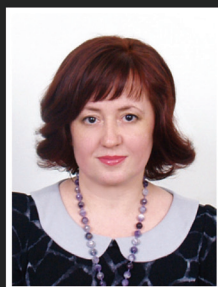


ASSESSMENT OF THE QUALITY OF PRODUCTS OF ROAD MAINTENANCE ORGANIZATIONS

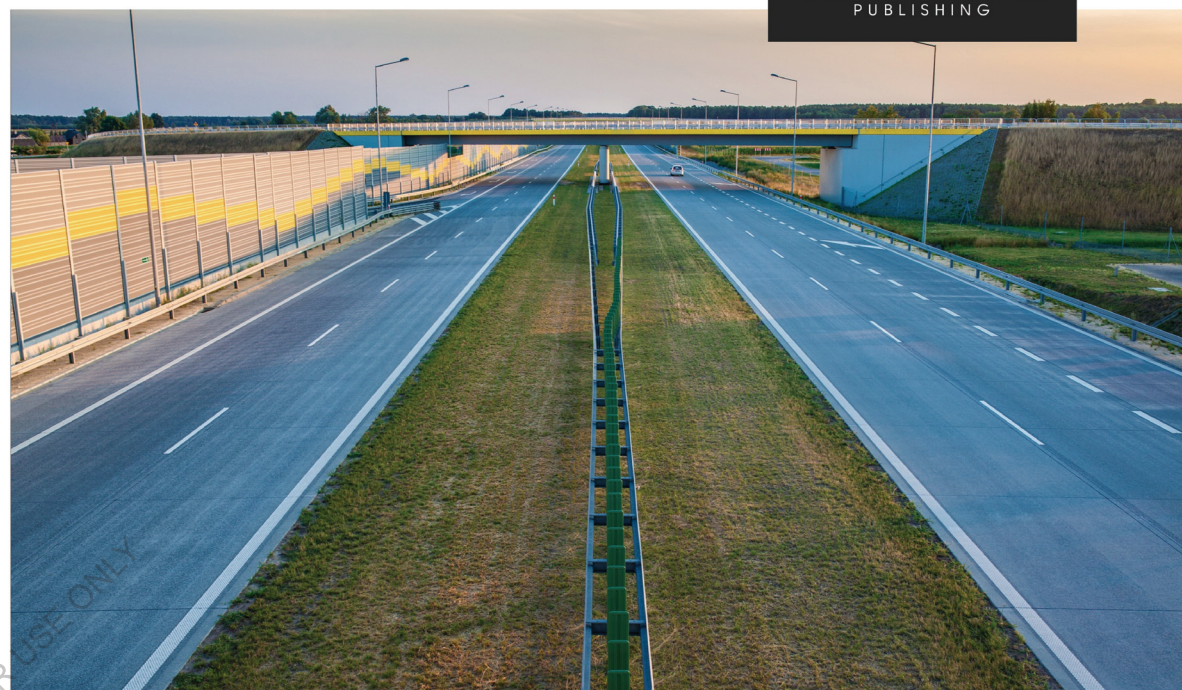
The monograph reflects the results of the research, the purpose of which was to clarify the theoretical and methodological basis for assessing the quality of works and products of road maintenance enterprises. As a result, the solution of the problem was clarified the essence of the concept "quality of road products"; the quality as an object of the road economy was studied; the analysis of quality management methods and quality assessment of road works was done; the most appropriate method for assessing the quality of road robots was chosen. To implement it, the methodological approach to the deployment of quality function through its adaptation to the economic conditions of road maintenance organizations, based on the implementation of not eight but seven stages of structuring the quality function and determine the consumer's requirements for road works and their characteristics has been improved. The primary requirements are comfort and safety of traffic, continuity of traffic, speed of traffic, capacity and load level, permissible dimensions and level of road service. The proposed developments will allow road organizations to perform works according to the priority requirements of consumers.



Dogadaylo Yana Viktorovna, PhD in Economics, assistant professor of Management department of Kharkov National Automobile and Road University. Areas of scientific research: quality management, controlling, budgeting, project management and ensuring the effectiveness of the enterprise



OUR KNOWLEDGE
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ASSESSMENT OF THE QUALITY OF PRODUCTS OF ROAD MAINTENANCE ORGANIZATIONS

**Dogadaylo Yana
Man'ko Margarita**

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MAINTENANCE ORGANIZATIONS**

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INTRODUCTION

At the present stage of economic development, increasing production efficiency brings to the fore one of the most important tasks - improving the quality of road works. Improving the quality of road works is a complex task and depends on a number of factors: the quality of regulations, design, manufacture of materials, structures, semi-finished products and finally the quality of operation of roads and road structures. To date there are no clearly defined methods for assessing the quality of road works. This makes the process of quality improvement in road maintenance much more difficult. Therefore, a study on the topic "Quality assessment of products of road maintenance organizations" is very relevant at this time. The purpose of the study is to clarify the theoretical and methodological bases of quality assessment of works, products of road maintenance organizations. The object of the study is the process of assessing the quality of works, products of enterprises of road economy. The subject of the research are methods of assessing the quality of work in road sector organizations.

In order to achieve this goal, the following objectives were pursued in the monograph:

- Definition of the meaning and concept of the terms "quality", "quality of work", "quality of roadworks";
- the definition of road works as a management object;
- Analysis of quality management experience at home and abroad;
- analysis and choice of quality management method;
- Analysis of methods for assessing the quality of road works in road maintenance enterprises;
- Justification for the choice of indicators for assessing the quality of road works in road maintenance enterprises;
- Determining the needs of users and the characteristics of the road works;
- Improving the methodological approach to the deployment of the quality function;
- the adaptation of the structuring of the quality function in relation to road works.

The practical value of the results obtained in the monograph lies in the development of recommendations to improve the quality assessment of road products, which will allow management to more objectively monitor the quality of road products.

1 THEORETICAL FOUNDATIONS OF QUALITY ASSESSMENT IN AN ORGANISATION

1.1 Content and essence of the concept of quality

The term "quality" is accepted in all languages, it is important to know that in most Western countries the term is derived from the same Latin word *gualitas* (Eng. It is important to know that in most Western countries the term comes from the same Latin word, *guality*, French *gualite*, German *gualitat*, Italian *gualita*, Spanish *cualidad*, and in most Western countries the word is understood in any of these languages. In the languages of Scandinavian countries and the former Soviet Union, the roots are usually national (Swedish - *egenskap*, Finnish - *laatu*, Ukr. - *yakist*, Kazakh - *cana*). Quality is one of the most capacious, complex and universal categories that have many aspects, peculiarities and, consequently, interpretations. In its most general form, the essence of the concept "quality" can be considered in its fundamental and applied meaning [1].

The fundamental meaning of quality is given in philosophy, it expresses the essential certainty of the object and means the highest abstraction, the content of which is in the internal certainty of a thing, which makes it a given thing in contrast to other things in a particular system of connection.

If we try to consider the process of formation of the concept of "quality", we can see that the first attempts to establish the essence of quality were made by philosophers. Thus, Aristotle (3rd century B.C.) defined "quality" as the essential certainty of an object by which it is a given and not another object. According to Hegel's (19th century) definition, "quality" is the identity of being. There are many more definitions that have been given by various scientists in the course of the study of quality. However, since the concept of "quality" has many aspects (philosophical, social, economic, legal), each definition is dominated by one of its aspects and none of the definitions has the necessary completeness and accuracy [2].

The applied definition of quality refers to specific objects: products, services, processes, systems, etc. Two approaches are used to define it in the literature and in practice:

- Technocratic (traditional view) [3,4];
- Innovative (new quality paradigm) [5,6].

The technocratic approach views product quality as a set of inherent "objective" characteristics or the degree to which they meet certain

requirements. In this approach, quality is primarily associated with a certain production technology, material and technical facilities, and the availability of qualified personnel. At the same time, the difficulty of understanding is what load this term takes in relation to any object (thing, product, product) or subject (person producing and perceiving the object, learner and others): The structure, or construction of the thing, its type, properties of the thing (essence) or properties brought, (at the level of phenomenon, manifestation) is considered. An innovative approach to product quality involves the inclusion of suppliers of necessary resources, consumers and other stakeholders, which is in line with contemporary views and the concept of total quality management.

There are many definitions of 'product quality', among which the most precisely formulated definition of this concept by the European Organisation for Quality Control is: "A product is considered good quality if, at minimum cost throughout its life cycle, it contributes to the satisfaction and happiness of the people involved in its design and recovery (re-use) to the maximum extent possible, subject to minimum energy and other resource input and with acceptable (acceptable) impact on the environment and society. This formulation clearly defines the relationship between the problem of product quality and other vital human concerns - conservation of the environment, sustainable use of natural resources, and the impact of the results of economic activity on the living conditions of our descendants. In the economic sense, the concept of "quality" has been shaped by historical and productive circumstances. Each social production had its own objective requirements for product quality. At first, quality testing involved determining accuracy and durability. With the development of scientific and technological progress, which resulted in the automation of production, automatic devices for controlling complex equipment and other systems appeared. The concept of reliability emerged. Thus, the concept of quality has constantly evolved and been refined. The need for quality control led to the development of methods for collecting, processing and analysing quality information. Firms operating in a market economy sought to organise quality surveillance during production and consumption. Emphasis was placed on defect prevention.

It is understood in all countries that high quality is a good thing. The problem of the quality of manufactured products is a perennial problem. If there is any production, there is also the problem of quality. But depending on the historical epoch or specific conditions, this problem is formulated differently in literary form: either as a demand for the possible exact reproduction of samples recognized as reference, or as a demand to meet minimum but strict criteria often fixed in standards and norms, or in poetic form as a wish for progressive,

year by year, from model to model or even from sample to sample as quality experience accumulates, or in poetic form as a wish for unattainable perfection. Of course, notions of total progressive improvement in quality are simplistic and do not always correspond to reality. It is well known that some of the quality indicators are decreasing. Thus the durability of building structures is generally decreasing, the normative and actual service life of reinforced concrete structures is incomparably less than that of the stone and brick masonry of many temples, palaces and bridges, which have stood for centuries. Compared to mid-century, the average lifespan of car bodies has been considerably reduced, due to lighter structures using thinner steel sheet. Many modern fabrics wear out much faster than the glorious English woollen fabrics of the last century. In these cases, where the decline in some quality indicators is clearly attributable to the use of new technologies, the quality problem is characterised by the very realistic requirement of foreseeable decline in quality. Furthermore, irrespective of the general slogans and ideological attitudes of reality, practical quality assurance activities are of paramount importance. In a market economy, the problem of quality is the most important factor for the improvement of living standards, economic, social and environmental security. Quality is a complex concept that characterizes the effectiveness of all aspects of activity: strategy development, organization of production, marketing, etc.

There are different interpretations of the concept of quality in modern literature and practice. The International Organization for Standardization defines "quality" (standard ISO-8402) as a set of properties and characteristics of a product or service which give them the ability to satisfy a conditioned or anticipated need. This standard introduced concepts such as 'quality assurance', 'quality management', and 'quality circle'. In order to streamline the terminology in the field of quality, a lot of work has been done by the International Organization for Standardization (ISO), which culminated in the creation and publication of ISO 8402:1994. This standard was further developed and included into ISO 9000:2000, adopted in Ukraine as DSTU ISO 9000-2001. Terms and definitions, governed by this standard, are considered below. A product is the result of a process, and a process is a set of interrelated or interacting activities that transform inputs into outputs. Often the output of one process forms directly the input of the next process. The systematic definition and management of processes and their interactions in an organisation is called the 'process approach'. There are four generalised categories of outputs:

- services (transport);
- intellectual production (computer software, dictionary);
- technical means (the mechanical part of the engine);

- recycled materials (oil).

Many products are composed of elements belonging to different generalized categories. In such a case, the categorization of a product as a service depends on the element prevailing, e.g., products (cars) are created by technical means (engine), recycled materials (fuel), intellectual products (engine adjustment programme) and services (explanation of operation). A service is the result of at least one activity, necessarily carried out in an interaction between supplier and customer, and is usually intangible. The provision of a service may include, for example, the following:

- actions with material goods provided by the customer (vehicle to be repaired);
- actions with intangible products provided by the customer (income tax return required for the calculation of the tax);
- provision of intangible products (information in the context of knowledge transfer);
- creating a customer-friendly environment (in hotels or restaurants).

Intellectual production contains information, which is usually intangible, and may take the form of approaches, business agreements or methodologies. Technical outputs are usually tangible and their quantity constitutes a quantitative characteristic. A characteristic is a distinctive property, which may be intrinsic or appropriated, qualitative or quantitative. "Owned" means present in what exactly as a permanent characteristic. Characteristics assigned to products, processes or systems (product price, product owner) are not characteristics of the quality of that product, process or system. There are different classes of characteristics: physical (mechanical, electrical, biological, chemical); organoleptic (related to human senses); ethical (politeness, honesty, truthfulness); temporal (punctuality, dependability, accessibility); ergonomic (physiological or safety-related characteristics); functional (maximum air speed). Recycled materials are of course material, their quantity is not a continuous characteristic. Technical means and recyclable materials are often referred to as commodities. Quality is the extent to which a set of intrinsic characteristics satisfies a requirement. A requirement is an articulated need or expectation, generally understood or binding. Requirements can be related to any aspect, such as performance, efficiency or traceability. Effectiveness is the extent to which planned activities are realised and planned results are achieved. Effectiveness refers to the ratio between the result achieved and the resources used. Traceability refers to the ability to trace the background, application or location of what is being considered.

Quality requirements at the international level are defined in the ISO 9000 series of standards. The first edition of the ISO 9000 series of international standards came out in the late 1980s and marked the entry of international standardisation to a qualitatively new level. These standards intruded directly into the production processes, the field of management and established clear requirements for quality systems. They marked the beginning of the certification of quality systems. An independent area of management - quality management - has emerged. Nowadays scholars and practitioners abroad link modern quality management methods to the methodology of TQM (total quality management) - total quality management. Quality of a product is a component and consequence of the quality of work, it is here that the quality of an exploitable product and the thought (opinion) of the consumer is directly assessed. The object of quality management is the quality of the finished product and the quality of service. Today, there are many different aspects of the concept of quality related to economic, social, managerial factors, etc. But above all, the term "quality" is related to the creation and use of products and services, and each person's perception of quality depends on the role it plays in the process of their production and consumption. This affects the content, understanding and interpretation of the category "quality". The variety of existing interpretations of "quality" can be conventionally grouped as follows:

1. Quality as an absolute assessment. In this sense, quality is synonymous with excellence, i.e. product quality is a sign of unconditional compliance with standards. According to this approach, quality cannot be measured because it is an attribute of the product (for example, Japanese cars are believed to be of absolute quality). But excellence is an abstract and subjective category, as people's perception of the quality of the same product may vary considerably. Therefore, the definition of quality considered cannot be used as a basis for evaluating or measuring the properties of products or services.

2. Quality as a property of a product. In this sense, quality is a constant characteristic of some measurable quantitative parameter of a product (service). Quality is considered better if the indicator is better (e.g., a car that spends less fuel per 100 km compared to another car is considered to be of higher quality). But this perception is rather narrow, as it does not characterise the entire range of usefulness of the product for the consumer.

3. Quality as fitness for purpose. According to this thesis, quality is the ability of a product or service to perform its function, i.e. its fitness for use. But the fallacy of this approach may be demonstrated by the example of foreign-made (European, Japanese, American) cars delivered to Ukraine. As the quality

of our roads differs considerably from that of foreign ones, high-quality cars will be unsuitable for the full range of their capabilities, particularly at high speeds.

4. Quality as value for money. In this case, quality is defined as the ratio of utility to price of a product (service). From this point of view, a quality product is one that matches the competitors' products in terms of its useful properties, but sells cheaper, or surpasses the characteristics of similar products at the same price. This approach encourages the producer to seek a balance between improving the consumer properties of the product and reducing the cost of production and sales.

5. Quality as compliance with standards. According to this approach, quality is defined as compliance with some normative documents that contain target or limit values of certain parameters of products or services. At the same time, normative documents are meaningless if they do not meet the requirements of consumers of products (services).

Thus, the scope and practical application of the concept of quality is limited to the subjective perception of the properties and usefulness of the product by each individual person. That is, quality can only be defined by applying a system of evaluations of the person who uses the product (service). Therefore, today the concept of "quality" is associated with the satisfaction of certain needs and expectations of consumers with regard to a particular product or service.

To summarise the above, experts' understanding and interpretations of the content and content of the term "quality", particularly in the field of road maintenance, can be divided into two categories:

- The first level of quality is the production of such products or the provision of such services in the field of road maintenance, the measurable characteristics of which satisfy specific technical requirements having numerical values;

- the second level of quality of a product or service does not depend on any measurable characteristics and is determined by the extent to which the needs and expectations of the consumer regarding the use or application of that product or service in relation to the road sector are met.

The definition of the category "quality" using the phrase "needs and expectations of consumers" is not accidental, because the current understanding of the quality of products and services is based on the principle of the fullest satisfaction of the requirements and wishes of the consumer [7]. That is, the new understanding of the category "quality" characterizes such a state of a product (service), such a set of their properties that are designed to meet or exceed the needs and expectations of consumers. This approach is enshrined in the standard

[8], which defines the term "quality" as "the extent to which the totality of a product or service's own characteristics satisfies requirements". Since service delivery has its own characteristics [9], this approach is relevant when assessing the quality of service delivery, in particular in the road sector. In addition, more and more road sector enterprises are coming to the understanding that proper quality of services can be ensured by applying an effective quality management system (QMS) in the enterprise, built on the principles outlined in the standard [10], and which functions in accordance with the requirements of the standard [11]. Therefore, the modern understanding of the term "quality" should be understood and used by the developers of QMS in the road sector enterprises when building and implementing the QMS to reduce the risk of not meeting customer requirements, improve service quality, strengthen the mutual trust of enterprises and consumers of their products (services).

1.2 Product quality as an object of study in the road sector

At the present stage of economic development, increasing the efficiency of production brings to the fore as one of the most important tasks of improving the quality of construction products. Improving the quality of construction products is a complex task and depends on a number of factors: the quality of regulatory documents; design, manufacturing of construction materials, structures, semi-finished products; quality of construction works and, finally, the quality of operation of roads and road structures. Ensuring high quality is inextricably linked to the economic side of construction organizations. According to surveys, the unproductive costs due to poor quality in construction reached 2.5% of the estimated cost, with 6.7% of detected defects caused by violation of construction regulations and rules [12]. Standards ISO 9000 series has established a unified, internationally recognized approach to the contractual conditions for the evaluation of quality systems, while regulating the relationship between producers and consumers of products. In other words, ISO standards are strictly customer-oriented. Figure 1.1 shows the quality pyramid in the road sector. At the top of the pyramid is TQM - all-inclusive, total quality management, which involves high quality work across the board to achieve the required product quality. Above all, this is the work involved in ensuring

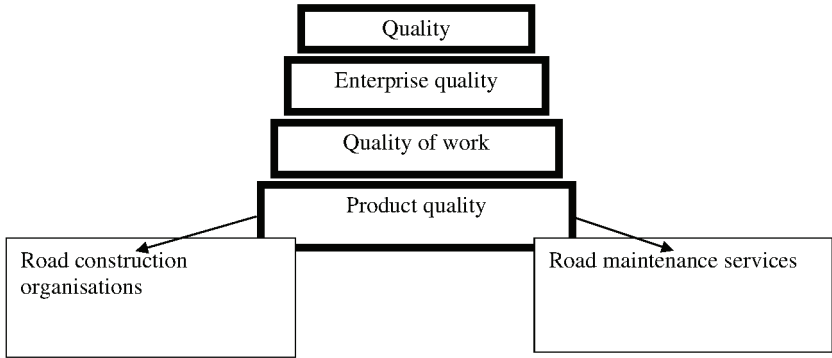


Figure 1.1 - Quality pyramid in road maintenance

The high organisational and technical level of production, and appropriate working conditions.

The object of governance is society; the components of governance are the quality of culture, the political and legal system, the economic system, information, science and technology, and life.

The object of work quality management is production; the components of management are the quality of equipment, technology, production processes, working conditions, and workers (their qualifications).

Many authors interpret the term 'quality' in different ways (Table 1.1).

In the road sector, the final construction product is a road with a complex of engineering structures. The quality of road construction determines the productivity and cost of transportation, as well as road safety. Therefore, quality control and quality management of road construction and repair work is an integral part of technology and organization of road construction production. The product is understood as an embodied result of economic activity, which is characterized by quality attributes, which determine the overall properties, and quantitative, defined by numerical values. The quality of products is evaluated by a quantitative indicator in the form of a quality level.

Table 1.1 - Interpretation of the term "product quality" by different scientists

№	Author and literature	Meaning of the term "product quality"	Advantages	Disadvantages
1	2	3	4	5

1.	[18]	The quality of a product is understood as a set of properties of the product, which determine its suitability to meet certain needs in accordance with its intended use. From the point of view of the consumer, the quality of a product is the degree to which the consumer's requirements are met.	Characterises a set of product properties	It is not specified which properties of the products
2.	[2]	The quality of a product is the totality of the useful properties of the product of labour, which determine its ability to serve certain human and social needs.	Characterises the totality of the useful properties of a product	Comprehensive product quality assessment is lacking
3.	[19], [30], [31], [14]	The quality of a product is a set of properties that determine its suitability to satisfy certain needs in accordance with its intended use.	Characterises a set of product properties	No indication of which properties of the products
4.	[20]	The quality of a product is of paramount importance to consumers because it determines its use value. And often, improving the quality of a product is equivalent to increasing the quantity of the product.	Of paramount importance to consumers	Product properties not specified
5.	[21]	The quality of a product is the set of properties and characteristics that give it the ability to satisfy a conditioned or anticipated need.	A set of properties and characteristics of products	Quantitative aspects are not characterised
6.	[12]	The quality of a product is characterised by its degree of usefulness and represents the totality of properties that determine the ability to satisfy certain needs in accordance with its economic purpose	Characterised by the degree of usefulness of the product	Product properties not specified
7.	[22]	A product quality indicator is a quantitative characteristic of one or more of the product properties that constitute quality. A single product quality indicator is an indicator of product quality characterizing one of its properties. A comprehensive indicator of product quality is an indicator of product quality characterizing several of its properties.	Shows the quantitative characteristics of products	Product properties not specified

Continuation of Table 1.1

1	2	3	4	5
8.	[33]	Product quality is a prerequisite for the successful and efficient operation of any industrial enterprise, since it is the core of competitiveness determines the objective parameters of the product and serves as one of the main forces for its promotional activities operating in the market.	Characterises a prerequisite for success	Comprehensive product quality assessment is lacking
9.	[34]	Product quality is the most important part of a product quality system. Product quality is a component and consequence of the quality of work, and it is here that the quality of usable products and the thought (opinion) of the consumer are directly assessed.	Product quality is the most important part of a product quality system	No quantification of product properties is described
10.	[35]	The quality of a product is the totality of its consumer properties that are capable of satisfying consumer needs. A product is considered to be of high quality if it meets the requirements of standards and technical specifications and satisfies the needs of consumers.	Characterises the totality of its use properties	Comprehensive product quality assessment is lacking
11.	Researcher	A product quality indicator is a quantitative characteristic of one or more of the product properties that make up quality.	Shows the quantitative characteristics of products	Product properties not specified

Nowadays, the quality requirements for works and objects under construction in road construction have increased dramatically. Due to the development of scientific research the problem of quality management in road construction has become a coherent system consisting of certain provisions, principles and methods of planning, control and maintenance of the required product quality in road construction. Requirements for materials and technological processes have been tightened, systems of certification of products and quality incentives have been implemented and control methods have become reliable. A quality indicator is a quantitative characteristic of a property of a product considered in relation to certain conditions of production, use or consumption of the product. It only describes a property that is part of the quality. Quality indicators can be singular, complex, integral and basic. One property of a product is characterised by a single index, while several properties

are characterised by an integral index. The integral index is a variant of the integral index and characterizes the ratio of total useful effect from the use of products to the total costs of their production and use. Quality is assessed quantitatively by comparing it with the basic (benchmark) indicator that is stable under the given conditions and at the given moment. For objective assessment of product quality, use a relative indicator - the level of quality, i.e. a quantitative characteristic of quality, based on a comparison of the set of indicators of its quality with the corresponding set of basic indicators. Quality control boils down to checking whether the quality indicators of a product meet the established requirements. Product quality management is the definition, provision and maintenance of an appropriate level of product quality in its development, production, operation or consumption, carried out through systematic quality control and purposeful impact on the conditions and factors affecting product quality [13]. Product quality management is a set of technical, organizational, economic, social, legal, administrative and other influences on the production processes and production relations that ensure the planned level of quality of road construction products. The most important task of product quality management is to ensure the optimal level of quality at all stages of its creation and consumption.

Quality management of road construction products is carried out at three stages:

1. In design, when normative indicators are laid down for Class I products and transport and performance indicators of the future road for Class II products. The object of control is the single indicators for materials, raw materials and the complex quality indicators of the design documentation of the final products.

2. In product creation, where the quality of raw materials, materials, road construction and repair work, and structures is the object of management.

The composite road quality indicator shows how the design indicators are being met.

3. In use, when the object of control is the quality of the finished product (asphalt mixture, road performance). Consequently, the quality of road construction products is established during their design, construction and use (operation).

Road construction is characterized by a wide range of local road construction materials, changeable natural and climatic conditions, a wide range of construction and component products and therefore great variability in technology and organization of road construction and maintenance works, planning and management methods. Standardization plays a significant role in solving these problems and ensuring high quality of road construction products. Applying a system of standardization, you can create optimal quality products based on the introduction into production of advanced scientific and technological advances, saving labor, material, energy and money resources. Its

introduction into production contributes to reducing the time of road construction, improving its quality, reducing the cost of works and final products [14].

1.3 Analysis of national and international experience of quality management

The methods and nature of work aimed at ensuring proper product quality are constantly changing. These changes are blurred in time and not always clearly separated from each other. At the same time, each stage of evolution has its own logic and pattern of development. In order for any designed and documented quality system, which includes process management, to work, it is necessary to

- (a) Use means to motivate staff;
- b) train staff in both professional and quality management matters;
- c) build the right relationship with consumers;
- d) learn how to manage suppliers so as to obtain the necessary products of a predetermined quality from them in a timely manner;
- e) introduce the organisational and administrative documents governing the introduction and use (implementation) of the quality system.

Characteristics of changes in these five areas during the development of quality systems (changes in the system of motivation, in the system of personnel training, in relations with suppliers, with customers, as well as in the documentation of the quality system) allows us to identify the stages of quality systems evolution. For a visual (graphic) illustration of which it is convenient to use a figure well known in Russian production - the "Quality Mark". The outline of this figure, which is known as the 'Pentagon', is filled in with a five-pointed star and what emerges is called the 'Quality Star' (Figure 1.2).

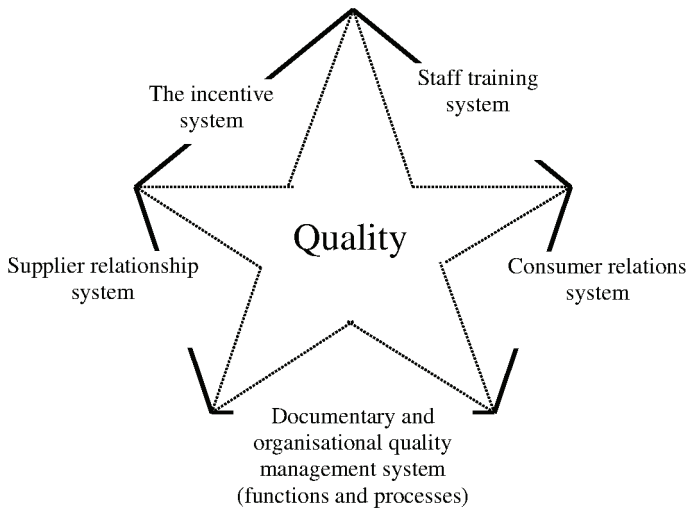


Figure 1.2 - Quality Star

At the heart of the quality star is a quality management system that conforms to a defined concept, this system is documented and covers the organisational management structure of the company as well as the process management system of the product creation. The latter is very important to emphasise: we view the organisation as both a functional structure and a set of processes. In Figure 2.1, the two upper boundaries of the Quality Star are the 'roof' of the organisation. The left-hand plane of the 'roof' is the system for motivating quality work, the right-hand plane is the system for training staff. The left-hand side edge depicts the system of relations with suppliers, the right-hand side edge is the system of relations with customers. The centre of the star shows which objectives the systems pursue and, if successful, achieve, while the bottom line shows when a system has been explicitly stated in documents and/or books, articles (for a particular quality system). The five elements of the quality star correspond to the different areas in which major changes have taken place during the development of the quality systems: changes in the motivation system, in the personnel training system, in the relationship to suppliers, to customers and in the documentation of the quality system. There are five phases in the history of quality, overlapping and continuing, which, in full accordance with the laws of dialectics, developed under the pressure of the contradiction between the internal and external objectives of the manufacturer - ensuring the quality of the products produced, and respectively strengthening the manufacturer's position in the market (external objective) and increasing production efficiency, i.e. increasing

company profit (internal objective). This contradiction at each stage of development of production, market and society has had its own specifics and has been solved differently.

The evolution of quality assurance methods is represented by five stages (phases):

1. Rejection phase (Taylor system (technical documentation));
2. Quality control phase (statistical quality management);
3. Quality management phase (total quality management TQC);
4. The quality management phase (total quality management TQM);
5. Environmental quality phase (total quality management TQM) [20, 21].

Five stages can be distinguished in the history of the development of documented quality, motivation, training and partnership systems and presented in the form of five quality stars (Figure 1.3).

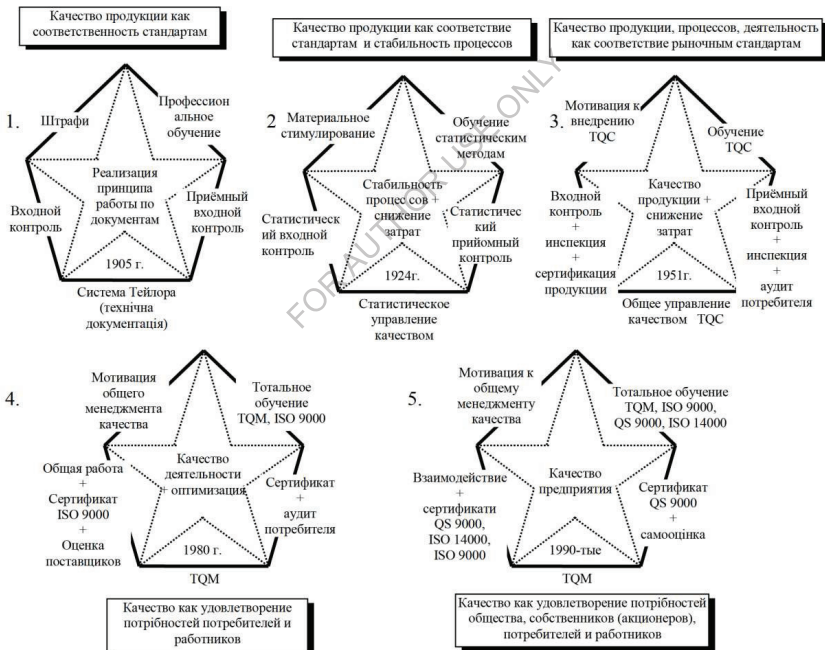


Figure 1.3 - Stages in the development of quality systems

1. The first star corresponds to the early stages of the system approach, when the first system, the Taylor system (1905), appeared. It established quality requirements for products (parts) in the form of tolerance fields or defined templates configured to upper and lower tolerance limits - pass and non-pass

gauges. To ensure the success of the Taylor system, the first quality professionals - inspectors (in Russia, technical controllers) - were introduced. The incentive system included penalties for defects and rejects as well as exemptions. The training system was limited to vocational training and training in the use of measuring and inspection equipment. The relationship with suppliers and consumers was based on requirements set out in technical specifications (TS), compliance with which was checked during the acceptance inspection (incoming and outgoing). All of the above features of the Taylor system made it a quality management system for each individual product.

2. Second Star. Taylor's system provided an excellent mechanism for managing the quality of each specific product (part, assembly unit), but production is about processes. And it soon became clear that processes had to be managed. In 1924 at BELL telephone Leborettries (now AT & T Corporation) a group headed by Dr. R. L. Jones was created, which laid the foundation for statistical quality management. These included the development of control charts by Walter Schuchart, the first concepts and sample quality control tables by H. Dodge and H. Romig. These works were the beginning of statistical methods of quality management, which later, thanks to Dr. E. Deming, became very widespread in Japan and made a very significant impact on the economic revolution in that country.

Quality systems became more complex as services using statistical methods were incorporated. The quality tasks to be performed by designers, technologists and workers became more complex, as they had to understand variation and variability and know what methods could be used to reduce them. A speciality emerged, the quality engineer, who had to analyse the quality and defects of products, construct control charts, etc. In general, the emphasis was shifted from inspection and detection of defects to prevention by identifying the causes of defects and eliminating them on the basis of process learning and management. Work motivation became more complex, as it was now taken into account how precisely the process was set up, how certain inspection, control and monitoring maps were analysed. Training in statistical methods of analysis, regulation and control was added to professional training. Supplier-customer relationships had also become more complex. Standardised tables for statistical acceptance control have become more important.

3. the third star. In the 1950s, the concept of total (total) quality management - TQC - was put forward. [8]. Its author was American scientist A. Feigenbaum. TQC systems have been developed in Japan with great emphasis on the use of statistical methods and involvement of personnel in the work of quality clubs. The Japanese themselves have long emphasised that they use the

TQSC approach, where S stands for Statistical. In this phase, marked by the third star, documented quality systems emerged which established responsibility and authority, as well as quality communication, for the entire management team, not just the quality specialists. Incentive systems began to shift towards the human factor. Material incentives decreased and moral incentives increased. Teamwork, recognition of achievements by colleagues and management, the company's concern for the future of the employee, his insurance and support of his family became the main motives for quality work. More and more attention is being paid to training. In Japan and Korea, employees study for an average of several weeks to a month, including self-study. Of course, the introduction and development of the TQC concept has been uneven around the world. Japan has been the clear leader, although all the basic ideas of TQC were born in the USA and Europe. As a result, Americans and Europeans had to learn from the Japanese. However, this learning has also been accompanied by innovation. Supplier-customer systems are also beginning to include third-party certification of products. At the same time, quality requirements in contracts have become more serious, with responsible guarantees for their fulfilment. It should be noted that the stage of development of systemic, comprehensive quality management did not pass by the Soviet Union. Many domestic systems were born there, and one of the best is the system of KanarSPI (quality, reliability, service life from the first products), which was knowingly ahead of its time. Many principles of CANARSPI are still relevant today. The author of the system was T.F. Seifi, chief engineer of the Gorky aircraft plant. He was one of the first who understood the role of information and knowledge in quality management, shifted the emphasis of quality assurance from production to design, and attached great importance to testing. It is fair to consider T.F. Seifi an outstanding specialist in quality management, and his name should stand alongside such names as A. Feigenbaum, G. Taguchi, E. Schilling and H. Wadsworth.

4. The fourth star. In the 1970s and 1980s, the transition from total quality management to total quality management (TQM) began. At this time, a series of new international standards for quality systems emerged:

ISO 9000 standards (1987) have made a very significant impact on management and quality assurance:

IC 9000 General Quality Governance and Quality Assurance Standards;

MS 9001 Quality Systems. A model for quality assurance in design and/or development, production, assembly and maintenance";

MS 9002 "Quality Systems, Model for Quality Assurance in Production and Installation";

MS 9003 Quality Systems. Model for quality assurance in final inspection and testing";

MS 9004 'General Quality Manual and Quality System Elements. Guidelines" as well as terminology standard MS 8402.

In 1994, a new version of these standards was issued, which basically extended the MS 9004-1,2,3,4 standard to focus more on quality assurance of software products, materials handled, services. While TQC is about managing quality to meet defined requirements, TQM is also about managing objectives and the requirements themselves. TQM also includes quality, which is interpreted as a system of measures that provide the consumer with confidence in the quality of products. Figure 1.4 illustrates this.

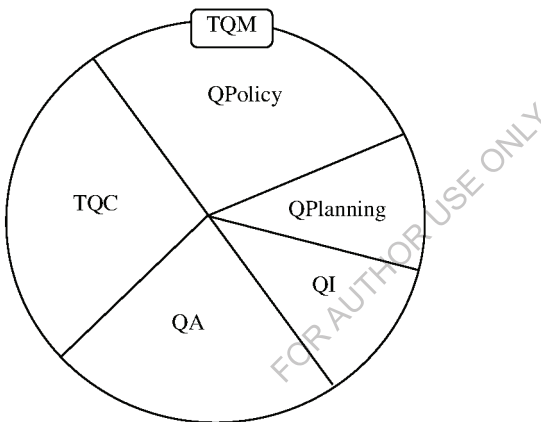


Figure 1.4 - Main parts of TQM

TQC - Total Quality Management;

QA - Quality Assurance;

QPolicy - Quality policy;

QPlanning - Quality planning;

QI - Quality improvement.

TQM is a comprehensive system focused on continuous quality improvement, minimisation of production costs and just-in-time delivery. The basic philosophy of TQM is based on the principle that there is no limit to improvement. The quality objectives are zero defects, zero unproductive costs and zero just-in-time delivery. It is recognised that it is not possible to achieve these limits, but that it is necessary to constantly strive for them and not to rest

on the results achieved. This philosophy has a special term - "quality improvement". The TQM system uses quality management methods that are adequate to the goals. One of the key features of the system is the use of collective forms and methods of search, analysis and solution of problems, constant participation in quality improvement of all the team. In TQM, the role of the individual and the training of personnel increases significantly. Motivation reaches a state where people are so enthusiastic about their work that they give up part of their holiday, stay late at work and continue to work at home as well. A new type of employee has emerged - workaholics. Training is becoming total and continuous, accompanying workers throughout their working lives. The forms of learning are changing significantly and becoming more active. For example, business games, special tests, computer-based methods, etc. are being used. Training is also becoming a part of motivation. Because a well-trained person feels more confident in the team, is able to take a leadership role, has career advantages. Special methods of developing the creative abilities of employees are being developed and used. Certification of quality systems in accordance with ISO 9000 standards has become very deeply embedded in the supplier-consumer relationship. The main objective of quality systems based on the ISO 9000 series of standards is to ensure the quality of products required by customers and provide them with evidence of the company's ability to do so. Accordingly, the mechanism of the system and the methods and tools used are oriented towards this objective. However, the focus on cost-effectiveness is very weak in the ISO 9000 series of standards and the focus on timeliness of delivery is simply absent. Despite the fact that the system does not solve all the problems necessary to ensure competitiveness, its popularity has been growing like an avalanche and it is now firmly established in the market mechanism. The external indication that a company has an ISO 9000 series quality system is a certificate for the system. As a result, in many cases, a company's possession of a quality system certificate has become one of the main conditions for its admission to bidding for various projects. The quality system certificate has found widespread use in the insurance industry: since a company's quality system certificate demonstrates its reliability, it is often awarded favourable insurance terms and conditions. The popularity of the ISO 9000 series of standards is evidenced by the general dynamics of quality system certification. For example, according to data from Mobil, about 50,000 quality systems were certified worldwide in 1993. In 1995 their number has increased to 100 thousand. It may be assumed that at the moment about 150 thousand certified systems are in operation. For successful enterprises in the modern market the presence of the quality system meeting the standards of ISO

9000 series and the certificate for it is not enough but still a necessary condition. That is why in Russia there are already dozens of companies which have implemented ISO 9000 series standards and have certificates for their quality systems.

5. The fifth star. In the 1990s, the influence of society on businesses increased and businesses became increasingly responsive to the interests of society. This led to the emergence of ISO 14000 standards which set out the requirements for management systems in terms of environmental protection and product safety. Certification of quality systems to ISO 14000 standards is becoming as popular as certification to ISO 9000. The impact of the humanistic component of quality has increased significantly. The attention of business leaders to meeting the needs of their personnel is increasing [15]. Thus an important step was taken in the automotive industry. The Big Three American automobile companies developed in 1990. (1994 - second edition) of the OS-9000 standard "Requirements for Quality Systems". Although it is based on ISO 9001, its requirements are reinforced by the industry (automotive) as well as the individual requirements of each of the Big Three and five other major truck manufacturers. The implementation of ISO 14000 and OS-9000, as well as self-assessment methods based on the European Quality Award models, are the main achievements of the five-star stage. Ukraine, like other CIS countries, has voluntary state standards for quality management systems developed on the basis of international standards ISO 9000 series. Meanwhile in Europe and in the world modern methods of quality improvement, business excellence and environmental management are applied. About 400 thousand quality management systems have been certified according to international standards ISO 9000 and 14000 series, i.e. annually this number increases by 50 thousand while in Ukraine about 600 systems are certified. In many domestic enterprises quality management systems have not been revised over the past 10-15 years i do not meet modern requirements. The analysis shows that the main reason for their low level is the lack of a systematic approach to management and training in this area.

To revive the economy of Ukraine it is necessary to improve the quality i competitiveness of products, to create conditions for the full disclosure of the potential of enterprises, the achievement of business excellence, to provide all possible support and promote the development of quality management. In other words, quality improvement should become a task of national importance, and the main way of its solution is the state support of modern methods of quality management and business excellence, development and implementation of quality and environmental management systems in accordance with ISO 9000

and 14000 standards, principles of total quality management, recognized in Europe and in the world. In Ukraine, the quality management process is carried out in accordance with the CMU Decree No. 447-r "On Approval of the Concept of State Policy in the Field of Quality Management of Products (Goods, Works, Services)" [16]. It is based on the optimal combination of interests of the state and producers to produce quality and competitive products. The objectives of state policy in the sphere of quality management are to create the necessary legal, economic and organizational conditions for:

- The production of quality products that are competitive on the domestic and foreign markets;
- to meet the demand for safe, quality products;
- preserving and restoring the safety of the environment;
- increasing budget revenues through the intensification of economic development;
- employment growth and an increase in the standard of living of citizens;
- The country's prestige in the international community, the stable development of its economy and the strengthening of its defence capabilities.

State policy on quality management is based on the following principles of comprehensive quality management:

- consumer orientation;
- The leading role of the management of enterprises and organisations in addressing quality issues;
- involvement of employees of enterprises and organisations in quality management processes;
- The process approach to resource management i activities of enterprises and organisations;
- A systematic approach to the management of enterprises and organisations;
- Continuous employee training, innovation and improvement of production processes;
- evidence-based decision-making;
- developing partnerships with suppliers.

Economic measures of state regulation in the sphere of quality management aimed at stimulating the activities of producers to improve product quality, increasing their responsibility for the manufacture and sale of low-quality products.

The organisational measures of state regulation in the field of quality management are aimed at:

- creating conditions for the implementation of quality and environmental management systems;

- The involvement of governmental and non-governmental organisations in activities to ensure the quality and competitiveness of products;

- disseminating the experience of enterprises and organisations that have achieved the best results in the field of quality management in the environment;

- promoting and raising public awareness of quality assurance activities.

State policy on quality management implies

- unconditional compliance with quality requirements for products procured with public funds. To this end, orders for the supply of such products should be placed with enterprises that have implemented quality and environmental management systems, subject to their certification in the national system;

- intensifying activities with certification of quality and environmental management systems, achieving a high level of professionalism among the participants in these activities and increasing confidence in their results;

- Promoting global recognition of the national technical regulatory system;

- The entry of domestic institutions and organisations working in the field of quality management into international and regional unions, ensuring accreditation abroad of authorised certification bodies and testing laboratories.

Domestic quality management went through the same five stages as foreign management. But in contrast, it had not only the industrial enterprise level, but also the territorial (Berdiansk City Quality Management System), sectoral and, finally, the state level, which was reflected in the development of the Unified State Quality Management System. As the domestic experience has shown, the quality system can be effective at the level of an industrial enterprise, so below we consider only the stages of quality management development at the level of an industrial enterprise. The development of domestic quality management systems ended in the 1990s. In spite of certain successes of individual enterprises, there was no significant improvement in the quality of USSR products due to such reasons:

- the design of overly complex systems was transferred to the companies themselves - the product manufacturers - rather than to professional specialists, i.e. there were pro- ignored words of academician V.M. Glushkov, who said in relation to complex control systems: "Aircraft are not designed by pilots, they only fly, but they should be designed by completely different specialists, specialised organisations"; the attention of system developers was

concentrated on creating quite a significant number of STPs, which resulted in systems being usually cumbersome, with

- the quality management work within the system was led by technical inspection departments rather than plant managers, which created international contradictions between them in working 'for the plan' and 'for quality' in many cases not in favour of the latter;

- systems did not allow for 'traceability' of materials, parts, assemblies and products in cases where they had defects and failures;

- the objects of standardisation were not always correctly defined in the normative documents;

- The quality management system is not customer-oriented and does not produce competitive products;

- there was insufficient incentive in the system to ensure a high level of product quality;

- The conditions and factors affecting the quality of products have generally not been fully encompassed by management.

All this led to the fact that, as a rule, the STPs developed as part of the system turned into formal documents. In addition, as studies have shown, in the 1970s and 1980s, negative socio-psychological attitudes were formed in the country: there was a shift of personal interests from public production towards family and household activities and consumer activity; the prestige of professional skills and quality of work declined; the motive of consumer orientation was pushed to the margins of public consciousness; a personality type with a high degree of conformity was formed; social and labour passivity spread massively, equal

In addition, the global shortage of products under the conditions of administrative-planned economy, command-and-distribution system with comprehensive state ownership had a system of values in which quantity rather than quality was in the first place. This determined the untimeliness of the introduction of a modern quality management system and led to the problem of a significant lag in the quality level in domestic enterprises compared to advanced foreign enterprises. Ukraine's transition to a market economy gave domestic enterprises the opportunity to fully use the accumulated global potential of scientific and practical approaches and methods of quality assurance, as well as to take a more active part in international cooperation in the field of quality assurance. Based on the TQM concept, specific approaches to quality assurance have been developed in leading countries, such as the USA, Japan and the UK. The emphasis on the human factor as the main production force and source of effective functioning of enterprises, organizations, firms is characteristic of Western and Japanese management within the deep development

of the school of human relations, which is especially evident in the example of the Japanese quality management system. The key elements of the Japanese approach (use of quality circles, kaizen approach) are the principles of voluntariness, giving initiative to workers, interrelation with specific work tasks and processes, creation of a creative and benevolent atmosphere. At the same time, training performs several important functions, such as providing work with creativity, team building, improving employees' skills, reducing losses from inefficient, irrational, unskilled actions [17]. It should be noted that the introduction of quality circles outside Japan and the adaptation of their principles to Western psychology are considerably limited by a clear focus on group work and the creation of an environment that denies individualism. These shortcomings are now also recognised by Japanese specialists, as evidenced by the desire to combine the achievements of Western and Eastern approaches, in particular by granting greater personal freedom, encouraging personal initiative and innovation, and applying new systems of measuring and rewarding the quality of an individual worker's work.

Summarizing the Japanese experience in quality management, its main features include: education of each manufacturer exclusively respectful attitude to customers and consumers (the practice of the cult of the consumer in both intrafirm and intercompany relations); real implementation of the principles of comprehensive quality management; participation of all departments and employees in quality assurance and management; continuous systematic training of personnel in quality assurance and management, ensures a high level of training. A characteristic feature of quality management in Japanese firms can be recognized the collection and use of data on the quality of products operated by customers ("traceability" of products). The information is collected not only on the quality of its own products, but also on the products of competitors. This data makes it possible to assess the quality of the firm's products and determine benchmarks for improving its own products compared to those of competing firms. Another important feature of Japanese firms' quality management systems is the promptness of control actions, in introducing new and upgraded technologies and products. The concept of quality control was not new, but the Japanese put forward the concept of total quality control, broader in scope, which involved a company-level quality improvement movement. Everyone, from the director to the cleaner, had to be part of the movement. In other words, the no-fault concept developed by American scientists was transformed in Japan into a nationwide movement. The no-fault movement had the goal of achieving certain standards of quality, Qc - gradual improvement of quality beyond certain standards. The Qc programs were really both about product quality and aimed at a general revolution in the organisation at the shop floor level.

Quality management activities in the US are aimed at building quality management systems that include all aspects of a firm's operations. Responsibility for quality assurance belongs to the top management of the firm, not limited to the functions of a specialised quality management service. Administrative control over the execution of the quality assurance plan and clear planning of production for quantity and quality have also become characteristic features. At the same time, the approach to development and improvement in the USA is much more individualistic and less group-oriented, the preference is given to the development of innovation and ensuring cardinal changes [18]. Analyzing the American experience in the field of quality, we can note the following characteristic features: strict quality control of product manufacturing using methods of mathematical statistics; attention to the process of production planning by volume and quality indicators, administrative control over the execution of plans; improving the management of the firm as a whole. The measures taken in the US to constantly improve product quality have not been slow to have an impact on closing the quality gap between Japan and the US, which has intensified competition in the global market, turning it into a single, global market.

Particularly noteworthy is the purposeful work of Western European countries in documenting quality systems, developing common requirements and procedures capable of ensuring high quality production, as well as the introduction of product and quality system certification by a third independent party. The distinctive features of the European approach to solving the problems of quality are: a legislative basis for all work related to the evaluation and confirmation of quality; harmonization of requirements of national standards, rules and certification procedures; creation of a regional infrastructure and network of national organizations authorized to carry out the certification of products and quality systems, laboratory accreditation, registration of quality professionals, etc. [19]. Thus, the links between the models of quality improvement in organizations operating in the UK are reflected in Figure 1.5.

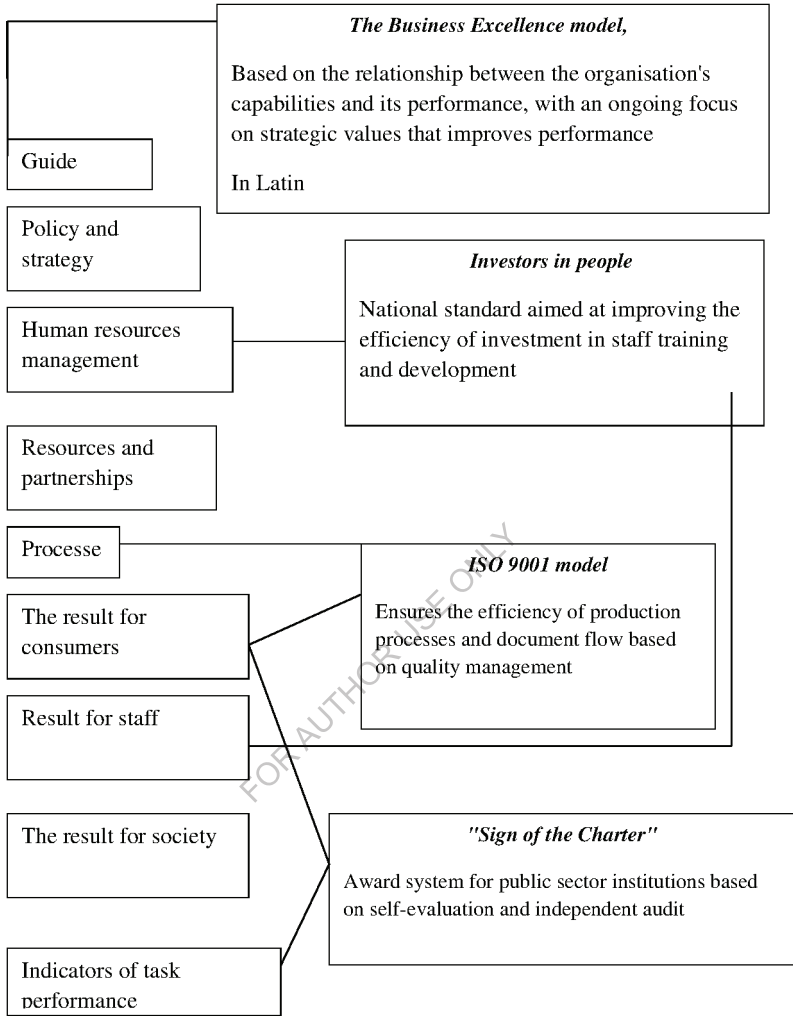


Figure 1.5 - Links between quality improvement models in UK organisations

An integral part of the total quality management concept in all industrialised countries are the following two main elements: 1) continuous improvement of products and services, focusing on customers, optimisation of business processes and communications, and 2) change management, i.e. changes aimed at developing and improving organisational culture, employee training and development and knowledge management.

1.4 Analysis of quality measurement and assessment methods in the organisation

Product quality management refers to actions carried out in the creation, operation or consumption of products in order to establish and maintain the required level of quality. In order to manage quality effectively, it is necessary to be able to quantify it. Quality assessment is the first and basic step in any enterprise's quality management system. The science of quantitative methods of quality assessment is called qualimetry (from Latin *qualitas* - quality and Greek *metreo* - to measure, to measure). The object of study in qualimetry is the general principles and methods of quality assessment, and the subject of the study is a set of properties of the products of human labour.

All methods used in qualimetry can be divided into two groups: differential and complex. Differential methods are used when assessing the main quality. The main (singular) quality, the quality, is identified with a single defining, dominant property, characterising the use value of a given labour product, provided that all its other properties are abstracted away. The choice of such a property must be conditioned and supported by a sufficiently long and sustained practice of using it precisely as a synonym for the quality of that labour product. For example, for concrete, the main quality may be strength, for fuel it may be calorific value, for a wristwatch it may be the average daily rate (accuracy). Differential quality assessment is a necessary step in any comprehensive assessment. Comprehensive quality assessment can be seen as a two-step process: the first is the assessment of simple properties; the second is the assessment of complex properties of the object and its quality as a whole. In carrying out each stage, it is necessary to work out a number of operations that are listed in the algorithm for comprehensive quality assessment of any object (subject or process) [20]. The diagram in Figure 1.7 shows that, unlike the differential method, the comprehensive method assesses quality by a set of properties.

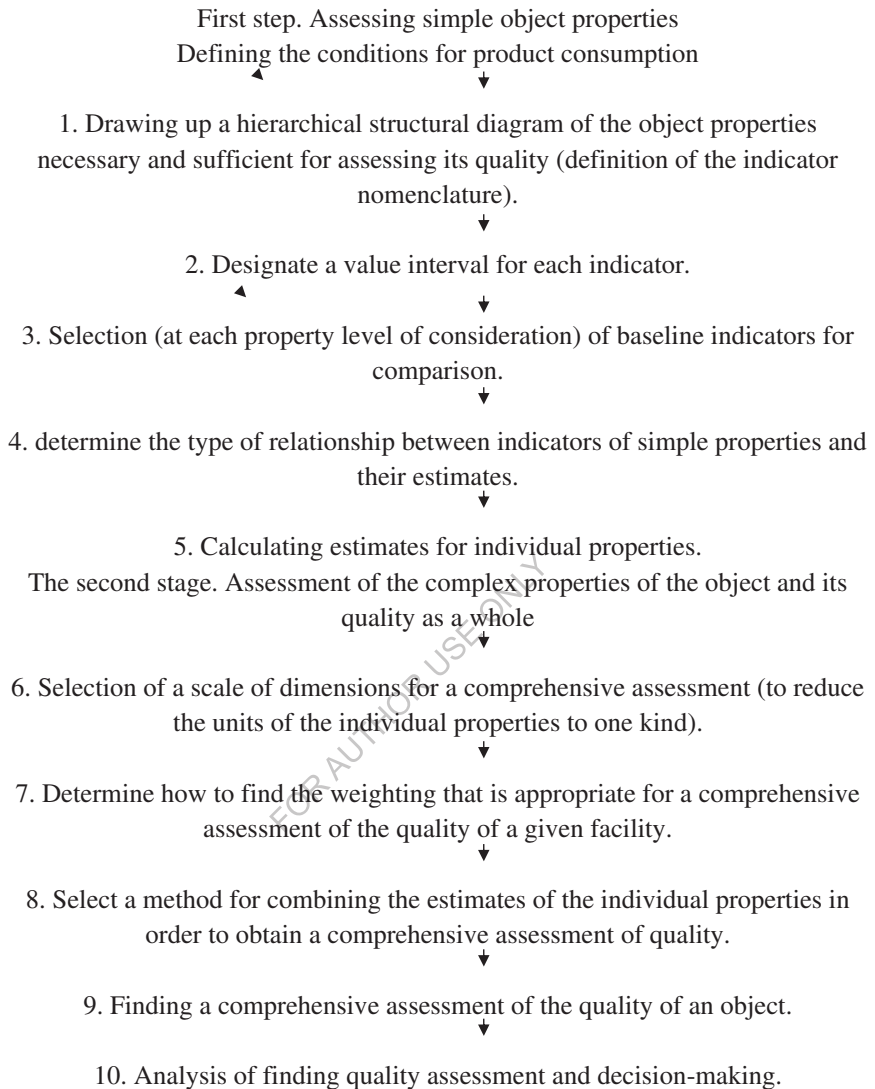


Figure 1.7 - Integrated site quality assessment algorithm

Product quality assessment refers to the result of the assessment, namely, the comparison of the quality indicators of the assessed products with the reference values. This assessment can be presented in quantitative and qualitative form. In quantitative form, the assessment is expressed by a single number, which is a value of a complex quality indicator that reflects a certain set of product properties. In qualitative form the evaluation is presented as a

statement as to whether a product in a given set of properties meets, exceeds or falls short of the requirements of a given market. The reference values are the indicators selected for comparison. As a rule, they are the values of product peers. An analogue is a product that has a similar functional purpose.

Quality assessment refers to the evaluation of the conformity of a product with the requirements contained in its documentation. Quality assessment should be preceded by the selection of quality indicators against which the assessment is made [21]. With regard to product quality assessment, it is carried out at such stages of the life cycle as: marketing and market research; design and development; production; operation or consumption.

At the marketing and market research stage, the following types of work are carried out to assess the quality level of products: establishing the class and group of products; determining the conditions of product use; establishing consumer requirements, including those of foreign markets.

At the stage of product design and development, the following assessment activities are performed: selection and justification of the range of indicators that determine the technical level of the product; identification of the best domestic and foreign counterparts of commercially developed products and the choice of a reference specimen; selection based on patent documentation of the best technical solutions and establishment of performance indicators that determine the optimal level of product quality; determination of numerical characteristics of quality indicators of the assessed product

At the stage of production, the following types of work are performed to assess product quality: establishing the scope, frequency, methods and means of quality control and testing of products; determining the actual characteristics of product quality indicators based on the results of control and testing; statistical assessment of product quality level; assessment of quality level of product manufacturing by performance indicators; obtaining the results of assessment and decision-making.

The following types of evaluation work are carried out at the operation or consumption stage: establishing the conditions of operation or consumption of products; establishing the method of collecting and obtaining information on the quality level of products in operation or consumption; establishing the actual characteristics of the quality level indicators of the product resulting from its operation or consumption; determining the overall useful effect of operation or consumption of products; calculating the overall costs of development, production and operation or consumption of products

The first section reviews the theoretical foundations of quality assessment in the enterprise. The definition of such concepts as "quality",

"products", "product quality" is given, the concept of "product quality" based on the quantitative characteristic of one or more product properties is improved. The experience of quality management in the country and abroad, analyzed the methods of measurement and evaluation of quality in the enterprise. The quality as an object of road economy is investigated.

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2 THE METHODOLOGICAL BASIS OF QUALITY ASSESSMENT IN THE ORGANISATION

2.1 Analysis of quality measurement and assessment methods in road sector organisations

Different indicators are used at different stages of road construction product development to assess quality. For example, physical indicators are used at the stage of work execution to assess quality, and operational indicators at the stage of road operation. The need to ensure an appropriate level of quality in production activities leads to the formation of a certain nomenclature of indicators for assessing the compliance of manufactured products with the technical specifications. For a comprehensive assessment of product quality, standardised groups of indicators are used: purpose, reliability, ergonomic, aesthetic, technological, economic, transportability, unification, patent-legal, environmental, and safety. Depending on the class of products and the stage of their production, the corresponding groups of indicators are applied, and, if necessary, additional groups are introduced [22]. These indicators are determined depending on their belonging to one or another group by various formulas. Reliability indicators define the property of products to maintain their ability to work for some time before failure. Serviceability is defined as the state of a product at which it is still capable of performing the specified functions. These include the four indicators of uptime, durability, maintainability and serviceability. Fail-safe is the property of a product to remain functional for some time before failure occurs. The probability of failure is assessed, as is the rate of failure. Failure is a failure to perform. Fatigue life is characterised by operating time (average operating time) before the first failure. The operating time is the amount of work done in hours or other units (t-km, million tonnes). For example, the operating time of a pavement or overpass before the first overhaul. Longevity is the ability of a product to remain in service until it reaches a limit state. It is characterized by the average service life or life span. Service life is the period of operation of the object until the limit state specified in the technical documentation. For example, the average service life of coatings is the onset of their normative roughness, roughness, wear and tear. Service life refers to the exhaustion to the limiting standard condition. For example, the depreciation of asphalt pavement to the limit equality. Repairability is the adaptability of a product to prevent and repair failures. It is characterized by the duration or labor intensity of repairs. Maintainability is the ability of a product

to retain its characteristics during storage and after the period of storage and transportation. It is characterized by the average retention time (storage time of cement in storage, emulsion decay period). All reliability indexes are calculated from statistical test data. Technological indexes characterize the degree of manufacturability. Indexes of manufacturability are equal to labor input, mechanization, technological equipment, material capacity, collectability. Ergonomic indicators are used to assess the activities of the system man-environment, man-machine, man-product. Four groups of indicators are used: hygienic, physiological, psychological, anthropometric. Hygienic indicators are used to assess working area illumination, temperature, humidity, dustiness, toxicity, radiation, noise, vibration (fluctuations), characterizing compliance of products with hygienic conditions of life and human capacity for interaction with these products. A group of physiological and psycho-physiological indicators determines the product's compliance with human psychological features. These include indices of compliance with a person's strength, speed, sound, visual capabilities, as well as his or her ability to perceive and process information [23]. Anthropometric indicators determine the appropriateness of the size, shape and weight of the human body in conditions of interaction, for example, with the bulldozer arms, which is important in the design of work organization. Ergonomic indicators are defined by measuring the characteristics of the environment and psychological indicators of a person, and assessing them by comparing them with the corresponding baseline values. The aesthetic indicators of products are characterized by four group indices: information expressiveness (originality, style conformity), form rationality (functional and constructive peculiarity, ergonomic conditionality), integrity of composition (graphic expressiveness of elements, volume and space solution, plasticity) and perfection of production execution (purity of contours and joints, accuracy of finishing). The indicators of transportability, uniformity, environmental, patent-legal are rarely used in assessing the quality of road construction products [24]. Product quality indicators can be determined in different ways: measuring, calculation, organoleptic (by the senses), expert, sociological. In road construction the most common methods are measuring, calculation and expert methods. To assess the quality the actually measured indicators are compared to the baseline. The totality of the baseline indicators characterizes the optimal level of product quality for a given period of time. The optimal values of the quality indicators achieve the maximum effect from the operation of the product at a given cost of its production and operation. Determining the optimal values of quality indicators makes sense if the optimization criteria and constraints are established.

In the production or operation of road construction products there is a need to assess their quality. The quality of works, structures and roads is assessed. When manufacturing or operating road construction products it is necessary to assess their quality. Quality assessment of works, structures, roads is carried out using different methods: differential, complex, expert, mixed. The differential method is based on the application of single indicators for assessing the level of quality, when it is established whether and by how much the level of the basic sample is achieved. The differential method is based on the application of single indicators for assessing the level of quality, when it is established whether and to what extent the level of the basic sample has been achieved. The quality level of the product is determined for each i -th indicator:

$$k_i = \frac{P_i}{P_{i6}} \text{ or } k_i = \frac{P_{i6}}{P_i}, \quad (2.1)$$

where P_i is the value of the i -th product quality indicator;

P_{i6} is the value of the i -th baseline indicator.

Consequently, the increase corresponds to an improvement in quality. This method is appropriate if the level of quality of the product can be objectively assessed by a single indicator. For example, in the case of soil compaction, the degree of compaction is a sufficient indicator, i.e. if $k_i = \delta/\delta_{tp} \geq 1$, and the quality of the soil compacted corresponds to the reference sample. If n indicators are used to evaluate product quality, two options are possible: product quality is high enough if n indicators have $k_i \geq 1$, the product quality is low if for n indicators $k_i < 1$. If at least one of the indicators has $k_i \geq 1$, the differential method will not give a definite answer. A thorough analysis with weighting coefficients is required, and in such cases a complex method is used. The differential method is widely used in road construction to evaluate the quality of raw materials, materials, roadbed construction works, rough pavements, pavement strength, etc.

The composite method for assessing the level of product quality is applied with several differential indicators. This method allows for a more comprehensive characterisation of product quality through a system of indicators. Comprehensive assessment is particularly relevant in road construction when comparing structures, completed construction projects (bridges, houses), road sections, multi-parameter mixtures (asphalt and cement concrete), when their quality is assessed by geometric, mechanical, thermal and other properties. For a comprehensive assessment of road-building products using different methods: the main indicator, integral index, a comprehensive method with an assessment of the mean value, the expert method, assessment using the function of desirability, the method of defects. Comprehensive evaluation by the key indicator is used if it is a determinant for the main product and there are regularities that make it possible to establish the relationship between the key

indicator and its components. For example, when assessing the quality of pavements, the main indicator will be the pavement quality, which determines the transport and operational performance of the roadway (the main product essence). There is a definite relationship between pavement equity and its constituents (web strength, layers). A comprehensive assessment with an integral index takes the economic factor into account. For products with a service life of more than one year, which is typical for any road construction product (bridges, houses, roads in general), and with constancy over time. Comprehensive evaluation by an integral indicator takes into account the economic factor. For products with a service life of more than one year, which is typical for any road construction product (bridges, houses, roads in general), and when the annual effect and the annual operating costs are constant over time, the integral indicator

$$K_{\mu} = \frac{E}{3_{\kappa}f(t)+3_{\vartheta}} \text{ or } K_{\mu} = \frac{3_{\kappa}f(t)+3_{\vartheta}}{E}, \quad (2.2)$$

where E is the total annual effect of production operation in physical units, t-km, h, pcs.

Zk - one-time capital investment in road construction, UAH

f (t) is a coefficient that is set according to the lifetime of the product, t years;

Ze - total annual operating costs, UAH

The value of f (t) is calculated according to the formula

$$f(t) = \frac{E_n(1+E_n)^{t-1}}{(1-E_n)^{t-1}}, \quad (2.3)$$

where En is the standard cost-effectiveness ratio, En = 0.15.

The value of f (t) as a function of t is shown in Table 2.1

Table 2.1 - Coefficient *f(t)* as a function of road life

t	1	2	3	4	5	6	7
f(t)	1	0,381	0,262	0,174	0,149	0,139	0,134

If the products are used throughout the year, the integral indicator

$$K_{\mu} = \frac{\vartheta_n}{(3_{\kappa}+3_{\vartheta})} \text{ or } K_{\mu} = \frac{(3_{\kappa}+3_{\vartheta})}{\vartheta_n} \quad (2.4)$$

Comprehensive method of quality level assessment by integral indicator is used when assessing options of technology and organisation of facilities construction, selecting compositions of SDB and MDZ, rational mixtures at the ASBZ, CBR, as well as when assessing the quality level of the final product. The integrated method of quality level assessment by weighted average indicators is applicable when it is difficult to assess the main indicator.

The simplest method is the one in which the quality level is calculated according to the following expression

$$k_{\kappa} = \prod_{i=1}^n P_i, \quad (2.5)$$

where P_i is the differential quality indicators.

An example of this method is the measurement of road quality by crash severity of the final indicator:

$$a_n = a_1, a_2, \dots, a_n,$$

where a_i are the individual crash rates.

The method does not take into account the significance of properties.

The following expression is convenient for estimating:

$$k_{\kappa} = \sqrt[n]{\prod_{i=1}^n P_i}, \quad (2.6)$$

The most common composite assessment using an arithmetic weighted average

$$k_{\kappa} = \sum_{i=1}^n b_i P_i \quad \text{or} \quad k_{\kappa} = \sum_{i=1}^n b_i K_i, \quad (2.7)$$

where b_i are weighting coefficients;

P_i is the value of the i -th product quality indicator;

K_i is the quality level of the i -th indicator;

n is the number of quality indicators of the products being assessed.

These expressions are valid if $\sum_{i=1}^n b_i = 1$ or 100%, then

$$k_{\kappa} = \frac{\sum_{i=1}^n b_i P_i}{\sum_{i=1}^n b_i}, \quad (2.8)$$

Based on formula (2.8), a modified formula is used in road construction

$$k_{\kappa} = \frac{5P_5 + 4P_4 + 3P_3}{P_5 + P_4 + P_3}, \quad (2.9)$$

where P_5 , P_4 , P_3 are the number of activities that received an 'excellent', 'good' and 'satisfactory' grade, respectively.

This expression also does not take into account the weighting of product properties.

The value of a comprehensive quality assessment is that it allows the impact of any property (product indicator) on quality as a whole to be established.

The expert method of assessing product quality is used when differential or comprehensive methods are not possible or difficult to apply, as well as in product certification, evaluation of final products, road sections, etc. Expert quality assessment consists of four stages: preparatory, evaluation, processing of expert judgement and analysis of the result. During the preparatory period, working and expert groups are formed, product classification is developed, the nomenclature of indicators is established, questionnaires with scales are prepared, a minimum, but sufficient number of experts is selected. Based on the product classification and choice of indicators, an evaluation scale in the form of

a product quality model is constructed. In some cases, instead of a model, an evaluation is made using a scale table. In road construction the assessment usually takes place in one round - when quality of road pavements, bridges, houses and road commissioning are assessed. Expert judgement processing comes down to determining the mean and standard deviation coefficients. Coefficients of variation are calculated to assess the objectivity and reliability of expert opinions on individual properties or indicators:

$$k_B = \frac{\sigma_i}{a_i}, \quad (2.10)$$

where σ_i is the average deviation for the i -th property;

a_i is the average value of the assessment of the i -th property.

The following criteria are used to assess validity: $k_v \leq 0.1$ - consistency is high; $k_v = 0.1 \dots 0.15$ - agreement is above average; $q_v = 0.16 \dots 0.25$ - medium coherence; $q_v = 0.26 \dots 0.35$ - agreement is below average; $k_v > 0.35$ - agreement is low. If the consistency is below average, a second round of questioning is conducted.

The method of defects is based on taking into account the various types of non-conformities that occur in road construction and repair work. A defect is defined as any non-compliance of a product with established regulatory requirements. Road construction products, at any stage of their creation and operation, usually have some kind of defect. The more there are, the lower the quality level. The defect method is based on a relative assessment of the number and weighting of defects, which are taken into account by the defectiveness coefficient:

$$k_d = \frac{1}{n} \sum_{i=1}^m q_i b_i, \quad (2.11)$$

where q_i is the number of defects of a given type in the sample n ;

b_i is the weighting coefficient of a defect of a given type, %;

m is the total number of defects in the sample;

n is the sample size.

The lower the number of defects and the lower their weighting, the lower the K_d values and the higher the quality level.

Level of product quality

$$K_K = 1 - \frac{K_d}{K_{db}}, \quad (2.12)$$

where K_{db} is the value of the baseline defect level of the product assessed.

Product certification is a formal assessment of the quality level provided by a set of organizational, technical and economic measures aimed at the timely introduction of scientific and technological achievements into production and systematic improvement of the quality of manufactured products [25]. All the

above methods have been analyzed in detail and the results of the analysis are summarized in Table 2.2.

Table 2.2 - Quality assessment measurement methods in road maintenance

Name of method	The essence of	Advantages	Disadvantages
1	2	3	4
Differential method	Based on the application of unit indicators for assessing the level of quality, where it is established whether and to what extent the level of the reference sample has been achieved. The product quality level for each i-th indicator is determined: $k_i = \frac{P_i}{P_{i6}}$ or $k_i = \frac{P_{i6}}{P_i}$	Widely used in road construction to assess the quality of raw materials, materials, roadbed construction, rough surfacing, pavement strength, etc.	If at least one indicator has, the differential method will not give a definite answer.
1	2	3	4
Comprehensive method	Applied with several differential indicators, it allows a more complete characterisation of the product quality by means of a system of indicators. Comprehensive assessment is particularly relevant in road construction when comparing the structures of completed road sections, multi-parameter mixtures, when their quality is assessed by geometric, mechanical, thermal and other properties.	It makes it possible to establish the impact of any property (product indicator) on quality as a whole.	A cumbersome and time-consuming method to use
Expert method	The essence of expert judgement is to subjectively choose from a number of situations the best one, which in the expert's opinion is the best in terms of the generalised indicator.	The use of expert methods relies on in-depth specialist knowledge and the ability to summarise their own and the world's experience of research and development on a particular issue	A disadvantage of the method is that the subjective opinion of the expert is decisive

Method of defects	<p>It is based on taking into account the various types of non-conformity that occur in road construction and repair work. A defect is defined as any non-compliance of a product with the established regulatory requirements. It is based on a relative assessment of the number and weighting of defects, which are taken into account by the defect ratio.</p> $k_d = \frac{1}{n} \sum_{i=1}^m q_i b_i$ <p>The lower the number of defects and the lower their weight, the lower the Kd value and the higher the quality level.</p>	This method is simple, clearly characterises product quality and is widely used in assessing the quality of pavements, bridges and roads	The disadvantage of this method is that it is based on a relative assessment of the number of defect weights
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Quality assessment in road maintenance can be done on two fronts during construction and operation of the road. In turn, these two areas can be considered as a whole road quality as well as by element. Table 2.3 presents the results of an analysis of road construction quality assessment methods.

Table 2.3 - Analysis of road construction quality assessment methods

Name of method	The essence of	Advantages	Disadvantages
1	2	3	4
Construction of the entire road			
Point method [26]	<p>5 (excellent) - when the work has been carried out with special diligence, craftsmanship and technical performance, exceeding the values required by regulations and standards, or when the project performance has been improved without increasing the estimated cost of the works in question, and it has been delivered on first submission, provided that upon acceptance of the work the number of actual deviations equal to the limits of the set tolerances amounts to 5% of the total number of measurements for the first group and up to 10% for the second gr</p> <p>a score of "4" (good) - when the work is completed in full compliance with the design, regulations and standards and handed over from the first presentation, provided that, when accepting the work, the number of actual deviations equal to the extreme values of the specified tolerances is between 5.1% to 8% of the total number of measurements for the first group of works and 10.1% to 25% for the second group;</p> <p>Point "3" (satisfactory) - when the works are performed with minor deviations from the technical documentation, agreed by the design organization and the client, but do not reduce the reliability, strength, durability, appearance and performance indicators, provided that, upon acceptance of the work, the number of actual deviations equal to the extreme values of the specified tolerances is from 8.1 to 10% of the total number of measurements for the first group of works and from 25.1 to 50% for the second group.</p> <p>The quality of the road as a whole is measured by a weighted average of the individual structural elements, taking into account their significance:</p> $K_a = \Sigma K_i * n_i$	The criteria for assessing the quality of road products are clearly defined in theory	The disadvantage of this method is that there are no formulas for calculating quality. It is theoretical

Continuation of Table 2.3

1	2	3	4
Construction of a motorway by element			
Weighted average of individual types of road construction works, taking into account their weighting	$K_i = \sum_{i=1}^{\alpha} p_i * m_i,$ where is the quality rating for this type of work / excellent, good, satisfactory; - Weighting coefficient; α is the number of works comprising the structural element	Quality is assessed on the basis of the weight of the construction work	No theoretical assessment
Assessment of the quality of the earth bed [26]	$K_{\text{эл}} = 0,40p1 + 0,20p2 + 0,15p3 + 0,10p4 + 0,10p5 + 0,05p6$ de p1 - p6 - estimate per type of work for the earthwork	A comprehensive product quality assessment is underway	No expert opinion is taken into account
Assessment of the quality of drainage [26]	$K_{\text{вод}} = 0,45p1 + 0,30p2 + 0,25p3$ de p1 - p3 - estimate per type of work for drainage	The weights of each indicator are taken into account	No overall assessment
Assessment of the quality of the base course [26]	$K_{\text{осн}} = 0,30p1 + 0,20p2 + 0,20p3 + 0,15p4 + 0,10p5 + 0,05p6$ de p1 - p6 - estimate per type of work for the base of the pavement	Quality is assessed for each indicator	A cumbersome method in assessing product quality
Assessment of the quality of asphalt and concrete pavements [26]	$K_{\text{асф}} = 0,25p1 + 0,20p2 + 0,20p3 + 0,15p4 + 0,10p5 + 0,05p6 + 0,03p7$ de p1 - p7 - estimate per type of work for asphalt pavements	Assessment of the types of work being carried out	No theoretical assessment
Quality assessment of cement concrete pavements [26]	$K_{\text{бг}} = 0,20p1 + 0,20p2 + 0,15p3 + 0,15p4 + 0,10p5 + 0,10p6 + 0,05p7 + 0,05p8$ de p1 - p8 - estimate per type of work for cement concrete pavements	Quality is assessed on the basis of the weight of the construction work	A cumbersome method in assessing product quality
Quality assessment of bridges	$K_{\text{м}} = 0,25p1 + 0,20p2 + 0,20p3 + 0,15p4 + 0,10p5 + 0,05p6 + 0,05p7$ p1 - p7 - estimate per type of work for bridge	The weights of each indicator are	No theoretical assessment

[26]	construction	taken into account	
Assessing the quality of pipes [26]	$K_{tp} = 0,20p1 + 0,20p2 + 0,20p3 + 0,15p4 + 0,15p5 + 0,10p6$ p1 - p6 - assessment per type of work for pipes	A comprehensive product quality assessment is carried out	No overall assessment
Assessment of the quality of the environment, road belonging and landscaping	$K_{o6cr} = 0,25p1 + 0,20p2 + 0,20p3 + 0,10p4 + 0,10p5 + 0,05p6 + 0,05p7 + 0,05p8$ p1 - p8 - estimate per type of work for setting, road accessory and landscaping	Quality is assessed for each indicator	No expert opinion is taken into account
Assessing the quality of coatings [26]	$K_n = 0,40p1 + 0,35p2 + 0,25p3$ p1 - p3 - evaluation of smoothness, grip and ergonomic properties of the pavement on a five-point scale	Assessment of the types of work being carried out	No expert opinion is taken into account

Consequently, it can be concluded that methods for assessing the quality of road construction in general relate to expert methods, and element-by-element quality assessment methods to a comprehensive method, as each element-by-element method is assessed using several differential indicators. Table 2.4 presents the results of an analysis of existing methodological approaches to assessing the quality of road maintenance.

Table 2.4 - Analysis of road maintenance assessment methods

Name of method	The essence of	Advantages	Disadvantages
1	2	3	4
Maintenance of the road in general			
Ratio method [27]	Deflection strength coefficient, pavement flatness coefficient, wheel traction coefficient, pavement wear coefficient, final crash coefficient, safety coefficient, traffic coefficient	A clear assessment of the quality of the road behind the coefficients	No final quality assessment of the road
Controlling the maintenance of the earth bed [28]	In order to prevent deformations of the roadbed from surface and groundwater it is necessary to ensure quality maintenance of the	Requirements for the maintenance of the earth bed have been defined	Evaluation is carried out on a theoretical basis

	<p>roadbed. Control of bed maintenance includes correction of minor damages without adding soil, grading of slopes and shoulders, removal of minor landslides, rockslides, debris flows and scree, eradication of weeds by cutting bushes on shoulders and slopes. In addition, to prevent over-wetting of the soil bed, air gullies are constructed on the shoulders during the thawing period and then filled in.</p>		
<p>Control of roadway maintenance [28]</p>	<p>The roadway must be cleaned of dirt and debris and traffic control lines must be applied. The pavement is protected against damage during frost heaving. Fast drying of the subgrade must be ensured in order to protect the pavement from damage. The joints in the concrete pavement must be systematically cleaned of dirt and filled with plastic materials. The surface treatment of black pavements must be carried out regularly, at least every 5 years, and also when the roughness coefficient of the pavement is insufficient. When carrying out maintenance work on the road, it is necessary to check that the devices are clean and in good working order.</p>	<p>Theoretically describes the requirements that must be met when maintaining the carriageway</p>	<p>No final quality assessment of the road</p>
<p>Control of right-of-way maintenance [28]</p>	<p>When maintaining the right-of-way it is necessary to check the quality of drainage from the right-of-way, its cleaning and the maintenance of older roads. During the spring, summer and autumn periods rainwater and other water runoff from the right-of-way must be constantly ensured by planning and giving it the necessary longitudinal and transverse gradients.</p>	<p>Checking the quality of work in right-of-way maintenance</p>	<p>No final quality assessment of the road</p>

Maintenance of roads in winter conditions [29]	In areas with abundant and persistent snow cover, the openings of pipes and small bridges should be well covered before snowfall, and in the spring period snow ditches should be dug along drainage systems, the beds at man-made structures should be cleared and the structures themselves should be cleared of ice and snow. Ice and snow should be removed from the roadway shoulders and slopes during road operation. When there is ice on the roadway, slip-resistant material should be used on gradients and descents. Heavy and medium-slush road sections are protected with snow guards.	Winter maintenance measures for roads	The evaluation is carried out on a theoretical basis on the basis of
Control of road maintenance in special conditions [29]	Maintenance of roads in special conditions requires additional control of the following works: control of landslides in mountainous conditions, landslides, scree, debris flows and sand drifts. To prevent landslides in mountainous conditions, rainwater and meltwater runoff from landslide areas is regulated by planning their surface and installing a network at an acute angle to the direction of landslide movement	Additional control is carried out when road maintenance is carried out in special conditions	Evaluation is carried out on a theoretical basis on the basis of

Deflection modulus coefficient is the ratio of the actual value of the equivalent modulus of elasticity of the road structure, determined experimentally in the design period of the year, to the required value of the modulus of elasticity, calculated from the composition and traffic intensity. The road structure is considered to be strong if $K \geq 1$. Coefficient of pavement flatness is the ratio of the limit equality, normalized for different types of pavements, to the physical flatness of the pavement, determined with a thickness gauge. When measuring the evenness of the pavement by a thickness gauge, the following limit values of equality at the acceptance of the pavement cm / km not more: asphalt concrete - 80; cement concrete - 80; macadam after treatment with organic binder material and surface treatment - 110; macadam, gravel - 150.

Coefficient of Relative Grip - determined by the ratio of the actual coefficient of longitudinal traction of the wheel to the pavement, determined

experimentally, to the required road safety conditions. The value of this coefficient determines the need for pavement roughening works.

The final crash rate is determined on the basis of crash statistics as the product of specific crash rates that take into account the impact of the individual plan and profile elements of the road. Each of these partial coefficients is the ratio of the number of accidents on a road section with different plan and profile elements to the number of accidents on a reference horizontal straight section of road with two lanes, a carriageway width of 7.5 m, a rough surface and hardened shoulders.

A safety factor is the ratio of the maximum speed of a road section to the maximum speed of vehicles entering that section. For a more accurate and complete safety assessment, a comprehensive or integrated indicator including technical, ergonomic and economic indicators is used.

Traffic intensity coefficient is the ratio of the calculated traffic intensity for a given road category, to the actual traffic intensity as recorded. Road sections provide traffic of a given intensity if $K \geq 1$.

Consequently, we can conclude that methods for assessing the quality of road maintenance in general refer to the comprehensive method, and methods for assessing quality by element refer to the expert method.

2.2 Analysis of quality management methods

Any quality management system is based on the application of advanced quality management methods. The main methods of product quality management are represented by two groups of methods: statistical methods and exotic methods.

Statistical methods include:

- Statistical process control consists of measuring the deviation of relevant process parameters over a period of time. This is done by constructing control charts (the so-called Schuchart charts - named after the American engineer who developed them in the 1920s) The following values are used to construct a control chart:

- t is the average value of the parameter;

- q is the standard deviation of the parameter;

- n is the sample size;

- x is the average value of the sample.

- statistical acceptance inspection (a decision to accept or reject products based on the results of the sample inspection).

Quality control, irrespective of the perfection of the methods used for this purpose, primarily involves separating defective products from quality products. At the current stage of development of quality management enterprises focus their attention not on detection of defects, but on their prevention, i.e. in the conditions of quality management the problem of quality improvement is solved by prevention, but not by detection of defects. Statistical acceptance inspection is among the most important means of defect prevention in product quality management. Defect prevention is carried out by establishing strict requirements for the quality level of products, raw materials, components from supplier and consumer, and checking compliance with these requirements on the basis of mathematical statistics methods. The main task of the statistical acceptance control is to ensure with high reliability of the quality evaluation of the products, and unambiguity of mutual recognition of the results of quality evaluation between supplier and consumer, carried out by the same plans of sampling control. Statistical methods are described in sufficient detail in the national literature. In Ukraine, there are still specialists in academic, scientific and university spheres, who have a good command of the theory of these methods. However, in the practice of our enterprises, only statistical control is used, and not always qualified. As for the application of statistical process control, it is a very rare phenomenon. At the same time, the initial stage of the Japanese revolution in quality management is associated with the mass application of statistical methods. The use of statistical methods presupposes that the enterprise has a group of specialists skilled in these methods.

The remaining methods, in terms of application in domestic practice, can be classified as exotic.

1. The seven quality tools. Easy-to-use methods for implementing quality control in the workplace.

2. Group methods of analysis and problem solving. In the domestic literature, this is reflected in the form of quality circles. It consists of organising groups of employees in an enterprise who deal with quality management problems on a voluntary basis. A quality group is an entity formed on the principles of voluntary participation and activation of human factor, whose main task is continuous education, research, studying and solving of practical problems in the quality management system. The main objective of all theoretical and practical activities of the Quality Circles is to improve the competitiveness of the product. This main objective is served by all the specific goals that the senior management sets for the members of the clubs.

3. Failure Cause and Effect Analysis (FMEA) methods. First developed and applied in the Shuttle programme. It is most often applied at the

design stage. Its essence consists in the fact that the most critical failures of a product possible in operation are expertly assumed. Possible consequences of these failures are assessed (expertly). Depending on the severity of these consequences, the possible causes of failures are analysed and constructive and technological decisions are made to avoid these causes.

4. The quality function distribution (deployment) method (QFD). Concludes in the translation of quality requirements from one language to another, i.e. allows the transformation of consumer requirements for the organisation's product, defined at the marketing stage, into technical characteristics of the organisation's activities at the development and production stage, using a requirements matrix ("quality house").

5. Taguchi method. An engineering and economic method in which product quality and cost are considered together and linked by a common characteristic is called the loss function. Minimisation of the loss function is considered from both the consumer and producer perspectives.

Table 2.5 presents the main quality management methods and their application depending on the stage of the product life cycle.

Table 2.5 - Matrix for the application of quality management methods

Name of the quality management method	Name of the product life cycle stage					
	marketing	designing	Technological preparation	production	implementation	Maintenance and repair
Statistical process control				+		
Statistical acceptance control			+	+	+	
Seven quality tools	+	+	+	+	+	
Group methods for analysing and solving problems	+	+	+	+	+	+
Analysis of the causes and consequences of failures		+	+			
Allocation of quality	+	+	+	+		+

functions						
Taguchi methods		+	+			

It is very important to continuously build up and update the matrix of quality management methods used in the enterprise. For road products, the method of structuring the quality function is the most appropriate.

The second section examines the methodological basis of quality assessment in the enterprise. Methods for measuring and assessing quality in the road construction industry are analysed. A quality function allocation method for assessing the quality of road construction has been chosen.

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3 ASSESSING THE QUALITY OF THE PRODUCTS OF ROAD MAINTENANCE ORGANISATIONS

3.1 Improving the deployment method of the quality function of road maintenance organisations

The Structural Quality Function (SQF) method, sometimes called quality function deployment, was pioneered by Mitsubishi in 1972. The essence of the SQF method is that customer requirements should be 'deployed' and specified step by step, from pre-investment studies to pre-sales preparation. This method is a technology for designing products and processes to translate customer wishes into technical requirements for products and process parameters for their production. The basic idea of technology (SFC) is the understanding that there is a big difference between the consumer properties and the product parameters set in the standards. Technology (SFC) is a sequence of actions by a manufacturer to transform the actual quality parameters of a product into technical requirements for products, processes and equipment. Such authors as Shapiro V.D., Mazur I.I. consider product planning in the framework of SFC method in 8 stages [20] on road product planning this stage includes 7 stages.

The first step (SFC), is to find out and clarify consumer requirements. The main task of the (SFC) method is to make the consumer's opinion clear to the engineer. The (SFC) method also performs other tasks. For example, it allows comparing the performance of the designed product with that of competitors, as well as determining the economic and technical feasibility of creating the product.

The second step (SFC) is the ranking of consumer claims. For ranking, it is necessary to assess the rankings of the consumer demands that were identified in the first step. The list of consumer requirements needs to be ranked in order of importance.

The third stage (SFC) is to develop the engineering specifications. In this stage, a list of engineering characteristics of the future product is drawn up.

The fourth step (SFC) calculates the dependencies between consumer requirements and engineering characteristics. At this stage, we do not need detailed information. We can be satisfied with concepts such as strong, medium and weak correlation. Once the relationship between consumer requirements and engineering characteristics is established, it becomes clear which engineering characteristics have the strongest impact on the satisfaction of certain consumer

requirements, - weak, and which ones do not create any added value for the consumer at all.

The fifth stage (SFC) is the construction of the 'roof'. The SFC is very often referred to as the 'quality house' precisely because of the 'roof' in which the relationships between the engineering attributes themselves are spelled out.

The sixth step (SFC) determines the weighting of engineering attributes, taking into account the ranking of the importance of consumer requirements as well as the relationship between consumer requirements and engineering attributes.

In step seven, the influence of competitors is taken into account.

3.2 Determining the characteristics of road products

A modern road is a complex engineering structure consisting of structural elements, structures and is characterised by a large number of geometric parameters, physical properties and performance characteristics as well as transport and operational indicators. The functional purpose of roads is to provide continuous, comfortable and safe vehicular traffic at high speed, with permissible dimensions, axle loads and overall weights, at all times of the year and in all weather conditions. Roads are designed to serve the interests of consumers, users of road services - drivers, passengers, vehicle owners and road transport enterprises - who use roads to travel or transport goods and passengers and pay taxes, charges and other contributions in one form or another for this purpose.

From the point of view of the consumer the most important are transport and operational indicators provided by the road: continuity, speed, convenience and safety of traffic, capacity and level of loading, permissible dimensions, level of road service. The mentioned properties can be taken as consumer properties of the road because all road transport performance indicators depend on them and first of all car performance, cost of transport, time of cargo and passenger delivery, fuel consumption and tyre wear, car repair and maintenance costs, etc. All these indicators are to a large extent derived from the use properties of roads. Also derived from use values are requirements for geometric and physical characteristics of the road and its condition of transport operation. Therefore, the main and ultimate responsibility of road authorities is to maintain and improve the utility of roads by maintaining them to a high standard and by improving their parameters and characteristics in the process of rehabilitation or reconstruction. Road speed and traffic safety are among the main useful features of a road that determine its quality and condition. Different road design concepts

and speed values are used in technical and economic calculations for the organization of road traffic, as well as in the assessment of road condition. The design or design speed and the average speed of traffic flow are the most important in road design. Design speed is usually taken to mean the maximum safe speed at which a single vehicle or a group of vehicles can proceed in a particular road surface and weather condition. These are normally dry or wet surface conditions and favourable weather conditions. All road elements and their combinations should be so designed as to enable a single or individual vehicle to travel safely in all road sections at the design speed under the specified weather and surface conditions. Geometric requirements for roads derived from design speed shall be taken as the maximum permissible in difficult road sections. The design speed has a direct influence on the quantitative values of the geometric parameters of the road and its construction cost, its operational performance requirements and the costs of maintenance and repairs during operation. The actual average speed of traffic flow determines all key performance indicators of road transport: cargo and passenger delivery time, vehicle productivity, transportation costs, etc. The greatest influence on the average speed of traffic provides the design speed, which determines the geometric parameters of the road and requirements for its transport and operational condition, as well as the intensity and composition of traffic, which affects the range of speed fluctuations and mutual interference in the traffic flow. Actual speeds, on the other hand, integrally reflect the influence of all geometric parameters and traffic, traffic flow and weather conditions at a given point in time on the conditions and mode of operation of vehicles.

3.3 Identifying consumer requirements for road products

In order to create a quality road product (road) it is necessary to determine what properties it should have according to the requirements of the user. To do this, the method of expert judgement is used. The method of expert judgement is practically a variation of the survey method, and both terms are used equally in describing it. The main peculiarity of this method which distinguishes it from mass surveys is that the most competent persons in the investigated area, i.e. experts, are the respondents. This determines the technique of information collection, analysis and use. Already at the stage of calculating the sample and determining its size, it is possible to note the difference in approaches to sampling in mass and expert surveys. In mass surveys, the larger the sample, the better; the criterion is representativeness, sufficient representativeness to solve research problems. In expert surveys, however, as the number of persons

enrolled as experts increases, the quality of information does not improve but rather deteriorates. It has been experimentally determined that this happens when the number of experts exceeds 25-30 (and sometimes 10). Of course, this is related to the research problem, but there are certainly not many real experts who are capable of being experts.

Expert questioning can be used in the study of all aspects of activity, but it is particularly effective in diagnosing, predicting, assessing the states of social objects, and in decision-making. The central issue of the method of expert judgement is the selection of experts. This procedure ultimately determines the value of the results obtained. Expert interviewing is divided into varieties according to the level of standardisation of procedures and work technique. According to the level of standardisation of procedures, it is possible to use a free and formalised interview or a questionnaire with open-ended questions. The technique refers to the use of scoring, ranking, paired and sequential comparisons by experts. The scoring technique means that the expert evaluates certain factors in scores or allocates them according to given criteria, and scores are assigned when processing the data. In ranking, the expert must order the items suggested by assigning the appropriate rank to each item. In pairwise comparisons from the pairs of judgements made by the researcher, the expert indicates the most preferred in each pair according to a given criterion. In a sequential comparison, the expert determines the importance or significance of each factor over the others. When collecting information using expert judgement, it is also possible to organise expert group work. The advantage of expert methods is their relative simplicity and applicability for forecasting almost any situation, including under conditions of incomplete information. An important feature of these methods is the possibility to forecast qualitative characteristics of innovation activities, e.g. changes in consumer needs and market demand or the impact of the environment on the production and consumption of certain goods. The disadvantages of expert methods include the subjectivity of experts' opinions and the limited nature of their judgement. However, these disadvantages cannot overshadow the fact that it is one of several methods that can provide quantitative information about the qualitative attributes of an object. In innovation, this method can be very useful both in selecting management decisions and in supporting the utility theory method.

The creation of a quality road product from a consumer's perspective is influenced by requirements such as:

- Speed of movement (X1);
- Continuity (X2);
- Convenience and safety (X3);

- Capacity and load level (X4);
- Permissible dimensions (X5);
- Level of road service (X6);

The questionnaire asked for a ranking of 6 factors affecting the quality of road products. The most important factors are given a score of 1, the next most important factor is given a score of 2 and so on. The results of the questionnaire survey were summarised in Table 3.1

Table 3.1 - Results of questionnaire ranking of factors influencing the quality of road products

Usualisation - designations	Factors	Consumers who are interviewed										$\Sigma \Sigma X_{ij}$ j	$\Delta =$ ΣX_{ij} - $\Sigma \Sigma \Sigma$ $X_{ij} /$ n	Δ^2
		1	2	3	4	5	6	7	8	9	10			
X1	Travel speed	3	3	6	5	6	3	6	6	5	3	46	25	625
X2	Continuity	2	2	1	2	2	2	1	2	2	2	18	-3	9
X3	Convenience and safety	1	1	2	1	1	1	2	1	1	1	12	-9	81
X4	Capacity intensity level	4	5	4	4	4	4	4	4	4	5	42	21	441
X5	Permissible dimensions	5	4	5	3	3	5	5	3	3	4	40	19	361
X6	Level of road service	6	6	3	6	5	6	3	5	6	6	52	31	961
$\Sigma \Sigma X_{ij}$		1	1	1	1	1	1	1	1	1	1	210		2478

The data in Table 3.1 show that, according to the majority of experts' judgment, convenience and traffic safety have the greatest influence on the quality of road products - X1, which received the lowest sum of the ranks. The second most important factor is continuity of traffic - X2, allowable dimensions, capacity and load level, traffic speed and level of road service.

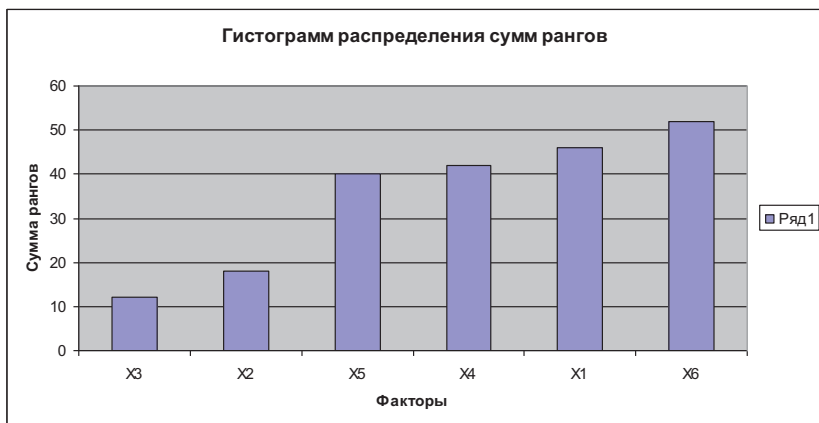


Figure 3.1 - Histogram of the distribution of rank sums

Thus, the quality of road products from the consumer's perspective is primarily influenced (Table 3.1):

- Traffic comfort and safety (X1);
- Continuity of motion (X2).

In order to identify requirements to improve the quality of road products it is necessary to assess the accuracy and reliability of the obtained results of the conducted experience. To this end it is necessary to assess the degree of consistency in the thoughts of the interviewed experts and the significance of the obtained results of the experience. The degree of expert agreement is characterised by the coordination coefficient.

$$W = \frac{12S}{m^2(n^3 - n)}, \quad (3.1)$$

where m is the number of professionals interviewed;

n is the number of factors that are analysed.

$$W = \frac{12 * 2478}{10^2 * (6^3 - 6)} = 0.75$$

The significance test for the correlation coefficient is calculated using Pearson's criterion.

$$X^2 = \frac{S}{\frac{1}{12}m*n*(n+1)} \quad (3.2)$$

$$X^2 = \frac{2478}{\frac{1}{12} * 10 * 6 * (6 + 1)} = 70.71$$

The calculated Pearson criterion (70.71) exceeds the tabulated value (18.3), suggesting that the consistency of expert opinions is not random.

The results of the accuracy and reliability assessment carried out by expert judgement are presented in Table 3.2

Table 3.2 - Assessing the credibility of the expert survey results

Number of interviewed professionals, m	Number of criteria, n	S	Coefficient of concordance, W	Pearson criterion, X ²	
				Calculated	Tabular
10	6	2478	0,75	70,71	18,3

The results of the experiment can be considered statistically significant for the creation of quality road products.

Thus, in order to create quality road products, attention must be paid to convenience and traffic safety and to continuity of traffic.

3.4 Structuring the road product quality function

It is suggested that the road product quality function be structured in seven steps (Figure 3.2). The first step involves the road maintenance staff in identifying user requirements for road products. The consumer's wishes are collected, processed and the importance of the requirements from the consumer's point of view is determined. The second stage involves ranking the consumer requirements. For the ranking, the ratings need to be assessed

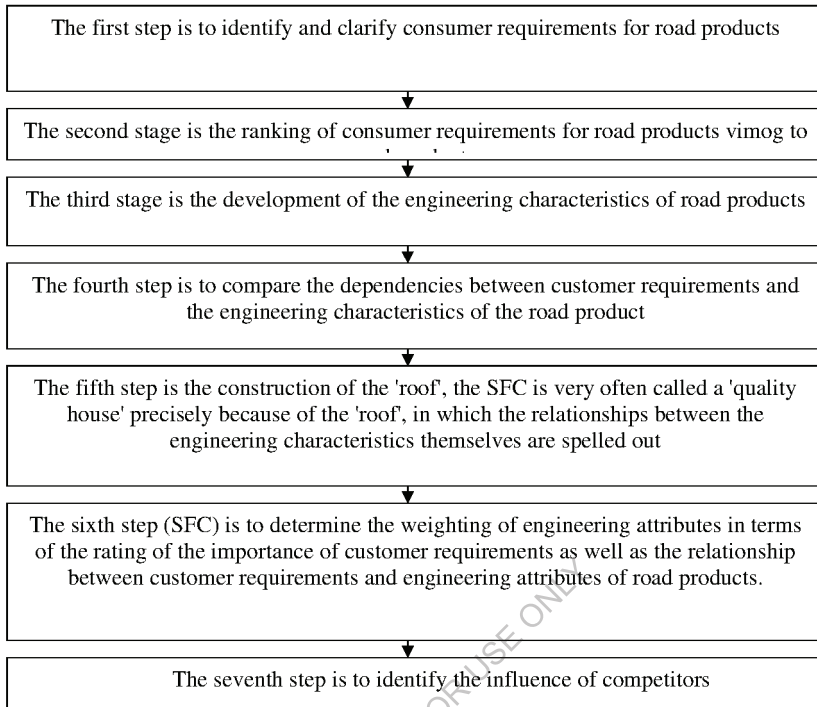


Figure 3.2 - Algorithm for structuring the road product quality function

consumer requirements that were identified in the first stage. The third step is to develop engineering specifications for the automotive one. The fourth step uses matrix diagrams to show the closeness of the relationship between consumer requirements and quality parameters. In the next step, a "roof" is constructed, in which the relationship between the engineering characteristics themselves is spelled out. In the future, this relationship will be taken into account when optimising the whole system. The sixth stage of structuring the quality function involves determining the weighting of engineering characteristics, taking into account the importance rating of consumer requirements, as well as the dependence between consumer requirements and engineering characteristics of road products. We calculate the relative importance of each engineering characteristic by multiplying the relative weight of consumer requirements by the numerical indicator of the relationship between consumer requirements and engineering characteristics identified in the fourth step. In the seventh step, the influence of competitors is taken into account. The results of the proposed methodology from stage one to stage seven are shown in Figure 3.3.

Требования	Требования потребителя	Характеристики					Оценка конкурентов				
		Собстоимость работ	Качество	Скорость движения	Безопасность движения	Стабильность перевозки					
							1	2	3	4	5
Скорость движения	3	Δ		Θ							
Непрерывность	4			О							
Удобство и безопасность движения	5		О		Θ						
Пропускная способность и уровень нагрузки	4	Θ			О						
Допустимые габариты	3	Δ	Θ								
Уровень дорожного движения	3		О						Δ		
Цели (необходимые значения Параметрлв качества)		min	100%	120 км/год	100%				Высокая		
Абсолютное значение, од.		42	51	39	39				36		
Относительное значенне, %		20,3	24,7	18,8	18,8				17,39		
Оценка конкурентов	1						- - - Конкурент А - - - Наш продукт - - - Конкурент Б				
	2										
	3										
	4										
	5										

Figure 3.3 - Road product quality function structuring matrix

The following symbolism has been adopted to determine the closeness of the relationships: Θ - strong relationship, О - medium relationship, Δ - weak relationship; their respective weights are 9,3,1. The absolute value describes the importance of the quality parameters and is calculated by multiplying the links by the weighting of the customer requirements. Thus "cost of transportation" affects the "carrying capacity" component (its absolute weight is $4 * 9 = 36$) but it also affects the "allowable dimensions" requirement ($3 * 1 = 3$), speed ($3 * 1 = 3$). As a result, the significance of this service characteristic is $36 + 3 + 3 = 42$ absolute weight units or (20.3% relative weight).

Thus, the existing method of structuring the quality function has been adapted to the economic conditions of the road sector by justifying the consumer requirements and characteristics which must meet the road products. The use of

the adapted method of structuring the quality function in the road sector will ensure the compliance of road products with consumer requirements.

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CONCLUSIONS

The monograph examines the main subsystems of roadworks quality management, justifying a three-level hierarchy of levels of roadworks quality management. The integration of quality into the business system has been carried out. The pyramid of quality in the road sector is built, this pyramid shows that there is a branching of quality in the road sector depending on the type of activity.

The analysis of existing approaches to the essence and concept of "quality of work" has been conducted, also researchers have contributed their interpretation of the concept of "quality of work" in the road sector. Thus, "quality of work" in road maintenance is a quantitative characteristic of the system of useful properties of the road. The experience of countries in quality management has been considered and the main approaches to quality management have been highlighted. The methods of quality assessment measurement have been considered, each method has been analyzed according to the stage of the life cycle of works, the method of structuring the quality function has been chosen to assess the quality of road works. The methods of quality assessment of construction and operation of the road are analyzed. These methods of assessing the quality of road works as a whole refer to the expert method, and methods of quality assessment by elements to the complex method, because each method by elements are assessed by means of several differential indicators. Based on the analysis of road quality assessment methods, a questionnaire survey was carried out to identify the factors that influence the quality of road works from the user's point of view. As a result of the questionnaire, the primary consumer criteria have been identified as: convenience and safety of traffic, continuity of traffic, speed of traffic, capacity and load level, permissible dimensions and level of road service. On the basis of the generally accepted algorithm of the method of structuring the quality function, the algorithm of structuring the quality function for the road works, which consists not of eight but seven stages of the process of structuring the quality function, taking into account consumers' requirements for the road works and their characteristics, based on which the matrix of structuring the quality function of road works has been constructed. The indicators for assessing the quality of road works in the road sector were also justified, they were the six indicators proposed by consumers, the paper defined the essence and method of measurement of each of the named indicators.

The practical significance of the results is to provide the ability to construct a road in a customer-oriented way, and the management to assess the

quality of the road work more objectively and to be able to incentivise staff when the road work is done well.

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