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THE COSTS OF QUALITY IN PRODUCTION ENGINEERING: BUSINESS DEVELOPMENT OR GROWTH INHIBITION?

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Abstract: Maintaining a strong market position is a significant challenge for manufacturing companies, requiring them to meet customer demands through high-quality products while balancing the associated costs. Proper quality management is essential but incurs substantial costs, particularly in terms of production maintenance and prevention. This paper explores the relationship between quality costs and business growth, emphasizing the need for manufacturers to constantly evaluate financial performance in relation to unit production costs and quality maintenance expenses. The study highlights that integrating quality into the production process is a key strategy for preventing business growth inhibition due to escalating quality costs. While investing in quality management can drive business development by improving product quality, customer satisfaction, and operational efficiency, poor management of quality costs can hinder profitability and growth. The findings suggest that strategic handling of quality costs can foster sustainable growth, whereas mismanagement may lead to competitive disadvantages.
Keywords: quality management, production costs, business development, quality control, manufacturing efficiency

1. INTRODUCTION

Quality is particularly important in the operations of enterprises, especially those with a production profile (Li, et al., 2018; Panagiotidou, et al., 2017; Piveteau and Smagghue, 2019). It encompasses both the organizational aspects of production processes and the properties of manufactured products.

The growing significance of quality drives manufacturing companies to produce and offer products that not only meet expectations but also fully satisfy both conscious and unconscious customer requirements—and even exceed them. Furthermore, ensuring the high quality of manufactured products is crucial for securing a competitive position in the market (Gittler et al., 2019; Weckenmann, et al., 2015). Consequently, enterprises focus heavily on quality management and on delivering products that align with customer preferences (Mazur, 2018, 2019).

In recent decades, the importance of quality has been particularly emphasized—quality levels significantly influence the efficiency of production processes and the characteristics of finished products (Jalali, et al., 2019; Voros, 2019). Scholars in the field of quality have proposed numerous definitions to explain this concept, which can generally be divided into four groups:

- Definitions based on product features: These explain quality by referencing the inherent attributes of a product.
- Definitions based on compliance: These interpret quality as the set of product features that ensure conformity with the requirements specified in design documentation.
- Definitions focused on customer needs: These define quality in terms of satisfying customer needs by meeting requirements and ensuring satisfaction with product use.
- Definitions emphasizing consumer value: These consider quality from the perspective of the value it provides to the consumer (Chen and Hu, 2015; Dolgun and Köksal, 2018; Khodeir and El Ghandour, 2019; Klimecka-Tatar, 2017; Klimecka-Tatar and Shinde, 2019). See Table 1 for further details.

Quality can be understood as a set of features that are decisive when choosing a product. These features enable the product to meet customer requirements. While these attributes are difficult to define universally—given their dependence on customer preferences and expectations—they are generally acknowledged to include the following (Ingaldi and Ulewicz, 2018; Ladewski and Al-Bayati, 2019) – Table 1:

- reliability,
- durability,
- functionality,
- practicality.

Table 1.
Practical approach to quality perception (in terms of known quality definitions)

Concept definition		**Strategic assumptions about quality (examples of tools supporting quality determination)**
Quality	• feature set • ensuring compliance with technical requirements • meeting customer requirements and expectations • creating product value for the customer	• creating algorithms for determining significant features (e.g. diagrams, basic areas of the QFD method, etc.) • technical tests enabling the determination of technical measures (destructive and non-destructive tests, statistical control of measurements, etc.) • consumer research, cause-and-effect analysis, Ishikawa diagram, Pareto-Lorenz diagram, etc. • determination of value in relation to customer expectations (economic analysis, production process quotations, process efficiency analysis, value stream mapping, etc.)

The significance of quality for revenue growth in a manufacturing enterprise lies in its ability to drive customer satisfaction, loyalty, and competitive advantage. High-quality products that meet or exceed customer expectations help build a strong brand reputation,

which, in turn, attracts new customers and retains existing ones. This leads to increased sales and market share.
Additionally, quality improvements often result in reduced production costs by minimizing waste, defects, and rework, thereby improving overall efficiency and profitability – which is the basic of Lean Production (Lean Manufacturing). In competitive markets, superior quality allows companies to justify premium pricing, further boosting revenue. Therefore, investing in quality management is not just a cost but a strategic approach to sustainable business growth and enhanced financial performance.
Based on the above definitions, it can be assumed that quality is a set of product features. These features are diverse and relate to both the physico-chemical and technical properties of the product. They are determined at the design stage and after manufacturing the product must comply with the design assumptions. Only then can the product satisfy customers, meet their requirements, and be in line with their preferences.

2. METHODOLOGY OF RESEARCH

The product acquires its characteristics (including an appropriate level of quality) during the production process. However, it is crucial that this process is properly planned, organized, coordinated, and controlled. Additionally, factors such as the production process itself, its type, nature, and the level of employee qualifications significantly influence the outcome. Dynamically changing customer preferences and increasing demands have led many enterprises, particularly those in manufacturing, to focus not only on quality but also on quality management. Quality management is a key function of enterprise management. Its implementation aims to plan and improve quality by: establishing a quality policy within the enterprise, defining objectives for the implemented quality policy, and continuously improving quality (Gittler et al., 2019; Jalali et al., 2019; Kafetzopoulos, et al., 2015). In most companies operating in the market, quality management is based on a structured quality management system. This system is closely tied to the management quality of the organization and system supervision (Rahaman and Zaman, 2013; Rusu, 2016; Stegaru, Moisescu, et al., 2013).
The aim of the research was to analyze the impact of quality costs on business growth in industrial and manufacturing engineering. Specifically, the study sought to examine how the costs associated with maintaining quality - such as prevention, management, and control - affect a company’s financial performance and overall market position. The research aimed to identify strategies that can help balance the costs of quality with the goal of sustaining business development, while also avoiding potential growth inhibition caused by excessive quality-related expenditures.

2. RESULTS AND DISCUSSION

Incorporating quality into processes is a fundamental challenge for every organization. Quality management is a continuous process that involves all employees of the company, with the primary goal of ensuring product quality. One definition highlights that comprehensive quality management is a management philosophy that companies apply to implement all projects and processes. This philosophy is consistently grounded in the active involvement of management and staff in carrying out their assigned tasks.
In this approach, comprehensive quality management entails the commitment of all employees to continuous improvement, employee training, enhanced communication, and the elimination of barriers and fear (Hsu and Liu, 2016; Kowalik and Klimecka-Tatar, 2018;

Ladewski and Al-Bayati, 2019; Pietraszek, et al., 2020; Rahaman and Zaman, 2013; Satanova and Sedliacikova, 2015).
The essence of comprehensive quality management is contained in several theses of the creators of TQM theory - W.E. Deming and J. Juran (Chiarini, 2011). According to them:

- the definition of quality is created by the customer, not the manufacturer,
- the client of the enterprise is every person purchasing the product manufactured by this enterprise, but the division into internal clients (i.e. located within a given institution) and external clients (located in its environment) is important,
- quality should meet the standards and requirements set by the client,
- a high level of quality is achieved both through continuous product improvement and avoiding activities that do not lead to specific achievements as well as through,
- quality is a feature that can be measured using appropriate statistical methods,
- in each enterprise, an effective team of employees is a tool that is particularly important in shaping quality in interpersonal contacts,
- employee improvement is essential to quality.

Theses presented above allow to state that TQM is an extensive philosophy which covers all areas of the company's activity. Above all, the customer is important to every company. Products manufactured by the company should meet all its requirements. Only then the customer will be satisfied, so the products offered by the company can be considered as high quality products (Momeni, et al.,, 2019; Zehir, et al.,2012).

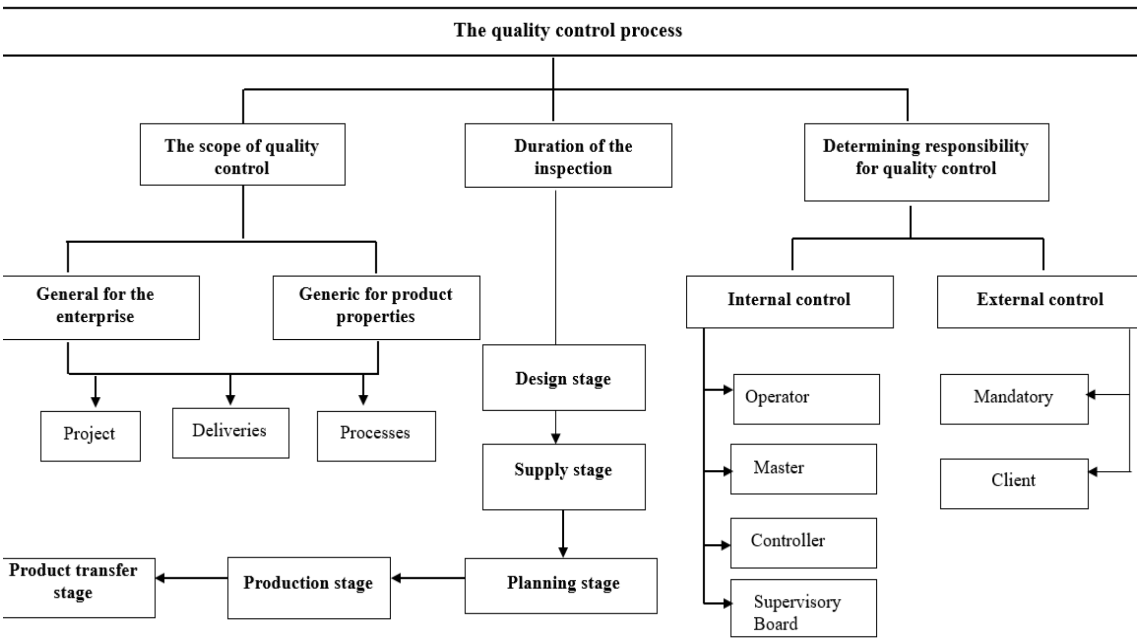

Fig. 1. The process of quality control in the enterprise the quality control model (QC)

The quality control (QC) model provides a structured approach to monitoring and maintaining product quality throughout the production process. By integrating systematic checks, standards, and corrective actions, this model ensures that products meet defined specifications and customer expectations. The diagram illustrates the practical application of QC, showcasing key stages such as inspection, testing, and feedback loops that enable continuous improvement. This model is essential for minimizing defects, reducing waste, and enhancing overall operational efficiency, making it a critical tool for achieving consistent quality in manufacturing and other industries.

The scope of quality control

The scope of quality control is wide. In enterprises conducting manufacturing activities, it includes the control of: product design, including in particular project documentation, materials and raw materials used in the manufacturing process, the course of individual production processes, in particular the course of the manufacturing process, measuring means used to control product quality, final products. In addition, as part of quality control is also carried out: gap analysis, complaint analysis, assessment of the functional characteristics of the products manufactured. Depending on it, three types of control are specified. These are: input control, also called pre-operative control, control in manufacturing processes, also referred to as operational and inter-operational control, final control, also called post-operational control. Input quality. control is carried out at the stages of: product design, supply of production raw materials, design of the production process. As part of this control, activities are carried out to develop the correct product design, and to prevent the use of raw materials that do not meet relevant quality standards in the production process. In addition, as part of the entrance control, machines and devices that will be used in the implementation of production processes are checked, as well as measuring tools that will be used in the quality control of implemented processes and manufactured products (Chiarini, 2011). During the implementation of production processes, so-called control in manufacturing processes. It involves checking the most important product parameters to eliminate any incompatibilities and defects. This type of quality control can be random and include individual pieces of manufactured products, one selected batch of products, but can also cover a whole series of products. The control of a whole series of products is called total control (100%). In enterprises whose basic activity profile is production, it is used for controlling serial processes. It involves checking all products from the entire series. This consumes a lot of time, therefore, it is mainly used in the production of products manufactured in small series. In multi-series production, total quality control is used only in justified cases. This is usually the case when the delivery of defective products to the recipient can have serious consequences. The opposite of total control is the control of individual pieces at random. Depending on the size of the production batch and the type of controlled products, it can have the character: ordinary control - it is used to control homogeneous production lots; current control - it is carried out at specific time intervals or in certain situations; first item control - this covers the first item in the product series and performs after actions that could cause errors during production; checking the last pieces in a batch of products - it is carried out at the end of the manufacturing process in order to check whether production has occurred in the course of production for non-compliance and manufacturing defects. Random quality control is carried out using random sampling methods and mathematical statistics. The batch of products selected for inspection is evaluated on the basis of the parameters of a randomly selected sample. Depending on the result of the control, decisions are made to suspend the controlled batch of products or release them for sale. However, it should be borne in mind that the use of random quality control involves the risk of defective products among those that have not been inspected (Krynke, et al., 2021; Momeni et al., 2019; Satanova and Sedliacikova, 2015).

Quality vs. cost of production

The cost and the cost of maintaining an appropriate level of product quality (in the manufacturing industry) are the part of four basic components that build the value of the product. The two other factors that create product value are functionality and usability (Schiffauerova and Thomson, 2006). Interestingly, both functionality and usability exist in close correlation with quality - because functionality and usability are quality parameters (Bevan, et al. 2015; Klimecka-Tatar and Obrecht, 2024; Schiffauerova and Thomson, 2006).

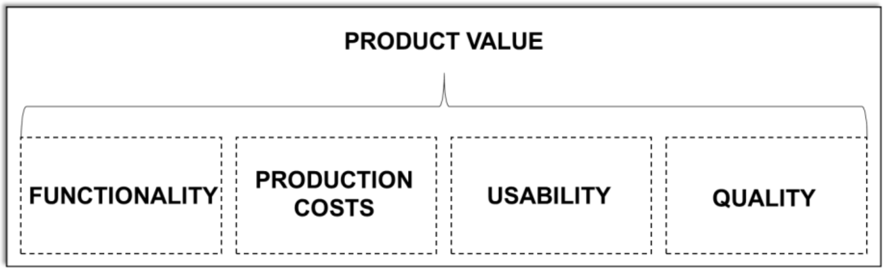

Fig. 2. The basic parameters affecting the value of products

The cost optimization resulting from maintaining an appropriate level of quality, in a production company refers to the model presented in the work of Omachonu et al. (figure 3) (Omachonu et al., 2004). As it comes from the model, unfortunately the need to meet the customer's requirements necessarily involves the costs incurred. In addition, it can be seen that as the quality level increases (the number of defects decreases), the summarized costs of quality increase: the costs of maintaining quality and the costs of preventive measures. It should be emphasized that as the quality level increases (if the company carries out statistical control), the unit costs of the product decrease. The reduction in unit costs of the production of products is due to the fact of gaining experience of the process in producing products "zero defects".

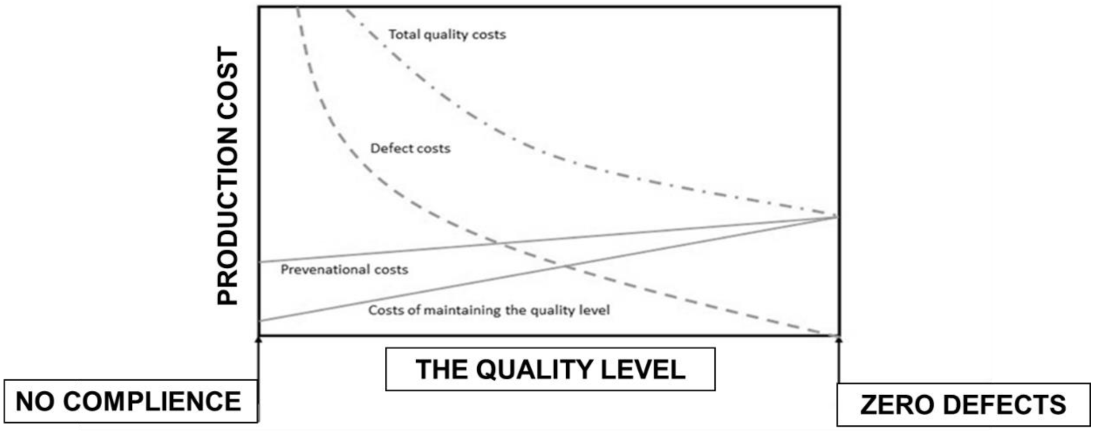

Fig. 3. A general and basic model for costs of production and quality maintanance costs in the manufacturing industry (based on (Omachonu et al., 2004))

Along with the increasing level of product quality, costs resulting from the need for remedial actions are also reduced - the costs of eliminating defects decrease. The elements that determine the profitability of quality maintenance are points of intersection

of curves: Prevention costs – Defect cost; Costs of maintaining the quality level – Defect costs. Therefore, for enterprises struggling with financial problems resulting from maintaining quality, all analyses regarding the profitability of production in the current process layout should refer to the elements indicated on the model.
Maintaining quality involves managing several types of costs to ensure an appropriate level of product and process performance. These include:

- Costs necessary to maintain the required quality level: These are investments in quality assurance processes, such as inspections, testing, and monitoring, to ensure products meet specified standards.
- Preventive quality costs: These are expenses incurred to prevent defects and ensure consistent quality, such as employee training, process improvements, and procurement of high-quality materials. Preventive measures are generally more cost-effective than addressing issues after they occur.
- Costs covering losses due to waste: Poor quality can lead to material waste, rework, and defective products, resulting in significant financial losses. Minimizing these losses is crucial for maintaining profitability and operational efficiency.
- Overall quality costs: This includes the total expenditure on quality management activities, comprising prevention, appraisal, and failure costs. Balancing these components is essential to achieving optimal quality at a reasonable cost, ultimately supporting customer satisfaction and long-term business success.

By carefully managing these cost categories, enterprises can achieve a sustainable approach to quality while minimizing financial risks and maximizing value creation (Tomov and Velkoska, 2022).

3. SUMMARY AND CONCLUSION

Maintaining a high position on the market carries a great deal of responsibility for manufacturing companies. First, to be among the leaders it is necessary to meet all customer requirements - to ensure the highest level of quality of manufactured products. However, proper quality management in a production company carries very high costs of maintaining production. Therefore, enterprises should constantly analyze their financial results, but in relation to unit costs of production in correlation with the costs of maintaining quality (management and prevention costs). The easiest way to properly manage a production company should be based on building quality into the production process. The proposed methods and results allowed to indicate the possibility of avoiding a inhibition of business growth caused by excessively increasing costs of quality maintenance.
The costs of quality in industrial and manufacturing engineering can play a crucial role in both driving business development and, if mismanaged, hindering growth.

- Business Development - investing in quality management supports ongoing improvements, enhances customer satisfaction, and builds a strong brand reputation. When businesses prioritize preventive quality measures, such as training, optimizing production processes, and sourcing high-quality materials, they can reduce defects, minimize waste, and improve overall efficiency. This leads to superior product quality, lower operational costs, and stronger customer loyalty. These factors contribute to a competitive edge, attracting more customers and fostering sustainable growth. Additionally, offering high-quality products can allow companies to charge higher prices, which further boosts profitability.

- Inhibition of Growth - however, if quality costs are not effectively managed, they can become a barrier to growth. Excessive spending on quality control, without clear benefits, or focusing too much on inspections rather than prevention can lead to higher operational expenses. Moreover, an imbalance between maintaining quality and controlling costs can reduce profitability, particularly in competitive industries where cost management is critical. Over-investment in quality management can also divert attention and resources from other essential business areas, such as innovation or market expansion.

In summary, the costs of quality, when handled strategically, can significantly promote business development. However, if not properly managed, they have the potential to impede growth.

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