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The Synergy Model of Quality Tools and Methods and Its Influence on Process Performance and Improvement

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Abstract: Implementing quality tools and methods creates a basic foundation for innovations, sustainability, optimization, and competitiveness in the era of Industry 4.0 and Quality 4.0. This paper aimed to investigate the use of quality tools and methods in the 24 divisions of a mother manufacturing company without the influence of external factors such as geographical location (America, Africa, Asia, and Europe). It was important for the mother manufacturing company to implement a uniform process standard for innovation and performance. Research methods focused on using the Kanban card, Ishikawa diagram, affinity diagram, Flowchart, 5S, OPL, layout, and Pareto analysis. It was determined in this research that the synergy (combination) of quality tools and methods in divisions improves the process performance. This hypothesis was confirmed by the results of implementing quality tools in processes within divisions. A top result was the new innovative model of synergy of the quality tools and methods for divisions of the parent company thus filling a gap in the scientific field. This model created the basis for the uniform process standard in all divisions. The results brought improvements in the processes such as material input inspection, spare parts production, production process, and product packaging. This model could be a proactive instrument for process innovation.

Keywords: process; quality instruments; improvement; performance; sustainability; efficiency

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1. Introduction

Focusing on the synergy model creation of quality tools and methods in processes of the manufacturing company with various divisions in various geographical locations around the world was the first step in preparing this scientific article aimed at filling in the gap in scientific research orientated to relevant combinations of the quality tools and methods for processes. The purpose of this paper is to investigate the use of quality tools and methods in the divisions of the parent company with geographical locations around the world, in the countries of America, Africa, Asia, and Europe. This research is important for a parent company, which could prepare the uniform process standard for all divisions. Our research will be based on the hypothesis that the synergy of quality tools and methods in divisions improves the performance of processes. This new suggested synergy model of quality tools and methods will have a scientific, social, and economic benefit for manufacturing companies. Quality management tools are widely used in various countries, industries, companies, processes, and activities. Teplická et al. (2021) commented that strategic innovation through realizing quality tool combinations in industrial companies is an important strategy for sustainable development, improving performance, innovation, and competitiveness [1]. Sokovic et al. (2009) said that for organizations to achieve continuous quality improvement, they need to use an appropriate selection of quality tools and techniques. A combination of seven old and seven new quality tools can be used in all process phases, from the beginning of product development up to management of a production process and delivery. This combination could be used in the PDCA approach, Six Sigma, DMAIC, and Lean production [2]. Mach et al.'s (2001) study showed that old quality tools such as statistical process control (SPC) had become some of the most important quality tools in the manufacturing industry. The known Six Sigma approach was based on using quality tools and techniques combined with well-orientated management [3]. Herbert et al. (2003) evaluated the use of quality tools and statistical process control in certain services (banks, hospitals, courier services) and underlined the key management prerequisites that help ensure their effective use [4]. Zasadzien et al. (2018) presented that quality methods and tools increase the quality of the logistic processes. The combination of quality tools made it possible to identify and prioritize key issues, identify their causes, and formulate improvement and prevention measures for the logistic process [5]. De Sena (2023) presented quality tools in school management and suggested using the PDCA cycle in connection with the 5W2H tool, in other words a combination of quality tools. This combination of quality tools has played a fundamental role in administrative and pedagogical activities, with positive effects on the level of process quality [6]. McDermott et al. (2022) presented relationships between the seven new quality control tools and the seven new management tools in manufacturing companies. The results of the research showed that 10% of participants within the manufacturing sector perceived that the seven new quality tools could solve above 80% of organizational problems. The common benefits of using these seven new quality tools in the manufacturing sector are helping people define, measure, and analyze the problem areas or even prioritize among them, and providing some form of structure to problem-solving efforts [7]. All mentioned authors state that the combination of quality tools brings improvements and innovations. All companies use quality tools for process improvement without orientation to area of industry or services.

Using different quality tools in various countries of the world will make it possible to create a standard for solving problems of innovation and process improvement in the divisions of a mother company with similar production processes. This research offers the scientific benefit of a new model following the theory of lean production, the social benefit of the introduction of a uniform standard for divisions in various countries of the world, and the economic benefit of cost optimization.

2. Literature Review

Quality tools are used differently according to process type and the conditions of each organization. In the scientific area, Pavletic et al. (2009) presented a quality improvement model in the production process of an automotive company, which used various quality instruments such as SPC (statistical process control) and methods such as Kaizen, Kanban, 5S method, and Lean production [8]. Škvareková et al. (2021) also pointed out the basic statistical characteristics, descriptive statistics, regression analysis, and correlation analysis which help to identify the dependence among the measured values, quality tools and methods which can improve the production processes [9]. For our research in divisions of the mother company, the results of the research by Fang et al. (2022) were important. They dealt with the methods of subcontracting production based on using SPC (statistical process control). This approach to quality identifies the problem of subcontracted manufacturing and improves the manufacturing process. This approach is an instrument for achieving continuous customer satisfaction in subcontracted manufacturing [10].

The purpose of using quality tools and methods is to reduce all forms of waste, streamline inventory, and minimize costs and downtime, in order to influence competitiveness and customer satisfaction. Zhou et al. (2020) explored the influence of supply chain practices and quality management on business performance. The analysis results show that supply chain information sharing has a significant positive impact on quality management practices and performance [11]. Buer et al. (2021) presented that the most recent trend manufacturers have embraced to seek operational performance improvements is the use of digital technologies and lean manufacturing [12]. Javaid et al. (2021) presented that Quality 4.0 corresponds to the growing digitalization of industry, which uses advanced technologies to enhance the quality of manufacturing. Quality 4.0 is a modern form of quality management [13]. Teplická et al. (2019) argued that the combination of managerial instruments with quality instruments is an important strategy for innovation in industry [14].

Total quality management is the base conception for implementing quality tools and methods in processes where the priority is culture and philosophy of organization. Chen et al. (2022) dealt with the total quality management approach for the procurement process within engineering construction. This TQM approach brought improvements in computer information processing systems for safety and the importance of terminal sensor quality management [15]. Kebede et al (2021) investigated the effect of TQM practices on the operational performance of manufacturing companies. The results revealed that the practices of TQM respecting supplier quality management, continuous improvement, and process management had significant and positive effects on the operational performance [16]. Das et al. (2006) obtained important measurement indicators for TQM implementation for the Thai manufacturing industry. The results show that customer focus, continuous improvement, top management commitment, employee involvement, and product innovation are significantly and positively related to product quality and influence the performance of the processes [17]. The problems of environmental deterioration and lower natural resources play an important role in total quality management (TQM). TQM has a significant and positive impact on corporate and environmental sustainability. The TQM approach can ensure sustainability in various industry companies [18]. The production rate in industry areas is vital as it determines how long the industry will run and how fast it will grow. Typical managerial quality methods such as TQM, Six Sigma, and Lean Manufacturing can increase productivity. It is for this reason that companies always look for better ways to produce their goods, minimize waste, and increase productivity. Ikumapayi et al. (2020) commented that Six Sigma and lean production are quality management techniques in production. The combination of these methods helps to increase productivity, improve processes, to eliminate waste [19].

The implementation of quality management tools creates a basic foundation of innovation, sustainability, optimization, and competitiveness in the era of Industry 4.0 and Quality 4.0 [20]. In manufacturing companies, the main goal of optimization is the reduction of costs and downtime, which form a barrier to processes and their innovations [21]. Yang et al. (2023) presented that defects in products are a significant problem for customer satisfaction and business performance. The detection of product defects is essential in quality control in manufacturing. The results of their research showed deep-learning methods in defect detection that are important for effective practice [22]. Today, such innovations constitute a fundamental tool for increasing the competitiveness and market value of enterprises [23].

Performance indicators in manufacturing enterprises focus on meeting customer requirements and increasing the quality of input production factors [24]. The performance of enterprises must be oriented towards the basic pillars of Industry 4.0 and the elements of Industry 5.0, where the basic focus is on the human factor [25]. In processes for the automotive industry, emphasis is placed on the sustainability of supply processes and supply chain management [26]. Each process of the manufacturing company affects the economic and financial side of the enterprise, which ultimately affects the innovations of business processes. Capable management of all business processes is a prerequisite for increasing the market value of the company. The financial impact of innovations can be supported by internal and external sources. Effective innovation demands strategic planning of financial resources in all processes through quality tools and methods [27].

Management of the company must focus on input management, process management, and output management (Figure 1). Input management includes facilities, equipment, staff, suppliers, transport, material, energy, and information. Output management includes products, services, customer satisfaction, environmental impact, and sustainability of products and services. Management of processes includes all processes in the company through process flow, process design, process control, and process improvement [28].

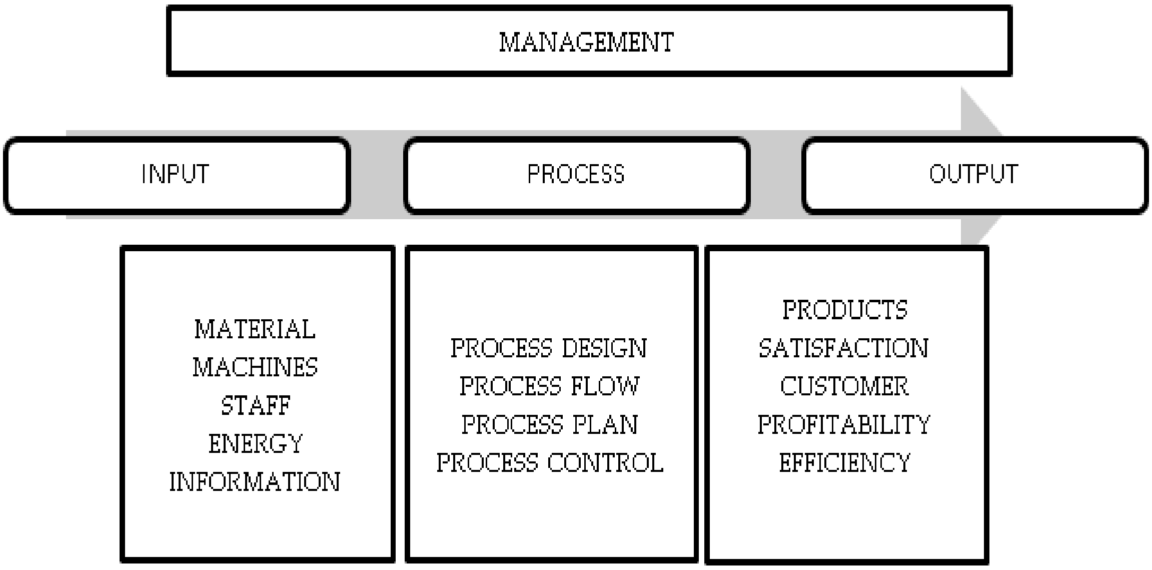

Figure 1. Input, process, and output management. Source: authors.

The performance of companies has a significant impact on the business environment and vice versa. Changes that bring economic growth and development to businesses are considered necessary and must be associated with various process innovations [29]. Innovations in processes can be achieved with the combination of quality management tools, which bring about changes in the synergy of different forms of management such as production management and environmental management [30]. An important factor for innovation is the supply chain, i.e., the efficient supply of components to the automotive industry [31].

Quality management tools are used in various types of industrial enterprises and thus their use is broad-spectrum. Junior et al. (2010) presented the Kanban method as a subsystem of the Toyota Production System (TPS), which was created to control inventory levels and the production and supply of components and raw materials [32]. Many authors have shown positive results from the TPS, but on the other hand, research indicates that the system is not appropriate to the organization's new productive needs. Akturk et al. (1999) defined the disadvantages of the Kanban method as the difficulty of adapting Kanban to unstable demands and processing times, complex flow of materials, poor equipment reliability, and a large number of suppliers, among others [33]. Sudarsan et al. (2020) said the strategy of Kanban is to optimize the inventory level by minimizing the inventory holding cost and the back order level. They created model to enhance the Kanban system in a product manufacturing industry by various optimization methods, considering the hurdles due to bottleneck operation [34]. Boca et al. (2021) investigated the use of a digital platform for Kanban. This approach, named Kanban 4.0, is driven by the application of an electronic Kanban material flow management system, using tablets, computers, digital labels, and a fast digital platform with cloud access [35]. Pekarcikova et al. (2020) presented a simulative model for material flow optimization through e-Kanban simulation [36]. Teplická et al. (2015) presented Bayes Principle Optimum, a model for storage optimization and effective storage material by optimal state and insurance storage level [37].

Toyota coined the phrase "Lean Manufacturing" to remove waste or non-value-added operations from a manufacturing process. Positive benefits have been established in achieving production efficiency and reducing waste through the implementation of lean manufacturing techniques such as the 5S method. Shahriar et al. (2022) wrote that the lean manufacturing concept brings benefits in the area of 'waiting'. The recommendation of the research was to use 5S, a lean manufacturing strategy, for reducing downtime. After implementation of 5S, the total operational time was reduced by 8% [38]. An important part of implementing quality instruments is the integration of the monitoring and visualization system as an instrument for the valuation of the quality of processes [39].

An significant innovation in quality tools is the agile manufacturing which uses Pareto analysis to pinpoint critical factors. This analysis is important in helping production processes to address the causes of problems [40]. Wuni and I.Y (2022) used Pareto analysis as an important instrument in the construction industry. This analysis is the main priority in the transition to a circular economy due to the waste of resources [41]. Improvement of business processes is important for the innovation process. The development of the industry is increasingly encouraging businesses to be competitive by increasing technical knowledge and improving systems, processes, and products.

Isniah et al. (2020) presented PDCA as a quality management approach that is used as a continuous improvement tool in the manufacturing sectors [42]. Ghatorha et al. (2022) argued that continuous improvement projects help in optimizing the use of available resources through waste reduction, which improves manufacturing costs and product quality. The plan-do-check-act (PDCA) cycle is used widely in response to globalization, which has resulted in increased market competition [43]. Sumasto et al. (2023) studied the use of this PDCA method in the automotive industry in Indonesia for the reduction of component defects. The defect rate of components was reduced from 12.7% to 8% [44].

With the rapid development of "Industry 4.0", attention has been attracted by "smart manufacturing". One of the most important parts of intelligent manufacturing is the manufacturing workshop. Teplická et al. (2020) presented that the ideal quality instrument for intelligent manufacturing is the model of manufacturing system layout. This has two targets: optimized workshop layout and expedition process with order picking area [45]. Guo et al. (2021) wrote that the layout optimization of discrete manufacturing workshops could promote the realization of intelligent manufacturing [46]. A high level of awareness of Quality 4.0 entails acquiring knowledge in various ways, including through quality training, work experience, self-reading, and Internet surfing. Quality 4.0 is the concept oriented to customer satisfaction, continuous product and process improvement, waste reduction, and decision support by managerial quality instruments [47]. Implementing managerial quality instruments creates conditions for the improvement of business performance. The performance indicators include innovation performance indicators [48].

Quality management practices and supplier-specific investment have a significant positive impact on innovation performance [49]. Supply chain management (SCM) is the process of managing the flow of goods and services to the ultimate customer. Effective SCM can help reduce waste, maximize customer value, and gain a competitive advantage in the marketplace [50]. The experience and availability of various techniques give space for the development of new models and management approaches in project management and quality management, which forms the basis for innovations [51]. All authors point to the importance of the synergy of quality tools and methods in business processes from the point of view of the Industry 4.0 and Quality 4.0 approach. New models will bring new opportunities for industrial companies.

3. Materials and Methods

In this article, we deal with process optimization in the divisions of parent manufacturing companies around the world. We focus on the processes of supplying input resources, the storage process, the production process, and improvement with an emphasis on layout, the expedition process, and the environmental, social, technical, and economical maintenance of all processes. The purpose of this paper was to investigate the use of quality tools and methods in the 24 divisions of a mother company with geographical locations around the world, in the countries of America, Africa, Asia, and Europe. The aim of the research was to determine the applicability of the same quality tools and methods in business processes without regard to external factors. Our research took as its subject the

24 divisions of a manufacturing company that supplies automotive components for the automotive industry around the world—in America, Africa, Asia, and Europe (Figure 2). This company combines quality with innovation, which is the main pillar of Industry 4.0. At the same time, it is the main supplier of lighting, electronics, and driving units in the automotive sector.

Figure 2. Geographical locations of the divisions. Source: authors.

As part of the research, we established our basic hypothesis for using quality instruments: H1: The synergy of quality tools and methods in divisions improves the performance of processes.

The examined period of our research was between 2021 and 2023. We tested this hypothesis by implementing selected quality tools and methods to address nonfunctional and ineffective processes (material input inspection, spare parts production and location, production, product packing) in some divisions of the mother company worldwide in 2021. Selected quality tools and methods were Kanban, 5S, Flow chart, OPL, Pareto analysis, affinity diagram, Ishikawa diagram, and layout; performance indicators were efficiency and functionality. These quality tools were selected based on processes that were optimized in 24 divisions. Then these quality tools were implemented in the year 2022 in some divisions. We selected quality tools to use in all divisions in America, Africa, Asia, and Europe. The use of quality tools in divisions of the manufacturing company was achieved by following the algorithm shown in Figure 3. We tested this hypothesis by quantitative indicators of the efficiency and functionality of processes in the year 2023 after the implementation of the selected quality tools and methods in the various divisions.

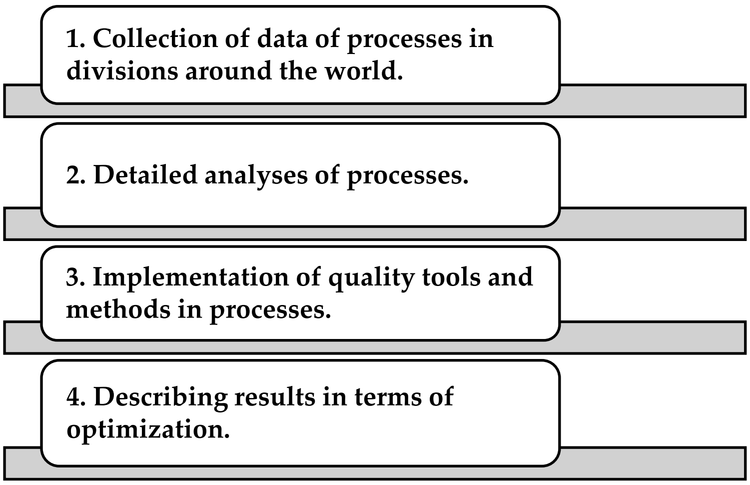

Figure 3. Algorithm of the research. Source: authors.

In the first step, we collected data (Table 1) for economic, statistical, and quality analyses for using managerial quality tools in the selected divisions of the manufacturing mother company. We obtained data from the management information systems SAP, ERP, and MBI in the selected divisions at the individual departments through an online platform or a visit to the division. Data collection was realized based on email communication with production managers of individual divisions. Contacts were available from the parent company, which allowed access to available information. All data for the research were averaged and we selected data from the same divisions with the same number of employees, and with the same turnover. The data must be relevant for all analyses and implementation changes in the processes. Table 1 presents processes that were included in all divisions. In this Table 1 are the planned and actual values of the processes in the years 2022 and 2023, which is the basis for determining the efficiency and functionality indicators of these processes. Such efficiency and functionality indicators of these processes are important for innovation and improvement.

Table 1. Selected processes in the divisions and their performance.

Processes	Plan 2022	Reality 2022	Plan 2023	Reality 2023
Document management (number of documents)	15	15	13	13
Fulfillment of management goals (number of goals)	29	28	28	28
Material input inspection (number of inspections)	380	280	300	200
Spare parts production and location (number SP)	523	430	500	400
Production (number of defect products)	100	83	90	70
Product packaging (number of returnable packs)	3000	2500	2500	2000
Promotion (marketing costs in €)	35,600	35,000	36,000	36,600
Internal system audits (number of audits)	25	26	25	27

Source: internal documents.

We analyzed the processes in individual divisions in detail and evaluated the processes based on the efficiency coefficient (Ke) and the functionality index (If). At the end of the research, we selected processes that needed to be optimized and implemented quality management tools in some processes. We have investigated the coefficients of processes in the ordinary period (1) and the base period (0). We have used actual and planning values of economical parameters (X), production (pcs) and control (number). The purpose of measuring the coefficient of efficiency of the process is to identify and correct deviations in processes, and to provide information on development trends. This index of functionality expresses the increase or decrease of the efficiency coefficient, which makes it possible to determine the functionality of the processes in the monitored periods. For the calculation of the functionality index, we used Formula (2).

Formula (1) calculates the indicator of efficiency of processes, and efficiency results will be determined by limited values—theoretical knowns (Table 2).

Table 2. Limited valuation of the processes.

Type of Process	Limit
Effective process	$Ke \geq 0.85$
Mostly effective process	$0.85 > Ke \geq 0.70$
Ineffective process	$Ke < 0.70$

The coefficient of effectiveness:

$$(Ke)\ Ke_{(1,0)} = X_{reality(1,0)} / X_{plan(1,0)} \tag{1}$$

where (Ke) is efficiency coefficient, (X) is economical parameters, (1) is ordinary period, and (0) is base period.

Formula (2) is for calculates the indicator of functionality of processes, and functionality results will be determined by limited values—theoretical knowns (Table 3).

Table 3. Limited valuation of the processes.

Type of Process	Limit
Functional process	If ≥ 1
Mostly functional process	$1 >$ If ≥ 0.90
Nonfunctional process	If < 0.90

The index of functionality:

$$\text{(If) If} = \text{K}_{\text{e1}}/\text{K}_{\text{e0}} \tag{2}$$

where (If) is functionality index, (X) is economical parameters, (1) is ordinary period, and (0) is the base period.

In the area of analysis, we used Pareto analysis, one of the most effective, commonly available, and easy-to-apply tools in the field of quality management. The analysis expresses that 20% of the causes are causally related to 80% of poor quality. This makes it possible to separate the essential factors of a certain problem from the less significant ones and to show which direction to focus efforts in eliminating shortcomings in the quality assurance process. For the realization of the Pareto quality management tool, we need data such as the scale of causes (Kv), number of defects, and multiplicity.

Pareto analysis was realized in the steps:

1. To rank the causes from the largest to the smallest value,
2. To determine the percentage of causes based on the formula Structure (S) by Formula (3),

$$\text{Structure}: \; S(\%)\frac{Xi}{SUMXi} * 100(\%) \tag{3}$$

where (X) is causes and (i) is time period.

3. To determine the cumulative structure of causes, based on the formula Cumulative structure (CS) by Formula (4),

$$\text{Cumulative structure}: \; CS(\%) = \sum X_t + X_{t+1} \tag{4}$$

where (X) is structure of causes and (t) is time period.

4. To set category of causes (affinity diagram)—A, B, C—by rules 80/20; Category (A) represents various analyzed items for condition less than 80% of cumulative structure, Category (B) represents various analyzed items for condition less than 98% of cumulative structure, Category (C) represents various analyzed items for condition greater than 98% of cumulative structure.
5. To create a bar graph of the number of causes,
6. To create Lorenz curve of cumulative percentage.

By the Lorenz curve, using cumulative percentages, we determine the critical defects that represent high costs (category A).

4. Results

The research was provided in the selected 24 divisions of a manufacturing company that is a supplier of automotive components for the automotive industry around the world. The research followed the four-step algorithm shown in Figure 3.

4.1. Process Analysis in Divisions

For the economic analysis of the processes (Table 4), we selected processes by hierarchical level and by level such as managerial, main, and supporting, which have the best scale in all divisions. We selected managerial processes (document management, fulfillment of management goals, promotion), main processes (material input inspection, production, product packaging), and supporting processes (spare parts production and location, internal system audits) in the divisions of the mother company. To introduce changes in processes using quality tools, it was necessary to determine their effectiveness and functionality (by the Formulas (1) and (2)).

Table 4. Valuation of processes. Source: authors.

Processes	Ke (0)	Ke (1)	If	Effectiveness (0) (1)	Functionality (2023/2022)
Document management (number of documents)	1	1	1	Effective	Functional
Fulfillment of management goals (number of goals)	0.97	1	1.03	Effective	Functional
Material input inspection (number of inspections)	0.74	0.67	0.91	Mostly effective	Mostly functional
Spare parts production and location (number SP)	0.82	0.80	0.97	Mostly effective	Mostly functional
Production (number of defective products)	0.83	0.78	0.93	Mostly effective	Mostly functional
Product packaging (number of packages)	0.83	0.80	0.96	Mostly effective	Mostly functional
Promotion (marketing costs in €)	0.98	1.02	1.03	Effective	Functional
Internal system audits (number of audits)	1.04	1.08	1.04	Effective	Functional

The planning of changes in processes was carried out based on the analysis of processes in all divisions of the company. The changes were implemented in divisions around the world in the year 2022.

The results of the process analysis point to mostly efficient (material input inspection, spare parts production and location, production, product packaging) and mostly functional (material input inspection, spare parts production and location, production, product packaging) processes. Changes and implementation of quality management tools will be proposed in these processes. The other processes (document management, fulfillment of management goals, promotion, and internal system audits) were effective and functional. Promotion costs increased by 1600 € due to new innovative marketing instruments, which brings a positive effect in processes within the divisions even though costs are rising. This fact was connected to the product packaging process, in which a material's packaging required alteration; such packaging is part of promotion. The same situation occurred in the process of internal system audits; more internal audits in the division are a positive approach because internal audits reveal flaws and problems in processes. The internal audits are done by the employees of the divisions. Functionality and efficiency of the processes are important factors in the decisive quality criteria for the development of the company. Therefore, it is essential to use the strategic tools of global economics and management, enabling businesses to move forward and approach the enterprise level of "world-class".

4.2. Implementation of Quality Tools and Methods in Processes

In the first process, material input inspection, serious deficiencies were identified: time, quantity, personnel downtime, low-quality input materials, non-fulfillment of delivery deadlines by suppliers, lack of transparency of materials in storage areas, poor waste disposal system, and inefficient system of ordering and tracking material in the warehouse and in production. In this process, quality tools were designed: a flow chart for material delivery to production (Figure 4), incoming material inspection and visualization—diagnostics of components through a microscope (Figure 5), and streamlining of material flows with a Kanban card (Figure 6). A flow chart is an effective tool for the process description. It helps to understand how the process works for employees and suppliers. This procedure makes it possible to make the material delivery process more efficient, to perform a material inspection, and to complain about the material in case of poor quality. Implementation of this quality instrument reduced the costs of material procurement, introduced high material inspection requirements, improved the claims process, and simplified the transfer of received material to storage.

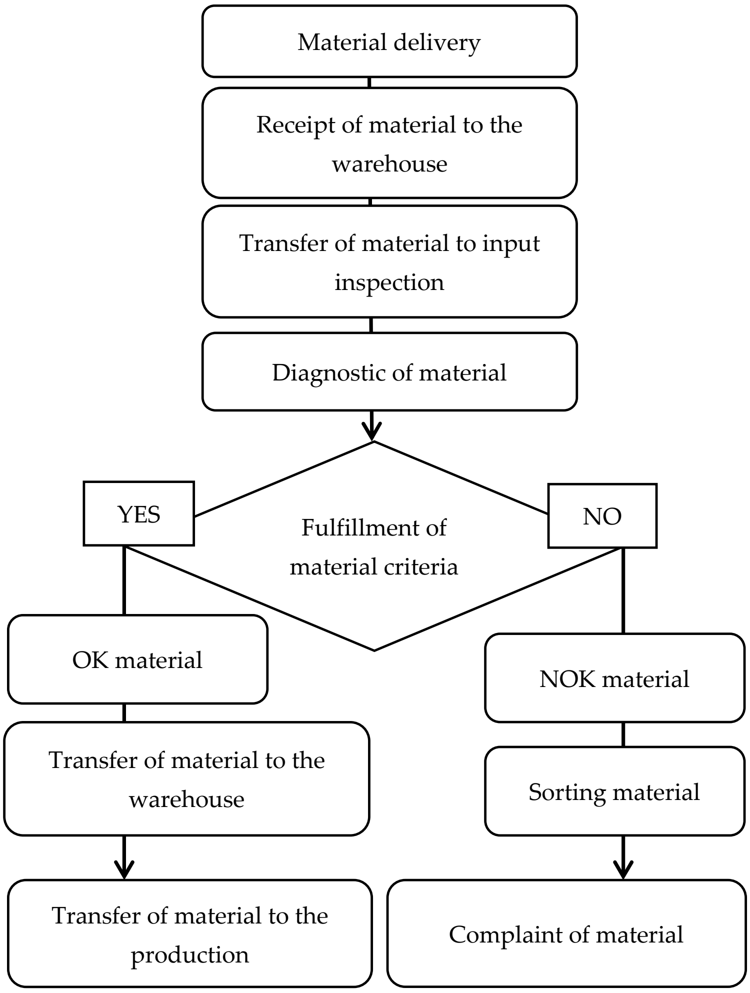

Figure 4. Flow chart for material delivery. Source: authors.

Figure 5. Diagnostic of material by microscope. Source: internal documents.

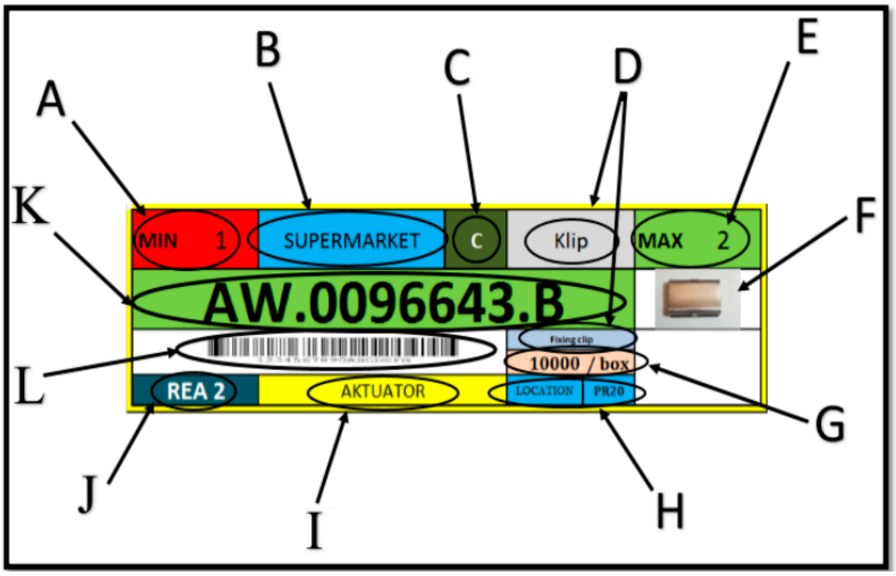

Figure 6. KANBAN card. Source: internal documents.

The incoming inspection of materials and components for the automotive industry is a basic prerequisite for the production of quality cars without errors and defects. The use of diagnostic methods in monitoring the quality of components is the basis for receiving material from the supplier and using it in production. The input inspection checks compliance with the requirements of the STN (Slovak technical standard) and with the requirements stated in the material order. This activity checks the condition of surface defects, scratches, cracks, and other mistakes. The input control describes a gear wheel on which surface defects are detected on materials (Figure 5).

If, during the incoming inspection, components are found that do not meet the requirements and do not meet the specified parameters, they are characterized as NOK pieces (marked in red) and are stored apart from the OK pieces which fill the requirements of the STN norm. Meanwhile, OK pieces that meet all requirements are returned to the warehouse for storage and are systematically released according to the requirements of the production process. Implementation of this quality instrument, visualization by microscope, improved the control of the material quality.

To make the transfer of material from warehouse to production more efficient, a Kanban card is also used, which is advantageous in the JIT material ordering system. The high cost of storing materials forces the company to minimize costs by implementing operational inventory management.

Kanban cards (Figure 6) contain all important information about material delivery via barcode. The Kanban card contains the following information: A—minimum quantity of components in the stack, B—place of occurrence of the component, C—class of the component, D—name of the component, E—maximum quantity in the stack, F—image of the component, G—value of the component, H—position of material in the warehouse, I—name of the product that the given component needs, J—production line for the component, K—number of the component in the SAP system, L—barcode/sensor.

This implementation of Kanban cards as quality instruments makes it possible to reduce costs and downtime, simplifies the ordering of components, increases clarity of components in the warehouse, identifies components, and simplifies handling and record keeping.

Process results—control of material input: efficient stock ordering system, reduction of time, movement downtime, higher productivity, removal of dead stock, increase of space for stock storage, increase of available information, effective record system.

In the second and third processes, production and spare parts production and location, it was necessary to streamline production and reduce product defects, reduce time and movement downtimes, change the layout of the workplace, make ergonomic changes to the workplace, and mark positions from the point of view of health and safety. The improvement of conditions in production was realized by the proposal of the implementation of the 5S system (Seiri, Seiton, Seiso, Seiketu, Shitsuke).

Figure 7 points out the removal of unnecessary items from the workplace to save space and mark space, the correct storage of tools (which reduces their loss), the localization of objects, the placement of frequently used tools near the point of use, the storage of a minimum amount of supplies, the marking of equipment for storage, and the marking of machines, which means increasing production efficiency. An important part of 5S is cleaning the workplace, determining the proper method of cleaning and areas for waste, marking waste, and setting cleanliness goals. The benefit was the improvement of working conditions for employees.

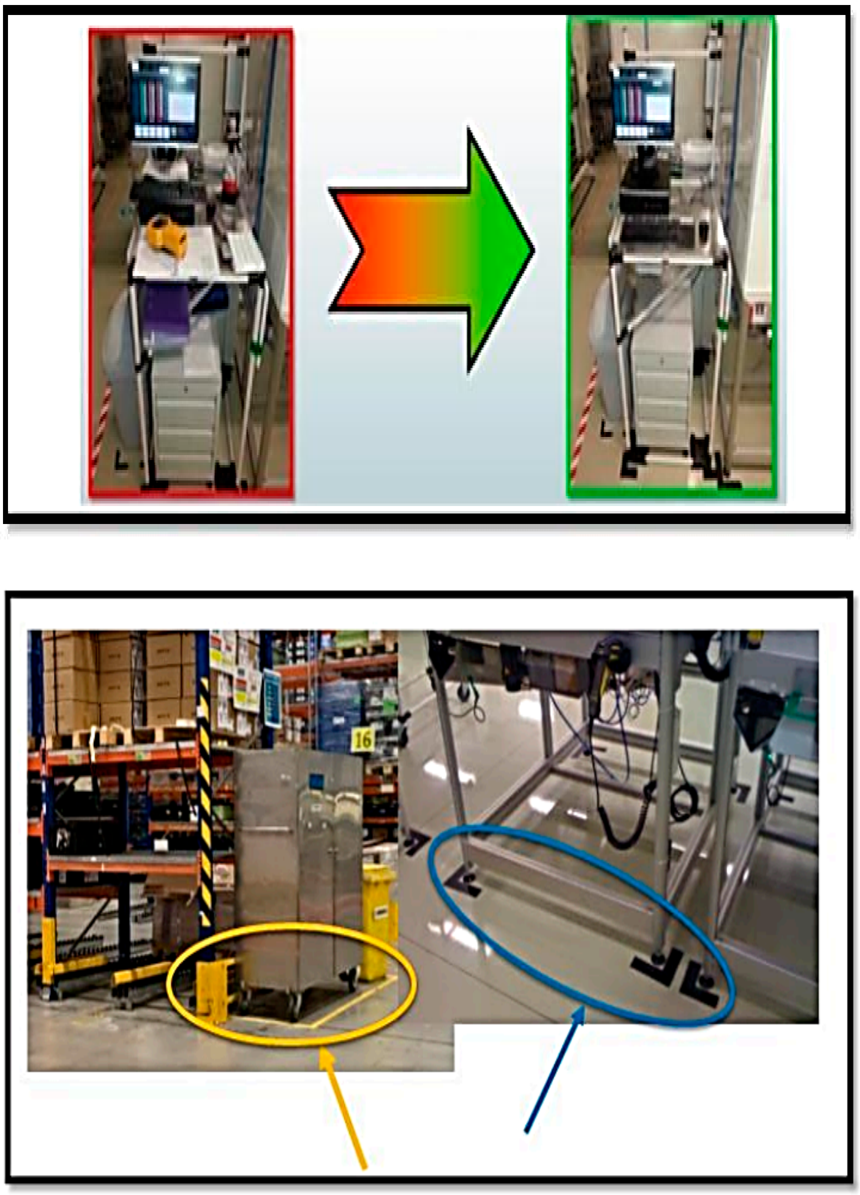

Figure 7. 5S system in production. Source: internal documents.

The layout of the workplace (Figure 8) presents the situation in the production hall before implementation of quality tools and methods. In this layout are parts of the production hall. W1—warehouse of material, W2—warehouse of spare parts, W3—warehouse of complete products, W4—warehouse of waste, P1—production area with machines and instruments, E1—packing and expedition of products.

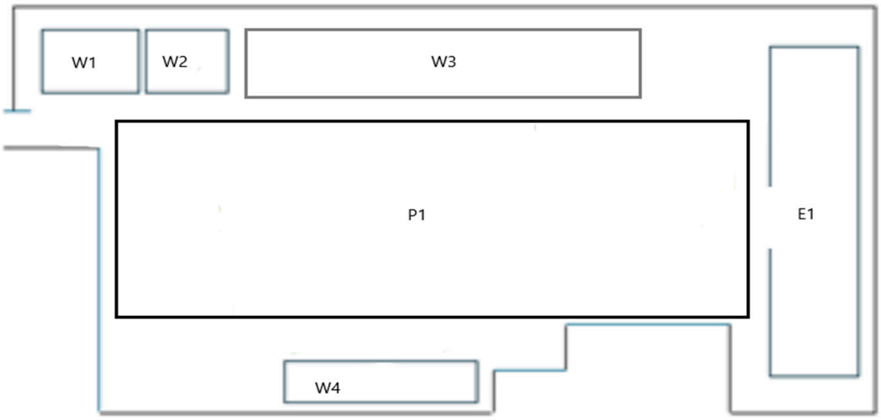

Figure 8. Layout of production hall. Source: internal documents.

The changes in the production layout (Figure 9) resulted in the division of the production hall into zones that enable better material transport and employee transfers, the succession of individual activities within the production process, and the availability of support tools for the maintenance process. In this layout are parts of the production hall. C1—input inspection of material, W1—warehouse of material, I2—equipment for production, C2—inspection of spare parts, W2—warehouse of spare parts, I1—equipment for maintenance process, W3—warehouse of complete products, P1—production area with machines, W3—warehouse of complete products, C3—inspection of complete products, W4—warehouse of separated waste, E1—packing and expedition of products.

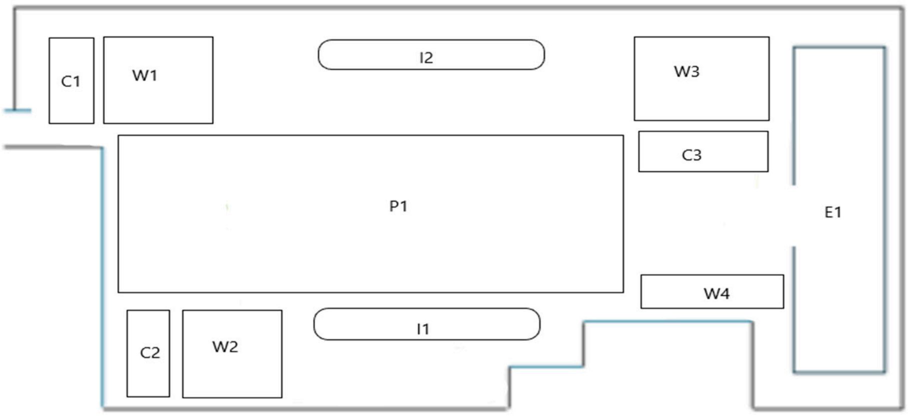

Figure 9. New layout of production hall. Source: internal documents.

The last step of 5S was the development of a standard for information: inspection plan, cleaning plan, inspection criteria, and determination of inspection personnel. The implementation of 5S and layout changes in the production process have brought a reduction of costs, improvement of safety, reduction of accidents, reduction in the time of transfer of materials, reduction of occupational risks, increase of morale, reduction of absences of workers, and improvement in communication and relations.

Work procedures and their compliance are also an important part of production, so it was necessary to design an OPL (Figure 10)—a tool that visually presents the instructions and tools used to perform tasks at the production line. This tool is used for training and informing employees about correct work procedures and compliance with standards.

Figure 10. OPL (one-point lesson) in production process. Source: internal documents.

An important goal of production is the reduction of defects. Therefore it was necessary to analyze the causes of defects and determine the "critical" causes that need to be eliminated or minimized in production. We solved this problem with the quality management tools of the Ishikawa diagram (Figure 11) and Pareto analysis. Pareto analysis will determine the 20% of critical causes associated with an 80% share of the number of defects.

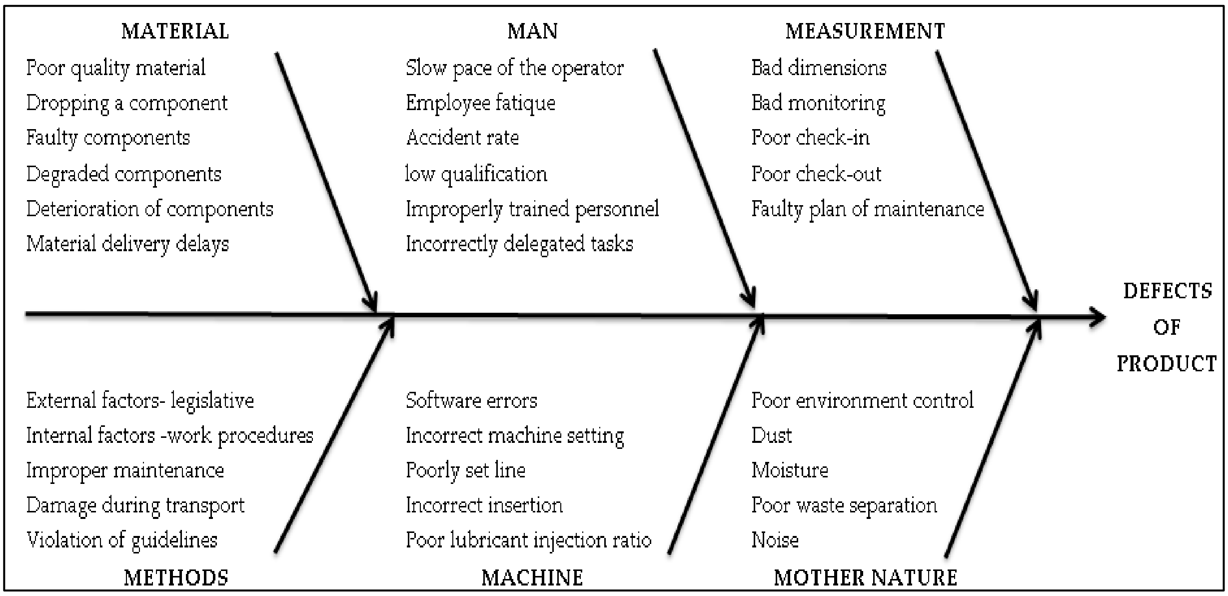

Figure 11. Ishikawa diagram of causes. Source: authors.

The results of the analysis presented a large number of various causes of production process issues in all divisions: incorrect machine setting, poor-quality material, deterioration of the components, violation of guidelines, incorrect insertion into the machine, internal factors, external factors, slow pace of the operator, software error, dropping a component, degraded component, people factor, damage during transport, faulty components, bad dimensions, dust, moisture, poorly set line, improper maintenance, poor lubricant injection ratio, material delivery delays, material damage during transportation, improperly trained personnel, poor check-in, poor check-out, faulty plan of maintenance, bad monitoring, poor environmental control, poor waste separation, and others. The main goal of the research was to design a functional and applicable model of quality tools for all divisions of the parent company with different geographic locations.

We focused on selecting the "critical" causes (Figure 12) of the production process that appeared in all divisions. We have chosen the 10 most frequently occurring causes for the Pareto analysis. The Ishikawa diagram was used to search "critical" causes in the divisions from the point of view of the 6M approach, so we wanted to capture the causes from multiple perspectives and connect their solutions.

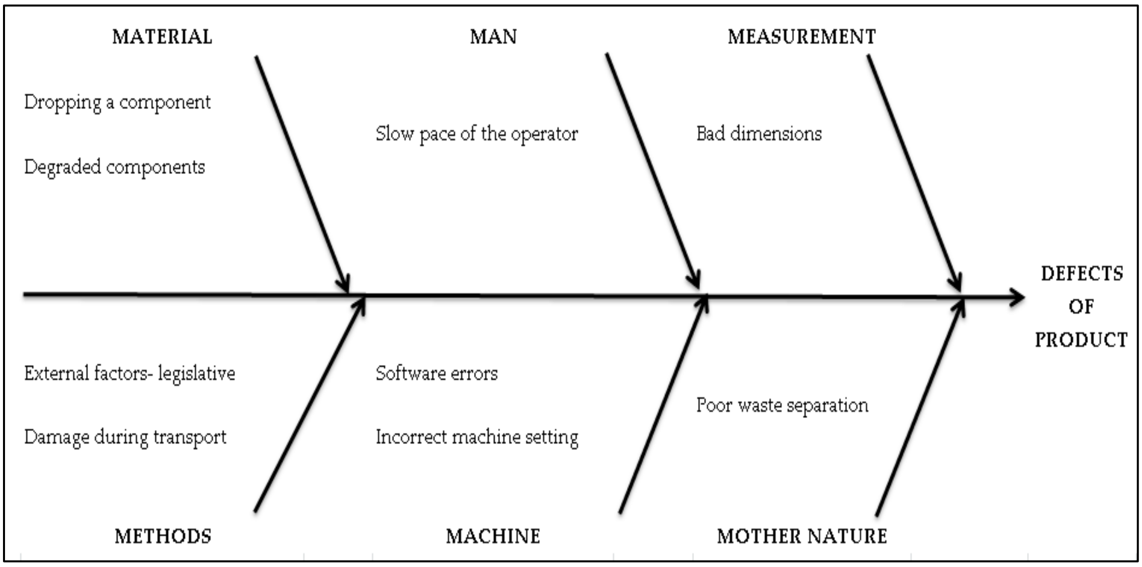

Figure 12. Critical causes of production process. Source: own authors.

An Ishikawa diagrams is a causal diagram, created by Kaoru Ishikawa, that shows the potential causes of problems in the production process. Based on the performed Pareto analysis according to Formula (3), we obtained the following results (Table 5). We calculated indicators such as structure (%) of causes and cumulative structure (%) of causes in the production process.

Table 5. Causes of problems in production process. Source: authors.

Causes	Number of Defect	Kv	Multiplicity	Structure (%)	Cumulative Structure (%)
Incorrect insertion into the machine	3000	4	12,000	29.52	29.52
External factors	2500	3	7500	18.45	47.97
Slow pace of the operator	1500	4	6000	14.76	62.73
Software error	897	5	4485	11.03	73.77
Dropping a component	4000	1	4000	9.84	83.61
Degraded component	2000	2	4000	9.84	93.45
People factor	310	5	1550	3.81	97.26
Damage during transport	370	2	740	1.82	99.08
Faulty component	180	2	360	0.89	99.97
Bad dimensions	130	0,1	13	0.03	100

The support instrument of Pareto analysis is the Lorentz curve (Figure 13). Based on the 20/80 relationship, we determined the critical causes of production process problems in all divisions. Based on the Lorenz curve (20%), it was found that the "critical" causes are incorrect insertions into the machine, external factors—legislative, slow pace of the operator, and software errors. The value (80%) amount of those causes renders 29,985 defects.

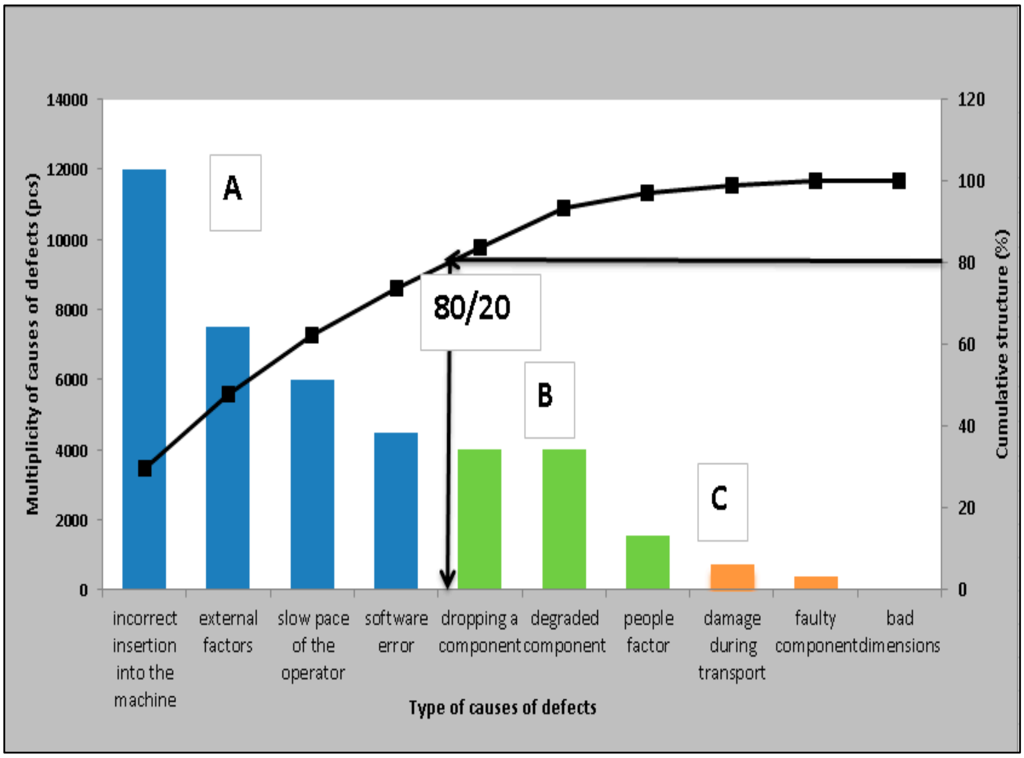

Figure 13. Lorentz curve. Source: own source.

On the basis of the Pareto analysis, we defined categories of all causes in the production process (Table 6). Category (A) represents various analyzed items for condition less than 80% of cumulative structure. Those causes are critical manufacturing defects and serious defects, which influence the production process and the quality of products. They are important to solve and remove because of their high costs. Category (B) represents various analyzed items for condition less than 98% of cumulative structure. This smaller amount of causes can be removed and does not create high costs. Category (C) represents various analyzed items for condition greater than 98% of cumulative structure. These are negligible causes that do not threaten the quality of the product and the quality of the production process. They do not need to be removed because they create small costs and their number is low. The advantage of this affinity diagram is the isolation of the causes of production process problems in group (A) that represent a serious problem for the divisions.

Based on the categorization by affinity diagram of the causes of the product—A, B, C—it is necessary to eliminate such causes as incorrect insertion into the machine, external factors, slow pace of the operator, and software error. Those causes create 29,985 defects, i.e., 72% of defects in the production. This is the highest portion of defects and it is important for this situation to be resolved in the production process.

The fourth process, product packaging, focused on reusing packaging and reducing packaging waste. Cardboard packaging in the production process was replaced by returnable plastic packaging (Figure 14), which reduced the amount of waste and resulted in more efficient use of resources. This change of the material packaging meant an increase in marketing costs of 1600 €, which was determined in the promotion process. The marketing costs increased, but on the other hand, the packaging process improved and packaging waste decreased. This change was seen in the profit statement, in the item costs decreasing about 20%. In terms of amount, this means packaging waste reduced from 90,869 tons to 73,153 tons.

Table 6. Affinity diagram—ABC categorization of defects. Source: authors.

(A) Category	(B) Category	(C) Category
Multiplicity 29,985	Multiplicity 9550	Multiplicity 1113
Cumulative structure (%) < 80%	Cumulative structure (%) < 98%	Cumulative structure (%) > 98%
Cumulative structure 73.77 (%)	Cumulative structure 97.26 (%)	Cumulative structure 99.08–100 (%)
Number of items (causes) 4	Number of items (causes) 3	Number of items (causes) 3
Incorrect insertion into the machine	Dropping a component	Damage during transport
External factors	Degraded component	Faulty component
Slow pace of the operator	People factor	Bad dimensions
Software error		

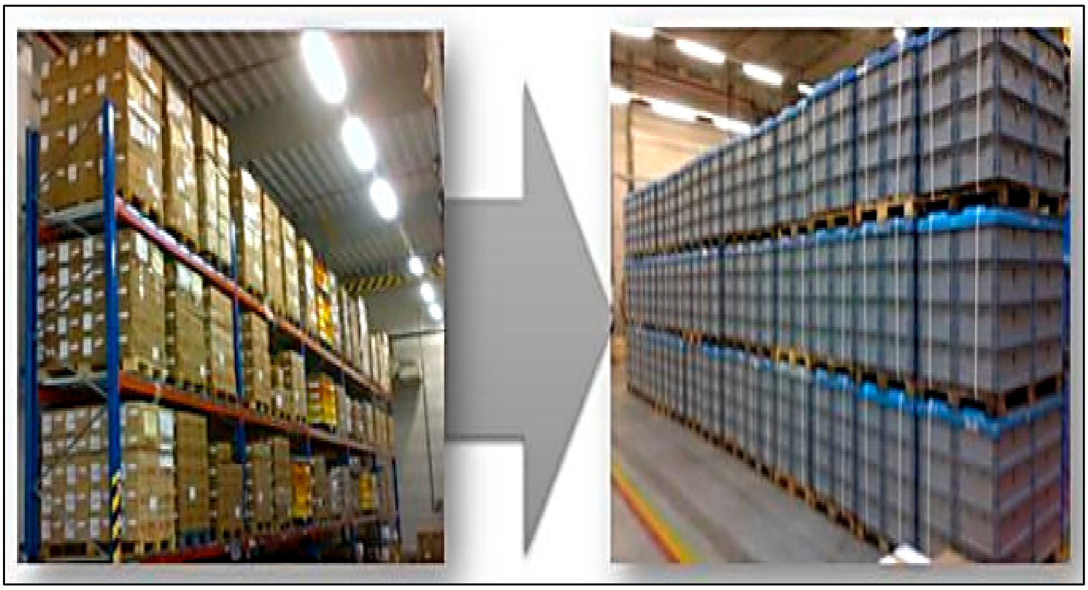

Figure 14. 5S approach for packaging. Source: internal documents.

Quality management tools are widely used in production processes and, in the area of process improvement, they also bring economic, social, technical, and technological changes that are reflected in the performance indicators of production companies. The implementation of these changes means increasing the market value of the parent company in its divisions all over the world, and creating a high market share and goodwill.

5. Discussion

Many authors in the scientific field mention the benefits of implementing quality tools in practice. In their research, however, they do not mention the benefits of several quality tools and their combination in individual business processes. At the same time, in the scientific field, we have not discovered a model of the combination of quality tools that would improve processes and increase their performance. An important part of our research was also the investigation of the implementation of quality tools in the divisions of a parent company all over the world, where it is important to accept the various factors that have an impact on performance. We considered the most important factors to be geographical location, corporate culture, legislative norms and laws, and patterns of customer behavior. The purpose of this paper was to investigate the use of quality tools in the divisions of a parent company without respect to the geographical location of those divisions around the world in the countries of America, Africa, Asia, and Europe. The research aims to determine the applicability of the same quality tools in business processes in various geographical locations. As part of this research, we established a basic hypothesis for using quality tools:

Hypothesis 1 (H1). *The synergy of quality tools and methods in divisions improves the performance of processes. We tested this hypothesis based on improvements after the implementation of quality tools and methods in the divisions' processes.*

Based on the research of various authors, we selected the quality tools presented by previous studies: Pavletic et al. (2009) used Kanban and 5S; Chen et al. (2022) dealt with the Ishikawa diagram and TQM approach; Wuni and I.Y. (2022) used Pareto analysis; Ghatorha et al. (2022) and Sumasto et al. (2023) used the PDCA cycle for improvement in such areas as OPL, visualization, and layout; and Kádárová et al. (2015) presented the DEA model to measure the efficiency of processes. We used the coefficient of efficiency and index of functionality as the base for the evaluation of processes in divisions [52].

The combinations of the quality tools and methods represent synergy of the personnel, economic, financial, technical, and technological aspects of the processes. We used a combination of the quality tools and methods in four selected processes within the divisions of a manufacturing company (Figure 15). This new model of combining quality tools and methods is suitable for divisions around the world. Synergy of quality tools and methods can mean a new approach to process innovation.

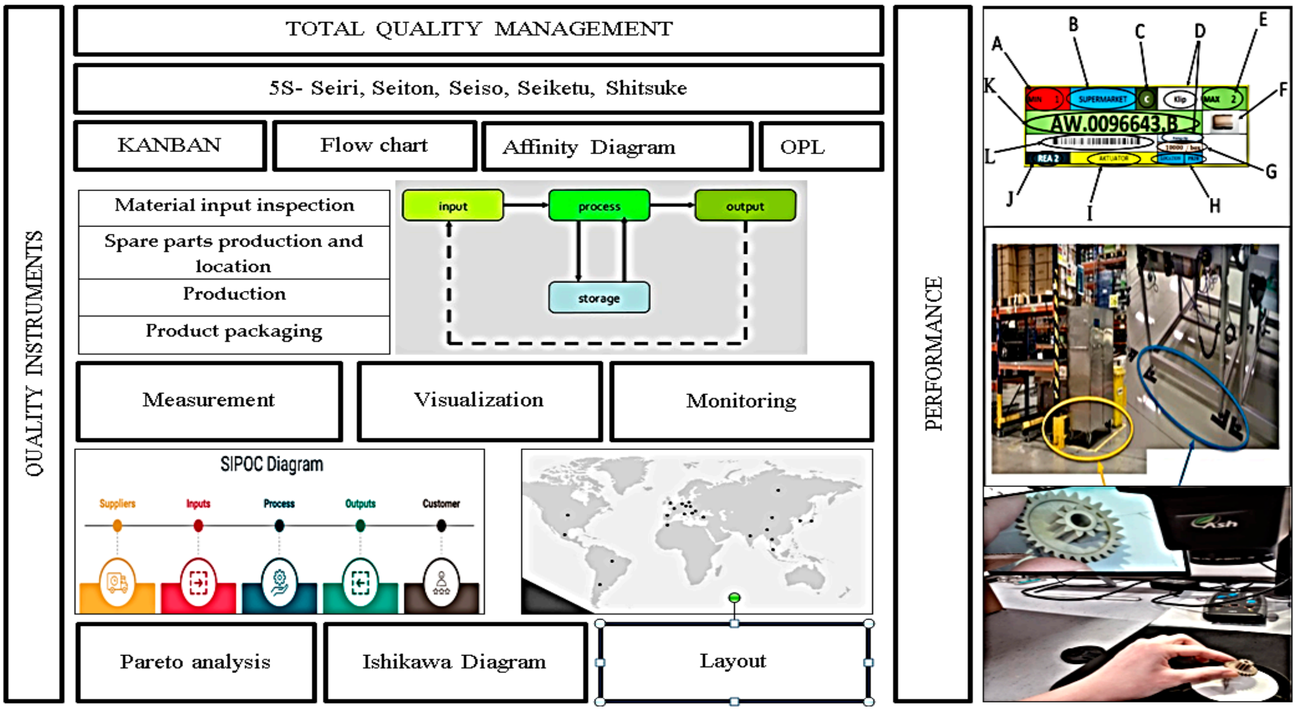

Figure 15. New model of synergy of quality tools and methods. Source: authors.

This new model of synergy of quality tools and methods makes it possible to implement appropriate quality tools into processes of company production. It points precisely to processes that can be improved and to quality tools that can be used, without the influence of various external factors. Visualization enables better implementation in businesses. The model emphasizes process performance with a focus on total quality management. Based on the results of process testing (Table 7), we determined the following improvement outcome for our H1: Combining various quality tools (for example, KANBAN, 5S, flow chart, affinity diagram, OPL, Pareto analysis, Ishikawa diagram, layout) in divisions of the mother manufacturing company with different geographical locations (America, Africa, Asia, and Europe) increases production and improves processes' performance.

Table 7. Results for hypothesis. Source: authors.

Processes	2021	Effectiveness 2022–2023	Functionality 2023	Implemented Quality Tools and Methods	Improvements
Material input inspection	Ineffective Nonfunctional	Mostly effective	Mostly functional	Flowchart Visualization Kanban	Material flow, Material control Claim process, Transport, Costs Material order, Downtime
Spare parts production and location	Ineffective Nonfunctional	Mostly effective	Mostly functional	5S method	Ergonomic location Mark the space
Production	Ineffective Nonfunctional	Mostly effective	Mostly functional	5S method OPL Ishikawa diagram Layout Pareto analysis Affinity diagram	Defects, Downtime, Layout Working condition Costs Employee training
Product packaging	Ineffective Nonfunctional	Mostly effective	Mostly functional	5S method	Returnable packing Material of packing

The hypothesis was confirmed.

The processes that were nonfunctional and ineffective were improved. The processes were set at the level of "mostly effective and functional" after the implementation of quality tools in the year 2023. The combinations of quality management tools, according to Figure 13, introduce a new approach to innovation in the processes in divisions of the manufacturing company, without the influence of geographical location.

This model can be used in various industrial companies. Implementation of quality tools brings many improvements in the areas of cost, time, downtime, material flow, transport, layout, claim process, documentation, location, marks, defects, safety, absence, risks, training, working conditions, and others.

Process optimization is a pillar of Industry 4.0 in synergy with Quality 4.0, with an orientation towards innovation, as presented in the article by Lachvajderová et al. (2022). Such pillars of Industry 4.0 are supported by digitalization, and the main goal of strategy direction is sustainable development in the sense of a circular economy, as presented in the research of Markulik et al. (2021). All processes (supply, transport, storage, production, marketing, design, and delivery) are interconnected and are reflected in the business performance of the processes through the performance indicators (KPI—key performance indicators) that were presented by Potkány et al. (2020) and Suchánek et al. (2015). Potkany et al. (2022) commented in their research that the performance model must include process results in terms of SMART criteria. SMART is an acronym that stands for Specific, Measurable, Achievable, Realistic, and Timely. SMART incorporates all of these criteria to increase the chances of achieving a defined goal, as presented in the article by Bilan et al. (2020). Such an approach allows manufacturing companies to be competitive.

The implementation of quality management tools creates a basic foundation of innovation, sustainability, optimization, digitalization, and efficiency, as presented in the research of Shahriar et al. (2022), Kumar et al. (2020), Ghatorha et al. (2022), Sumasto et al. (2023), and Guo et al. (2021).

The improvement model of processes (Figure 16) must contain the pillars of Industry 4.0—optimization, digitalization, efficiency, and automation. Teplická et al. (2021) argued that using quality instruments increases performance, with an emphasis on added value and business development. Using quality tools and methods introduces a proactive approach to optimization of costs and increases the sustainability of processes [53]. In each area of management, quality instruments and their synergy in various processes can be used to great effect.

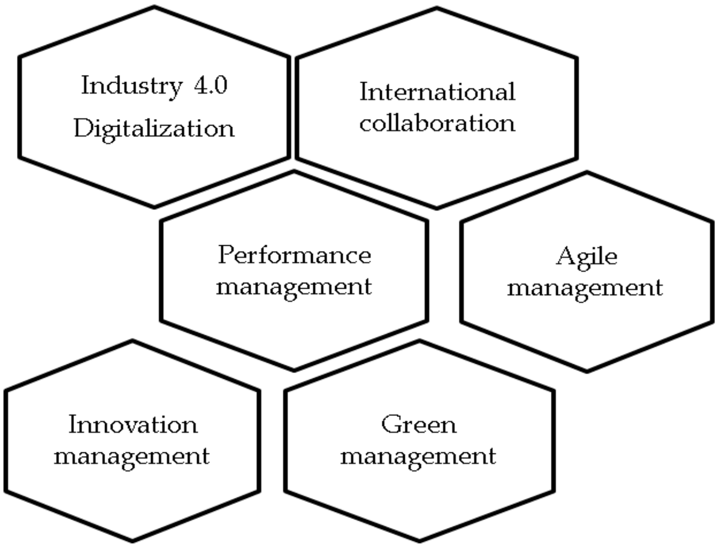

Figure 16. Improvement model of processes. Source: [53].

The first step is using digitalization, which makes documentation and evidence easier in each process. Potkány et al. (2012) wrote that the database of information on the processes creates the basis for performance management and the fulfillment of strategic goals. The database comprises a system of calculation and the budgeting of processes. This approach influences demand [54]. Part of innovation in processes is a quick response to changes: agile management, in the international market; international business collaboration, in the scientific field; and innovation management, in the environmental field and green management. Menon et al. (2022) noted that sustainable manufacturing is revolutionizing the industry's operation framework to optimize processes, increase productivity, and eliminate waste. Sustainable manufacturing has evolved from theory- and principle-based models to technology-driven functioning. Integrating automated control tools into conventional manufacturing methodologies has significantly increased overall performance, productivity, and output. Moreover, cost optimization and efficient consumption of resources are increasingly achieved, and most industries are shifting gradually towards sustainable manufacturing [55]. Digitalization in manufacturing contributes to environmental sustainability by boosting resource and information efficiency. Manufacturing and logistics operations intelligently linked across industry lines result in greater efficiency and an adaptive real-time lean manufacturing environment. A suitable combination of quality tools enables the connection of individual forms of management and affects the base frame of the company's growth, namely in the added value that is reflected in innovations.

6. Conclusions

The implementation of quality management tools and methods creates a basic foundation of innovation, sustainability, optimization, and efficiency. Instruments of quality management create a base frame for the circular economy. The principle of a circular economy is optimization focusing on sources, processes, people, machines, systems, and information. The creation of a synergy model of quality tools and methods in processes of a manufacturing company with various divisions, in various geographical locations around the world, was the first step to prepare this scientific article and to fill in the gap in scientific research orientated to relevant combinations of quality tools and methods for processes. These quality tools significantly influence the performance results of industrial companies. The subject of the research was a selected manufacturing company with divisions around the world, with workplaces in America, Africa, Asia, and Europe. The main goal of the paper was to point out the benefits of implementing quality management tools and methods in processes. Research methods focused on the use of economic analysis, Pareto analysis, and quality management tools such as flow chart, 5S method, Ishikawa diagram, affinity diagram, layout, Kanban, and the OPL method. We presented our hypothesis H1: The synergy of quality tools and methods in divisions improves the performance of processes. Combining the various quality tools previously mentioned, and applying them in divisions of the mother manufacturing company with different geographical locations, improved and increased the processes' performance. Thus our hypothesis was confirmed. The results of the process analysis point to mostly efficient (material input inspection, spare parts production and location, production, product packaging) and mostly functional (material input inspection, spare parts production and location, production, product packaging) processes. Those processes were optimized by instruments of quality management. This implementation reduced the costs of material procurement, inspection, and the claims process. The flowchart improved the transfer of received material to storage. The transfer of material from the warehouse to production was determined by Kanban card, supporting the JIT material ordering system. Results brought a reduction of time, reduction of movement downtime, higher productivity, removal of dead stock, increase of space for stock storage, increased available information, and new layout in production. Our study addressed a system of defects in category (A), which were high-risk and needed to be solved promptly. Cardboard packaging in production was replaced by returnable packaging, which reduced the amount of waste. The instruments of a quality management system offer possibilities for improving all processes in various industries. This new model offers the scientific benefit of lean production, the social benefit of introducing a uniform standard for divisions in various countries of the world, and the economic benefit of cost optimization.

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Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy.

Conflicts of Interest: The authors declare no conflict of interest.

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