general; geometric design; evaluation of the parameters of the created object. Analytical modeling and experimental research (this is the development of mathematical models, test methods and programs, the identification of analytical and experimental studies with operating conditions). Creation of a design automation system. Constant complication of structures, systems and complexes in the practice of designing systems and complexes leads to the clearly expressed following trends: on the one hand, complexity of the structure, increase in speed and performance, and on the other hand, requirements for reliability and efficiency in operation increase significantly. The presence of a set of tasks performed by a technical object, random and indeterminate parameters of individual elements in the actual design process, the multi-element systems and the significant influence of these factors, as well as external influences on the technical characteristics and appearance of the product being created lead to the need to take them into account in mathematical design models. In this connection, a whole line of research into universal or multi-purpose systems, the development of mathematical models and methods for solving optimization problems has arisen.
Currently, much attention is paid to the quality assessment of complex technical devices. This is due to the fact that new, technically and technologically more advanced devices appear on the market. Therefore, in the tasks of choosing and implementing modern technical equipment for special purposes, the need arises for an objective and reliable assessment of their characteristics, which is of particular relevance when equipping design organizations with advanced technologies.

The quality management system is a management concept that focuses the overall management of an organization on the primacy of quality as the highest strategic goal. With this understanding, ensuring the quality of products and services becomes not only the task of the main production services, but also affects the organization of activities in all functional areas of management, its provision and maintenance. The modern concept of organizing activities in business, the integral expression of which is the standard [6], considers quality as the main factor in business competitiveness, emphasizes the direct link between product quality and quality of an organization, activity in general.

Considering that one of the fundamental principles of quality management [8] is making decisions based on facts, it is necessary to organize a search for facts that characterize inconsistencies, in most cases they are statistical data, which requires the development of methods for analyzing and processing data, identifying the root causes of defects and develop measures to eliminate them.

The task of collecting, processing and analyzing the results is solved with the help of mathematical statistics [1-3], which includes modern methods of analysis and detection of defects (correlation and regression analyzes, testing statistical hypotheses, factor analysis, reliability analysis, etc.).

Problems of improving quality assessment methods include improving controls and developing assessment methods.

Computational work, in the development of which the greatest scientific and technical reserve has been accumulated, should provide a wide replacement of experimental development of real structures by computational experiments on models with a high degree of reliability and accuracy, which will significantly reduce the volume of field tests, physical and semi-physical modeling, conducting them mainly for verification and confirmation of the results obtained on mathematical models [5-6].

Compliance with quality standards [8-10] means that the achieved level of management meets the minimum set of standardized requirements (i.e. quality assurance) guaranteeing the production of marketable products, and this, in turn, determines the competitiveness of the organization as a whole.

In order to give a complex system the ability to achieve its goals, it is necessary to order key interactions, which means that the system must be accurately represented in its essential features.

As a result of the construction and optimization of the organization’s activity model, the “as needed” model will be obtained, in which all the main aspects of the organization of activity will meet the requirements of the standard [10].

Therefore, a modern solution that makes it relatively easy to solve the task of creating and constantly updating an organization’s management system is to support not just a system of interrelated documents, but information models that will generate the required documents. In addition, thanks to the technology of creating documents from a single model, they will not contradict each other.

One of the possibilities for ensuring quality and improving the efficiency of functioning of such a system is: firstly, the ability of its elements (workers) to interchangeability, taking into account the characteristics of work. Secondly, an increase in the intensity of direct and inverse relations in the exchange of information between a subject and an object (objects). Thirdly, improving the efficiency of vertical and horizontal interaction, while the subject and objects of activity should act as a single self-organizing and self-developing integral whole with respect to the external socio-economic super-system.

Regardless of the specifics of rationality or concreteness, the activity of an organization always fits into a strictly defined sequence of actions. This sequence of actions is characterized by a full product life cycle (life cycle) scheme - as a single object of development and implementation (Figure 4).
Thus, the analysis of quality assessment methods shows that the basis of existing methods is the evaluation of the quality of technical devices, which boils down to the evaluation of output parameters, which is considered as a deterministic event. In this case, the methods used do not have as an object the analysis of the process of forming parameters and evaluate the devices by the values of the parameters, without taking into account the randomness in the development of processes, which reduces the reliability of the assessment.

Therefore, the development of stochastic models and a criterion apparatus for assessing the quality of processes for creating complex technical devices will improve the evaluation of the characteristics of complex technical devices and more objectively and reliably estimate their level of functioning processes.

![Flowchart of the product life cycle](image-url)

**Figure 4.** Flowchart of the product life cycle
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