

QUALITY FEATURES OF PARTS AND COMPONENTS OF AGRICULTURAL TRANSPORT VEHICLES FROM THE PERSPECTIVE OF UNDERTAKING RESEARCH AND DEVELOPMENT PROJECTS

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Purpose: This publication aims to assess the significance of quality features of components and spare parts of agricultural vehicles from the perspective of manufacturers engaged in research and development (R&D) activities.

Design/methodology/approach: The study used the method of reconstruction and interpretation of the subject literature, which made it possible to define the areas relevant to the development of the research model. This provided the basis for preparing an evaluation sheet, developed through a combination of literature exploration and a study conducted among deliberately selected domain experts. A fuller understanding of the role of quality determinants in enterprises' R&D activities was obtained by verifying the model among deliberately selected enterprises from the agricultural machinery sector.

Findings: From the perspective of enterprises undertaking R&D activities, particular importance is assigned to those quality determinants of parts and components of agricultural vehicles that directly affect the organization's ability to generate innovation and build a lasting competitive advantage. The analysis indicates that technical and innovative factors play a particularly important role. Although enterprises' R&D activities focus primarily on determinants related to innovativeness, functionality, and broadly understood technical quality, environmental, regulatory, and economic conditions should also be taken into account. These factors significantly influence the directions of R&D work and the efficiency of its implementation.

Research limitations/implications: One limitation of the study is the potential subjectivity in the selection and interpretation of determinants, which may differ depending on the specificity of the industry, product type, or operating conditions. In particular, the agricultural machinery sector may have specific priorities. Another limitation is the lack of consideration of changes over time, as the significance of individual determinants may evolve with technological development, regulatory changes, or increasing environmental pressure. Additionally, the analysis does not fully account for organizational and competence-related factors, such as human resources and innovation culture, which have a significant impact on the effectiveness of R&D activities but were not directly included in the set of determinants. Further research

should therefore focus on quantitative operationalization, empirical verification, and extending the scope of analysis to include contextual and dynamic factors, enabling a more complete understanding of the role of quality determinants in enterprises' R&D activities across different sectors.

Practical implications: The theoretical implication of the study is the definition of quality attributes of components and spare parts of agricultural vehicles in the form of a theoretical and design-oriented research model, in which the weight of each attribute depends on the significance assigned to a given determinant. The practical implication is the formulation of recommendations for the design and production of spare parts, as well as for communication with customers regarding the fulfillment of specific quality requirements.

Social implications: The social implications of research on the quality determinants of parts and components, especially in the context of R&D activities, are multidimensional and extend beyond the technical or industrial sector. They include improvements in safety and quality of life, environmental protection, the development of skills and the labor market, as well as an overall increase in the innovativeness and competitiveness of the economy.

Originality/value: The originality of the study lies in the development of a multi-criteria approach to assessing the quality determinants of parts and components of agricultural vehicles from the perspective of R&D activities. The results may serve as a basis for building synthetic indicators that aggregate different determinants into a single quality assessment measure. Such models can be used in industrial practice as tools supporting investment and design decisions.

Keywords: parts and components of agricultural vehicles, research and development activities, product quality, operation.

Category of the paper: research paper.

1. Introduction

Modern enterprises operating under conditions of increasing market competition and dynamic technological change are increasingly focusing their activities on the development of innovative product and process solutions (Damanpour, 1991; Damanpour, Schneider, 2006; Ivanov, Dolgui, 2020). A key element in building competitive advantage is research and development (R&D) activity, which enables not only the improvement of existing products but also the creation of new solutions that respond to changing market needs as well as regulatory and environmental requirements (Singh et al., 2020; Li, Liu, Ren, 2024).

Parts and components of machines are of particular importance in this context, as they constitute fundamental structural elements affecting the quality, reliability, and efficiency of entire technical systems (Nowak, Kijek, Domańska, 2015). In the agricultural machinery sector, where operating conditions are characterized by high variability and heavy loads, the quality of components becomes especially important (Li, Zhang, Chen, 2024). Their properties determine not only the technical efficiency of machines, but also the continuity of agricultural production processes, which directly affects food security and farm efficiency (Kim, Kumar, Kumar, 2012).

The literature emphasizes the multidimensional nature of the quality of parts and components, covering both technical features, such as reliability, durability, performance, and service life, as well as economic, logistical (Achetoui, Mabrouki, Mousrij, 2019), environmental, and formal factors (Zhang, Zhang, 2023). At the same time, the importance of individual determinants may vary depending on the application context and industry specificity. In practice, this means the need to identify and hierarchize those factors that most significantly influence enterprise decisions concerning product design, production, and improvement.

In this context, it becomes particularly important to determine which quality determinants of parts and components of agricultural vehicles are critical from the perspective of manufacturers undertaking R&D activities. Such activities, aimed at creating innovations and improving products, require consideration not only of technical aspects, but also of economic, environmental, and regulatory conditions. The identification of these factors enables better targeting of R&D processes and may increase the efficiency of their implementation (Wolfert, et al., 2017).

Despite the broad interest in quality and innovativeness in the literature (Füller et al., 2021), there remains a research gap concerning the comprehensive assessment of the significance of individual quality determinants in the context of R&D activities, particularly in the agricultural machinery sector. Therefore, it is justified to undertake research aimed at developing an evaluation model that enables the hierarchization of quality factors and their relation to innovation processes carried out by enterprises.

The aim of this paper is therefore to identify and assess the level of significance of selected quality determinants of parts and components of agricultural vehicles from the perspective of enterprises' R&D activities. Achieving this aim will allow for a better understanding of the role of individual factors in innovation processes and may provide a basis for developing tools supporting decision-making in the area of product design and improvement.

The structure of the paper is subordinated to the adopted research objective. The first part presents the theoretical foundations concerning the quality of parts and components and R&D activities. Next, the research methodology is described, including the method of constructing the research model and the procedure for assessing the determinants. The following part presents the analysis of the empirical research results, while the paper concludes with a discussion of the results, final conclusions, and recommendations for business practice and further research.

This approach fits current research trends related to the integration of quality engineering, innovation management, and sustainable development, constituting a contribution to the development of knowledge in the field of managing R&D processes in industrial enterprises.

2. Literature review

Quality constitutes one of the fundamental paradigms of contemporary management and production engineering, determining both the efficiency of manufacturing processes and the competitiveness of enterprises in the market (Tortorella, Fettermann, 2018; Sony, Antony, Douglas, 2020). In a systemic approach, quality is not solely a product feature, but the result of the integrated impact of design, technological, organizational and logistical processes that collectively shape the organization's ability to meet customer requirements as well as technical and regulatory standards (Psomas, Antony, 2017).

In quality management, the process approach plays a special role, as it assumes that quality is created at every stage of the product life cycle - from design, through production, to operation and service (Peng, Jiang, Wang, 2024). In this context, both quality assurance and quality improvement methods are important, as they enable the systematic reduction of process variability and nonconformity costs (Zheng, Zhou, 2025).

In the field of production engineering, quality is closely related to the technical parameters of products and to the stability and repeatability of manufacturing processes (Chaciński, Jaskólski, Pałubicki, 2022). Key aspects include reliability, durability, functionality and dimensional-material consistency (Ng, Jin, Nee, 2011), which directly affect the efficiency of production systems and their ability to meet operational requirements (Wang et al., 2016; Wang et al., 2024).

The contemporary approach to quality also takes into account its multidimensional character, covering not only technical aspects but also economic, environmental and organizational factors (Brundage et al., 2018). In conditions of global competition and growing regulatory requirements, quality becomes a key factor determining the innovativeness of enterprises and their ability to adapt to a changing market environment (Gligor, Esmark, Holcomb, 2015).

As a result, quality in management and production engineering should be viewed as a complex system of dependencies integrating design, manufacturing and product use, while its effective management is a condition for achieving a sustainable competitive advantage (Kaynak, 2003).

In relation to parts and components of vehicles, quality is a multidimensional category encompassing a set of characteristics that determine the product's ability to fulfill specific functions under operating conditions. In the classical sense, quality is understood as the degree to which user requirements, technical standards and expectations regarding product reliability and durability are met (Cooper, 2004).

In the case of machine parts and components, particular importance is attached to properties such as reliability, durability, functionality, efficiency and service life. Reliability refers to the probability that an element will function correctly under specified conditions and over

a specified period, whereas durability and service life describe the component's ability to maintain the required technical parameters over a long period of use. Efficiency, in turn, determines the degree of effectiveness of the entire system in which the given element operates (Davenport, Harris, 2007).

Another important aspect of the quality of parts and components is their compatibility with cooperating elements, including dimensional, material and functional compatibility. Misalignment in this regard may lead to reduced efficiency of the entire technical system or to its premature wear (Wang, Zhang, Duan, 2012).

The literature also emphasizes the importance of factors supporting quality, such as maintainability, ease of servicing and availability of spare parts. These elements directly affect operating costs and the continuity of machine operation, which is particularly important in sectors with high usage intensity, such as agriculture.

Today, non-technical criteria also play an increasingly important role, encompassing economic, ecological, logistical and formal aspects. These include, for example, the price-to-quality ratio, impact on the natural environment, compliance with standards and certification, as well as the quality of information provided by the manufacturer. As a result, the quality of parts and components should be treated as a systemic category, encompassing both the product's physical attributes and its market and operational environment (Jardine, Lin, Banjevic, 2006).

Research and development (R&D) activities are one of the key elements of the modern knowledge-based economy (Ahn, Minshall, 2022). They encompass systematic creative work undertaken to increase the stock of knowledge and to use it to develop new practical applications, including new products, processes and services or their significant improvements.

From an enterprise perspective, R&D plays a strategic role, as it enables the building of competitive advantage based on innovation (Ferreira, Fernandes, Ferreira, 2020). These processes include both basic and applied research, as well as development work aimed at implementing research results into economic practice.

In the context of management and production engineering, R&D activities are closely linked to the processes of design, testing and improvement of technical products. It is particularly important to identify and optimize the quality parameters of products that determine their functionality, reliability and operational efficiency.

An important aspect of R&D activities is their interdisciplinary nature, combining knowledge from engineering, economics, management and environmental sciences. The contemporary approach to innovation also involves taking into account regulatory, ecological and social factors, which influence the direction of technological development of enterprises.

In practice, R&D also includes cost analysis, technological risk assessment and product life-cycle studies. Digital technologies, such as monitoring systems, data analysis and Internet of Things-based solutions, are also becoming increasingly important, as they support decision-making processes and increase the efficiency of development work.

The relationship between the quality of parts and components and R&D activities is bidirectional. On the one hand, R&D results determine the quality level of products by introducing innovative design, material and technological solutions. On the other hand, the analysis of quality and its determinants serves as a starting point for initiating new R&D projects.

In practice, this means that identifying critical quality features of components can serve as a basis for defining the directions of technological development of enterprises. Particularly important are those features that affect the reliability, durability and economic efficiency of products, as they determine both user satisfaction and market competitiveness.

Consequently, the quality of parts and components and R&D activities should be considered mutually interconnected domains that together shape enterprises' ability to create innovations and maintain a competitive position in the market.

3. Material and method

3.1. Research aim and hypotheses

The research hypotheses presented below were formulated in direct relation to the aim of the study, namely to determine the significance of quality features of parts and components of agricultural vehicles from the perspective of manufacturers making decisions in the area of research and development (R&D):

- H1:** *In the decision-making process regarding the directions of R&D works of manufacturers of parts and components of agricultural vehicles, technical features (reliability, durability, safety, efficiency) are assessed as more significant than features of a logistical, formal or after-sales nature.*
- H2:** *The level of significance assigned to innovativeness and modernity features determines the prioritization directions of R&D activities in companies producing parts and components of agricultural vehicles.*
- H3:** *Features related to long-term operational efficiency (durability, service life) are an important criterion for resource allocation in manufacturers' R&D activities.*
- H4:** *Environmental aspects have relatively low importance in the R&D activities of manufacturers of parts and components of agricultural vehicles.*
- H5:** *Logistical and after-sales factors play a supporting role in the quality assessment from the R&D perspective and do not constitute the main determinant of decisions regarding the development directions of parts and components of agricultural vehicles.*

3.2. Research implementation scheme

In order to ascertain opinions regarding the level of significance of quality features of components and spare parts from the perspective of manufacturers undertaking R&D work, and also to verify the needs and challenges in improving them, a cycle of studies was conducted. These included selected experts (purposely chosen representatives of micro, small, medium, and large enterprises in the agricultural machinery sector; specialization: production of parts and components of means of agricultural transport).

The research was conducted from November 2025 to April 2026. In the first stage of the research, as a preparatory study[A⁰] the author used the methods of literature review[A⁰¹] and an expert survey[A⁰²]. The preparatory study conditioned the conduct of the main study [B⁰³]. The research scheme is illustrated in Figure 1.

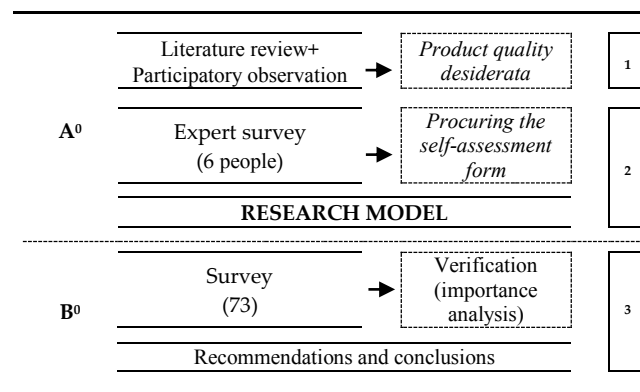


Figure 1. Research implementation scheme.

Source: Author's own elaboration

In summary, the research included a preparatory phase and the main study. The preparatory phase involved literature research, participant observation, and an expert survey involving six experts, which resulted in the identification of product quality requirements and the development of a self-assessment sheet that served as the basis for the research model. A survey was then conducted among 73 respondents to verify the significance of the analyzed features and to formulate recommendations and conclusions.

3.3. Formulating the research model [A⁰]

Using the method of reconstructing and interpreting available studies and subject literature supported by the author's observations, a catalog of desiderata was selected, relating to the significance of quality features of components and spare parts of agricultural vehicles from the perspective of manufacturers undertaking R&D activities. In the next stage, a team of six experts was appointed to work on ideas and solutions in this area.

The knowledge and experience of experts in the area defined by the conducted research was verified on the basis of a competence coefficient determined according to the following formula:

$$K = \frac{1}{2} (K_i + K_a) \quad \text{gdzie } 0 < K \leq 1 \quad (1)$$

The informativeness coefficient (K_i) was determined based on self-assessment (from 0 to 10 points) multiplied by 0.1. The argumentation coefficient (K_a) was determined on the basis of an interview with the expert. Competence, expressing the expert's qualification level, was determined based on practical activities and knowledge of the sector.

The study was based on the author's creative problem-solving method – written brainstorming (brain writing). This brainstorming approach allowed for preparing a list of variables referring to the quality features of components and spare parts from the perspective of manufacturers undertaking R&D work (Table 1).

Table 1.

Quality features of parts and components of agricultural vehicles – perspective of R&D works

Lp.	Determinant	Description	Category
1.	Reliability	is the measure of the ability of a component or part to perform its functions according to the assumptions for a specified period and under specified conditions. It is a feature that defines how effectively an agricultural machine or vehicle can avoid failures or disruptions in its operation, which, in turn, ensures continuity of operation (field work). It can be measured by various indicators, such as time between failures, probability of damage. It is the certainty or predictability that a given component or part will operate as expected under operating conditions.	Technical
2.	Functionality	The range of actions and possibilities that the component or part offers to the user. It defines what tasks can be performed using the given part or component. It is usually described in the form of functional requirements, which specify specific functions, operations and interactions possible within the given system (e.g., the drive system). It is also assessed in terms of effectiveness in accomplishing intended tasks.	Technical
3.	Durability	is the average time elapsed from the start of operation of a part or component to the occurrence of the first failure (MTTF – Mean Time To Failure). In the case of complex products, the key may be the mean time between failures (MTBF – Mean Time Between Failures) that elapses between subsequent failures of the same part or component. The longer the mean time between failures of a given element, the more durable the product.	Technical
4.	Performance	Parts and components allow maintaining the previous performance level of the machine.	Technical
5.	Service life	Specifies the time, use or number of working cycles during which a given part or component maintains sufficient technical parameters to fulfill its function in a reliable and efficient manner. Measuring the product's service life is essential for assessing its durability and planning maintenance and replacement schedules to ensure the continuity of the machine's operation.	Technical

Cont. table 1.

6.	Maintainability	The possibility of preventing failures and extending the life of elements; easy lubrication of moving parts, such as bearings, prevents wear and premature failures.	Operational
7.	Modernity, innovativeness	- Can improve the machine's performance, reduce fuel consumption and increase operator comfort. - Often use the latest technologies, such as telematics systems, automation or IoT (Internet of Things), which can facilitate the monitoring and management of the machine and improve its performance. - Parts or components meet the latest industry norms and standards, which translates into safe and effective use. - Designed in such a way that they can be easily expanded or updated in the future, allowing the machine to adapt to changing needs and working conditions.	Innovations
8.	Safety	Designed and manufactured according to the highest safety standards.	Technical
9.	Compatibility with cooperating elements	Exactly matched to the original element, taking into account dimensions, technical specifications and materials used in production.	Technical
10.	After-sales information, offer, logistics	Manufacturer's information, such as catalog numbers and assembly and operating instructions, can help ensure that a given part or component actually matches the design.	Logistics
11.	Environmental friendliness	- Choice of ecological materials, environmentally friendly, such as biodegradable, renewable materials. - Recycling (restoring used parts to circulation). - Reduction of emissions associated with the operation of agricultural machines, e.g., by improving fuel efficiency. - Durability (the need for less frequent replacement and generating less waste). - Eco-certificates.	Ecological
12.	Compliance with regulations and standards	Quality tested and possessing the necessary certificates confirming compliance with standards.	Formal
13.	Workmanship and aesthetics	Manufactured from high-quality materials and according to specifications, with an aesthetic finish of components and spare parts, such as anti-corrosion coatings and finishes, which can help prevent corrosion and extend the durability of elements. Carefully designed and manufactured elements may indicate attention to quality and detail.	Formal
14.	Warranty conditions	Attractive warranty conditions (duration and scope of warranty, terms of fulfillment) that give the customer certainty regarding the quality and reliability of the products.	Formal
15.	Price	Product analysis in terms of value relative to price and other factors such as durability, reliability and long term costs; the balance between price and quality (parts or components ensuring the optimal functioning of agricultural machines). A higher purchase price of parts can be offset by lower costs related to the need for replacement and repairs in the future.	Economic
16.	Availability	- It is an important factor that can be considered as an indication of quality. - Failure to maintain stocks of spare parts and components may indicate low quality.	Logistics
17.	Delivery speed	Parts and components delivered quickly in case of failure increase the reliability of the machine and minimize losses associated with downtime. A quick response and product availability can demonstrate the company's commitment to full customer service.	Logistics

Cont. table 1.

18.	Supplier reputation	Complying with the accepted quality standards in the execution of components and spare parts can positively influence the manufacturer's image.	Formal
19.	Packaging (aesthetics, information, handling)	The packaging of spare parts and components indicates the quality of the product, effectively protects the contents, facilitates identification and provides additional value to the customer.	Logistics

Source: Author's own elaboration.

The assessment of the quality of components and spare parts of agricultural machines, understood as means of agricultural transport, is a multi-criteria issue covering technical, operational, economic, and environmental aspects. Key importance is attributed to operational properties such as reliability, durability, and service life, which determine the ability of elements to operate for a long time and without failure under specified operating conditions. Functionality and compatibility of parts with cooperating elements are also important complements, as they ensure the proper functioning of the entire technical system.

The evaluation process also takes into account operational aspects, such as ease of maintenance, availability of parts, and delivery speed, which affect the continuity of machine operation and the reduction of downtime. The quality of workmanship, user safety, and the degree of innovation resulting from the application of modern technologies also play a significant role.

Formal and environmental factors, including compliance with applicable standards and certifications, as well as environmental friendliness, are also important. The evaluation is complemented by elements related to after-sales service, such as warranty terms, access to technical information, and supplier reputation. The analysis is further supplemented by economic criteria, particularly the price-to-quality ratio, as well as logistical and operational aspects, including product packaging.

Such a comprehensive approach enables an objective and multifaceted assessment of the quality of components and spare parts, which is crucial for ensuring the effective and reliable operation of agricultural machines.

4. Empirical exemplification

4.1. Characteristics of respondents

The scope of the problem required involving sector specialists in the expert study. Therefore, representatives of enterprises from the agricultural machinery sector, specifically those producing parts and components of agricultural vehicles, were selected for the next stage of the research. These individuals were actively involved in logistics and production processes in their companies. They were also initiators of change, seeking opportunities to implement

new products, undertake innovative activities, apply their own ideas to improve their own work and that of others, and, above all, understand the impact of R&D activities on the quality and performance of the company. Experts were selected based on characteristics such as competence, creativity, the ability to solve complex problems, a positive attitude toward research, constructive thinking, and self-criticism.

The main stage of the expert research was conducted from November 2025 to January 2026. For the purpose of collecting research material, a specially designed assessment questionnaire was prepared, and the data collection process was carried out using direct interview techniques as well as an online format. In total, the study included 73 experts.

The population of the surveyed experts consisted of representatives of manufacturing companies operating in the agricultural machinery sector (specialization: production of parts and components). The respondents were experts representing: micro – 6 persons (8.22%), small – 22 persons (30.14%), medium – 39 persons (53.42%), and large – 6 persons (8.22%) enterprises.

Considering the distribution by predominant type of production, mass or large-batch production was declared by 38.36%, short batch production by 53.42%, and unit production by 8.22%. In 35.62% of the companies, production mainly involved the assembly of components into finished products (purchased from external suppliers), whereas 64.38% of companies indicated a multi-stage production process, in which components and then finished products (parts and components of agricultural vehicles) are created in sequence. For the first group of companies, the majority fall into the category of suppliers of components dedicated to first assembly.

Regarding age distribution, 6.85% of respondents were under 30 years old, 26.03% were in the 31-40 age range, 30.14% in 41-50, 21.92% in 51-60, and 15.07% of respondents were over 60 years old.

Among the respondents, the majority had secondary or higher education, of which 67.12% of owners had higher education, 19.18% – secondary, and 13.70% – basic (vocational) education.

In the course of the research, an attempt was made to interpret the results based on the experts' declarations. For this purpose, a five-point scale was used, where 1 indicated a very low correlation of the parameter with expectations, and 5 – very high. The next step was to obtain the data and interpret it.

The structure of the surveyed sample indicates the predominance of medium-sized and small enterprises, which suggests that the obtained results reflect the perspective of entities characterized by relatively high flexibility and adaptability, an important aspect from the perspective of R&D activities. At the same time, the small share of large enterprises may limit the possibility of fully relating the results to entities with a high level of formalization and greater resource availability.

The predominance of short-batch production and the significant share of mass production indicate the diversified nature of the surveyed enterprises' activities, combining the need for design flexibility with the requirements of process standardization. At the same time, the dominance of multi-stage production processes indicates a high degree of technological integration, which is conducive to conducting R&D activities and implementing innovations.

The profile of respondents, consisting mainly of people aged 31-50 and individuals with higher education, indicates a high level of competence and experience in the surveyed group, which increases the credibility of the obtained assessments. At the same time, the participation of practitioners with diverse levels of education makes it possible to consider both strategic and operational perspectives.

Considering the purposive sampling and the limited size of the sample, the results should be interpreted as characteristic of the analyzed group of enterprises from the agricultural machinery sector. At the same time, they constitute a valuable basis for identifying directions of R&D activities and assessing the significance of quality determinants in industrial practice.

4.2. Research results

The aim of the conducted analysis was an in-depth determination of the level of significance of quality features of parts and subassemblies of agricultural machinery in the context of manufacturers undertaking research and development (R&D) activities. The obtained results (Table 2) enable not only the identification of the most important determinants of quality, but also indicate directions for resource allocation in the processes of product design and improvement.

The analysis of the distribution of ratings indicates a clear dominance of determinants of a technical and innovative nature. Modernity and innovativeness received the highest rating (4.64), which clearly confirms the growing importance of advanced technologies in the machinery and spare parts sector. In practice, this means that manufacturers should concentrate R&D activities on implementing solutions such as automation, telematics systems, and integration with digital technologies. Innovativeness is no longer a distinguishing factor but becomes a standard determining market competitiveness.

The next group, with a very high level of significance, consists of features directly related to the operational efficiency of the product, such as efficiency (4.58), safety (4.58), and reliability (4.52). These results indicate that users expect, above all, trouble free, continuous operation of machines, minimization of downtime, and maximization of operational efficiency. From an R&D perspective, this means the need to intensify efforts on improving structural quality, optimizing mechanical systems, and using materials with increased wear resistance. A particularly important element here is a system level approach that takes into account the interaction of individual components throughout the entire operational life cycle.

Table 2.
Results of own research

Group	Descriptors	1	2	3	4	5	Mean
		% ANSWERS					
Quality features of agricultural machinery components – R&D perspective	Reliability	-	2	2	25	44	4,52
		-	2,7	2,7	34,2	60,3	
	Functionality	-	-	7	25	41	4,47
		-	-	9,6	34,2	56,2	
	Durability	-	2	5	22	44	4,48
		-	2,7	6,8	30,1	60,3	
	Efficiency	-	1	7	17	48	4,53
		-	1,4	9,6	23,3	65,8	
	Lifespan	-	3	8	23	39	4,34
		-	4,1	11,0	31,5	53,4	
	Maintenance	2	4	18	27	22	3,86
		2,7	5,5	24,7	37,0	30,1	
	Modernity and innovativeness	-	-	2	22	49	4,64
		-	-	2,7	30,1	67,1	
	Safety	-	-	4	23	46	4,58
		-	-	5,5	31,5	63,0	
	Degree of compatibility with cooperating elements	2	3	19	29	20	3,85
		2,7	4,1	26,0	39,7	27,4	
	Information, offering, after-sales logistics	1	2	16	33	21	3,97
		1,4	2,7	21,9	45,2	28,8	
	Environmental friendliness	1	3	10	35	24	4,07
		1,4	4,1	13,7	47,9	32,9	
	Compliance with regulations and standards	-	-	7	22	44	4,51
		-	-	9,6	30,1	60,3	
	Care and aesthetics of workmanship	-	4	9	29	31	4,19
		-	5,5	12,3	39,7	42,5	
	Warranty terms	3	8	26	22	14	3,49
		4,1	11,0	35,6	30,1	19,2	
	Price	1	-	4	17	51	4,60
		1,4	-	5,5	23,3	69,9	
	Delivery speed	1	3	17	25	27	4,01
		1,4	4,1	23,3	34,2	37,0	
	Availability	3	7	21	25	17	3,63
		4,1	9,6	28,8	34,2	23,3	
	Supplier reputation	3	7	22	25	16	3,60
		4,1	9,6	30,1	34,2	21,9	
	Packaging (aesthetics, information, handling operations)	2	5	21	29	16	3,71
		2,7	6,8	28,8	39,7	21,9	

Source: own study.

An important conclusion is also the very high importance of price (4.60), interpreted not as the unit cost but as the quality to price ratio. This means that R&D activities should be aimed not only at maximizing technical parameters but also at optimizing costs throughout the entire product life cycle. In practice, this implies employing concepts such as life cycle cost analysis (LCC) or design-to-cost. Manufacturers should strive to achieve a compromise between high quality and an acceptable cost level, which is of crucial importance for customers' purchasing decisions.

High ratings of determinants such as durability (4.48), functionality (4.47), and lifespan (4.34) indicate the significance of long-term operational efficiency. Users prefer solutions characterized by a long operational life and a low frequency of failures. In the context of R&D, this means the need to develop material technologies, improve processing methods, and implement simulation methods that enable the prediction of wear and failures. It is also crucial to employ design oriented towards reliability (Reliability Engineering).

Determinants of medium level of significance, such as environmental friendliness (4.07), availability (4.01), and care and aesthetics of workmanship (4.19), indicate the growing role of sustainable development aspects and quality of workmanship. Although they are not the most important selection criteria, their significance is systematically increasing, due both to legal regulations and changing market expectations. Accordingly, manufacturers should include in their R&D activities the development of technologies that limit environmental impact, such as eco-friendly materials, recycling processes, or solutions that improve energy efficiency.

In contrast, the lowest ratings were obtained by determinants related to logistics, after-sales service, and formal aspects, such as warranty conditions (3.49), supplier reputation (3.60), delivery speed (3.63), and packaging (3.71). These results suggest that these factors are not a key focus in the context of R&D activities. They can be treated as supporting elements that influence the overall perception of quality, but they do not determine it to the same extent as technical and functional parameters. At the same time, it should be emphasized that marginalizing them in operational activities may negatively affect the customer experience; therefore, they should be developed in parallel, although not necessarily as part of main R&D investments.

A synthetic analysis of the results allows distinguishing three levels of quality determinants. The first level includes core quality features, i.e. reliability, efficiency, safety, and durability, which directly determine the product's functionality. The second level consists of supporting features such as functionality, lifespan, and the quality-to-price ratio, which affect the long-term operational efficiency. The third level includes supplementary features related to environmental, aesthetic, and logistical aspects. This structure indicates that users make purchasing decisions primarily on the basis of the product's functional and operational value, whereas the remaining factors serve a differentiating role.

The analytical conclusions clearly indicate that manufacturers' R&D activities should be primarily directed towards the development of technical and innovative features that directly influence operational efficiency, reliability, and safety. Also of key importance is integrating the technological approach with the economic one, which implies the need to design cost-optimal solutions throughout the product life cycle. In addition, environmental aspects and workmanship quality should be developed, as they may constitute a significant element of building competitive advantage in the longer perspective.

In summary, the study results constitute an important basis for formulating R&D strategies in manufacturing enterprises. They enable rational allocation of resources and a focus on those areas that generate the greatest value for the end user. Under conditions of increasing market competition and dynamic technological changes, such an approach constitutes a key factor for success and the long-term competitiveness of manufacturers.

5. Discussion recommendations and conclusions

The presented results allow us to identify a hierarchy of importance for quality characteristics of parts and components of agricultural transport vehicles from the perspective of manufacturers undertaking research and development activities. The obtained results indicate a clear dominance of technical and innovative characteristics, which is consistent with trends described in the literature on quality engineering, product management, and innovation theory. The particularly high ratings for modernity, innovation, reliability, safety, and efficiency confirm that the contemporary perception of quality goes beyond classic functional requirements and encompasses the product's ability to adapt technologically and integrate with solutions characteristic of Industry 4.0. Therefore, it can be assumed that these characteristics constitute potential areas for prioritizing research and development activities by companies.

The significant importance assigned to durability, longevity, and value for money indicates that the development process of new products should take into account long-term operational efficiency and economics of use. These results align with the concepts of total cost of ownership (TCO) and product lifecycle management (LCC), emphasizing the need to design solutions that reduce the risk of failure, extend service life, and reduce operating costs. This means that manufacturers' research and development activities should focus not only on improving technical parameters, but also on increasing the durability and reliability of components and improving their economic efficiency.

The results also indicate that logistical, formal, and after-sales factors primarily serve a supporting role and are not primary determinants of development decisions. A similar trend was observed with respect to environmental aspects, which were rated relatively lower in importance. However, this does not mean that these areas are marginalized, but rather that they are complementary to technical and operational characteristics. It can also be assumed that with the ongoing transformation towards a sustainable economy and the tightening of regulatory requirements, the importance of environmental aspects will systematically increase, also influencing the directions of future research and development.

The study results also allow for the formulation of practical implications for companies producing parts and components for agricultural transport vehicles. It seems justified to focus R&D activities primarily on the development of solutions that increase the reliability, safety,

durability, and efficiency of components. This implies a need for broader use of reliability engineering methods, FMEA analyses, wear modeling, fatigue testing, and durability testing during the design phase of new products. At the same time, the high importance assigned to modernity and innovation indicates the need to intensify efforts related to product digitization, the development of intelligent components, technical condition monitoring systems, telemetry, and solutions that align with the concept of Industry 4.0.

The high ranking of features related to long-term operational efficiency also indicates the need to implement a product lifecycle approach. From the perspective of companies, this means designing products with consideration of total operating costs, the potential for reducing failure rates, and extending the useful life of components. Such an approach can be a crucial element in building competitive advantage and enhancing the value of offered solutions.

The analysis thus allows us to conclude that the hierarchy of quality features is multi-level, with technical, innovative, and operational features being crucial for potential research and development activities, while organizational, logistical, and formal factors play a complementary role. Consequently, it can be assumed that effectively building a competitive advantage for manufacturers of agricultural transport parts and components requires the integration of classic quality engineering methods with modern technological solutions and an approach that takes into account product lifecycle economics.

It should also be emphasized that the conducted study addressed the perceived importance of quality features from the perspective of decision-making in the area of research and development, not the actual mechanisms of enterprise resource allocation. Therefore, the obtained results should be interpreted as a reflection of preferences regarding potential directions for prioritizing R&D activities, rather than as direct evidence of the impact of individual characteristics on actual investment expenditures or the effects of innovation activity. This also serves as a premise for further research that includes analysis of actual decision-making processes, the structure of R&D expenditures, and the results of implemented innovations.

6. Recommendations

In the agricultural machinery sector, the design of parts and subassemblies requires a systemic approach resulting from the specificity of their operation, including high load variability, exposure to environmental factors such as dust, moisture, and corrosion, as well as seasonal use. Consequently, product competitiveness should be analyzed in multi-criteria terms, taking into account technical, economic, and operational properties throughout the entire product life cycle.

The fundamental determinant of competitiveness remains reliability, understood as the ability of a subassembly to perform its intended function without failure within a specified time and under specified operating conditions. In the case of agricultural machinery, reliability is particularly important due to the high costs of downtime during periods of intensive fieldwork. For this reason, design should be based on reliability engineering methods, including FMEA analysis, wear process modeling, and assessment of the fatigue resistance of materials.

Durability and lifespan of components are also important factors, understood as the ability to maintain operational parameters over a long period of use. In this regard, design focused on minimizing the degradation of material and geometric properties is of key importance, especially under cyclic and environmental loads. In the relevant literature, durability is identified as one of the basic parameters determining Total Cost of Ownership, which directly influences users' purchasing decisions.

Another significant dimension is functional efficiency, encompassing the ability of a subassembly to perform its intended functions with optimal use of resources. In practice, this means designing solutions with high operational efficiency and low failure rates, which can be achieved through structural optimization methods and numerical simulations.

The economic efficiency of the product, analyzed from a life-cycle cost perspective, also plays an important role. In the agricultural machinery sector, users' investment decisions are strongly determined by the relationship between purchase cost and operating costs, including service, parts replacement, and losses resulting from downtime. Accordingly, design should aim to minimize total costs while maintaining the required functional parameters.

In the case of spare parts, dimensional and functional compatibility with original components is also of particular importance, as even small deviations may lead to system malfunctions or accelerated wear of cooperating elements. Consequently, a high level of manufacturing precision and quality control constitutes an important element of competitive advantage.

In addition, the growing significance of environmental aspects should be considered, including recyclability, reduced material consumption, and reduction of the negative environmental impact of operation. Although in the agricultural machinery sector these factors do not always constitute a primary determinant in purchasing decisions, their importance is systematically increasing due to tightening regulations and pressure toward sustainable development.

In summary, the competitiveness of parts and subassemblies for agricultural machinery is determined by an integrated set of features, including reliability, durability, functional efficiency, life-cycle economy, and technological integration capability. Therefore, achieving market advantage requires a holistic approach that combines classical quality engineering methods with modern concepts of digitalization and cost optimization.

7. Summary

The aim of this article was to determine the significance of quality features of parts and subassemblies of agricultural machinery from the perspective of manufacturers making decisions related to research and development (R&D) activities. This aim was achieved through the empirical identification and hierarchization of quality determinants, which provide a basis for assessing product development directions in the agricultural machinery sector.

The obtained results clearly indicate the dominance of technical features in assessing the significance of quality determinants. In particular, the highest importance was attributed to innovativeness and modernity, reliability, efficiency, and safety, which confirms that these categories constitute fundamental criteria determining the directions of R&D activities in the analyzed area. At the same time, significant importance was assigned to the quality-to-price ratio, which highlights the economic dimension of quality assessment understood in terms of user value and life-cycle costs.

The study results allowed for a positive verification of the formulated research hypotheses. It was confirmed that technical features have a significantly higher rank than logistical, formal, and after-sales features in the context of R&D decisions (H1). The key role of innovativeness and modernity in prioritizing product development directions was also verified (H2). The significance of features related to long-term operational efficiency, particularly durability and lifespan, was indicated as a criterion for allocating R&D resources (H3). Environmental aspects received a relatively lower level of significance, indicating their supplementary role in current R&D decisions (H4). The study also confirmed the auxiliary role of logistical and after-sales factors in the quality evaluation process from the product development perspective (H5).

In summary, the conducted study enabled the identification of a hierarchical structure of the significance of quality features of parts and subassemblies of agricultural machinery, highlighting the dominant role of technical and innovative determinants in shaping R&D decisions. The obtained results provide empirical confirmation of the need for manufacturers to focus their development activities on improving reliability, durability, and operational efficiency, while simultaneously taking into account the growing importance of economic and environmental conditions in the long term perspective of competitiveness.

The study's main limitations include the purposive sampling of enterprises and the dominant share of medium-sized companies, which accounted for 53.42% of respondents. The sample structure may have influenced the hierarchy of assessed quality determinants, primarily reflecting the perspective of enterprises in this category. Consequently, the obtained results should be interpreted with caution, as their generalizability to the entire population of producers of agricultural transport parts and components is limited.

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