

EXPLORING RELATIONS BETWEEN METHODS OF ASSURING QUALITY, CERTIFIED MANAGEMENT SYSTEMS, ADOPTION OF TECHNOLOGIES AND COMPANY PERFORMANCE

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Abstract

Research purpose. Integrating advanced technological solutions into production management and control systems heralds a new era of enhanced efficiency and defect mitigation in manufacturing processes. A significant reduction in human errors marks this advancement and encompasses the adoption of technological and environmental innovations. These elements, in synergy with quality assurance methods and certified management systems, are the foundations for the factory of the future. However, the pace of adoption of these digital technologies varies across different companies and industrial sectors and is influenced by distinct factors. This research aims to investigate the relations between methods of assuring quality in production, certified management systems, adoption of digital technologies for production management and control, and the performance of manufacturing companies in terms of product quality and customer satisfaction.

Design / Methodology / Approach. In this study, the authors employed a multivariable analysis approach, utilizing data from the Latvian and Finnish subsets of the European Manufacturing Survey 2022 (EMS, 2022) data collection.

Findings. Manufacturers utilizing traditional quality and production management approaches tend to adopt new technologies. However, using digital technologies to manage and control manufacturing processes alone does not ensure better product quality and increased customer satisfaction.

Originality / Value / Practical implications. The study enhances understanding of the nexus between established production management practices and the integration of digital technologies. Insights into this interplay enable manufacturing companies to streamline their digital transformation, optimizing operations for the benefit of the company, its customers, and the environment.

Keywords: Certified Management Systems; Digital Technology; Manufacturing; Production; Quality assurance.

JEL codes: L6, O11, P18.

Introduction

In the current time of uncertainty, high competition, and technological advancement, manufacturing companies must innovate in their operations and customization to maintain and grow their competitiveness (Kopp et al., 2020). As technology evolves, companies must continually improve and update their products and operations to stay ahead of their competitors. This constant innovation is critical because the existing product or methods may quickly become obsolete in the rapidly changing operational environment. By introducing new technologies and improving their processes, companies can offer better products, increase efficiency, and respond more effectively to market demands, thereby ensuring their competitiveness in their industry (Tasleem et al., 2015). Technological progress also

disrupts widely used management practices (Fadilasari et al., 2024; Skuza, 2019). Although the adoption and implementation of digital technologies, often referred to as Industry 4.0 technologies, have become increasingly popular and considered to be beneficial, the practical adoption and execution encounter many difficulties (Ali & Johl, 2022). Embracing standards-based management systems can lead to cost reductions, process optimization, increased sales and market share, improved reputation, better environmental and economic performance (Eng Ann et al., 2006), increased productivity and profitability (Mohanraj & Kumar, 2019), and higher product quality by reduction of errors and defects (Ramdass & Masithulela, 2018), alongside fostering a culture of continuous improvement (Sanchez-Lizarraga et al., 2020). Standards facilitate alignment with industry-specific requirements and state-of-the-art solutions and can be used to improve systems, processes, services, and products (Pilena et al., 2021).

The integration of Industry 4.0 technologies into existing manufacturing management systems remains an unexplored area (Buer et al., 2018; Kolberg & Zuhlke, 2015; Tortorella et al., 2019). While numerous studies have previously examined how quality and environmental management contribute to the competitiveness and sustainability of manufacturing companies (Haddaden & Safwan Altarazi, 2023; Liu et al., 2022; Potkany et al., 2022; Zhao et al., 2022) and how the adoption and integration of digital technologies impact quality management practices (Fadilasari et al., 2024; Robertsone & Lapina, 2022; Tortorella et al., 2019) the influence of quality management methods and standards-based management systems on the adoption of digital technologies remains underexplored. The research of Tortorella et al. (2019) examines how the adoption of Industry 4.0 technologies moderates the connection between Lean production and improvements in operational performance. Fadilasari et al. (2024) look into the challenges of quality management principles application in Industry 4.0.

The research of Ali and Johl (2022) analyses the effect of Total Quality Management (TQM) digitalization on Industry 4.0 readiness, having a company size as a moderator. Tasleem et al. (2015) investigate the relationship between TQM and technology management practices. However, according to the authors' best knowledge, there is no research on the impact of quality management and assurance practices on technology adoption.

The current research investigates how and to what extent standards-based management systems like ISO 9001 or similar, methods of assuring quality in production (TQM, procedures, continuous improvement of production processes) impact the implementation of digital technologies and whether these technologies have a positive impact on the performance of manufacturing companies in terms of quality and customer satisfaction. To be able to achieve these objectives, a survey was conducted to collect data, followed by a statistical analysis demonstrating the current situation in manufacturing companies in Finland and Latvia.

Literature Review

Quality Management and the Adoption of Technologies for Production Management and Control

Quality and production management are critical to a manufacturing company's longevity and directly affect its operational performance. The ability to satisfy and even surpass customer expectations by continuously improving is crucial for the survival of companies (Salikon & Saadon, 2023). Quality management (QM) focuses on enhancing product and service quality to achieve customer satisfaction (Sanchez-Lizarraga et al., 2020). Thus, QM is an integral part of overall company management, offering a variety of methods and tools for production control, problem-solving, and improvement (Skuza, 2019), leading to higher product quality and competitive advantage. Quality management can also enhance innovation by effectively transforming new ideas into marketable products and facilitating the adoption of advanced technologies (Udofia et al., 2021). Some methods and approaches, like the implementation of standards-based management systems, Six Sigma, and Lean, are often more widely used than other methodologies (Potkany et al., 2022).

The previous studies indicate that adopting quality management practices allows manufacturing companies to analyse quality-related data better, leading to increased customer satisfaction and improved management of suppliers, product design, and processes, thereby enhancing the quality of the

products and services offered (Alshourah, 2021; Bon & Mustafa, 2013; Lakhali et al., 2006; Liu et al., 2022). Process management and product design directly impact manufacturing companies' performance (Liu et al., 2022). Previous studies have also confirmed that QM facilitates environmental innovations - product and process improvements aiming to optimize resource consumption and use, thus contributing to achieving sustainability goals and generally having a significant positive effect on corporate sustainable development (Zhao et al., 2022).

Total Quality Management (TQM) is a concept of continuous improvement with the involvement of all functions of the organization widely used in manufacturing for production management and increase of the competitiveness related to product quality, customer satisfaction, productivity, and profitability (Potkany et al., 2022). Globally, organizations adopt TQM principles to achieve excellence in their operations. Combined with technology adoption, TQM contributes to achieving sustainability and better organizational performance (Tasleem et al., 2015).

ISO 9001 is an international certifiable standard that sets the requirements and criteria for quality management systems (QMS) (ISO, 2015a). Its primary focus is attaining and exceeding customer expectations and requirements (Sanchez-Lizarraga et al., 2020). Many previous studies have confirmed that ISO 9001 implementation has a significant positive impact on companies' operational and business performance, mainly in terms of product quality, customer satisfaction, productivity, and market share (Al-Refaie et al., 2012; Bakhtiar et al., 2023; Nurcahyo et al., 2021).

Manufacturing companies use the application of standards to apply a standardized approach in the development and implementation of management systems, addressing customer requirements and gaining competitive advantage (Potkany et al., 2022) for the improvement of environmental and social performance and better use of company resources (Eng Ann et al., 2006). Compliance with legislation, organizational strategy, and the need to improve internal processes are the factors that may affect the decision to implement standards-based management systems (Suzanska & Robertstone, 2023). In many cases, the certification is also requested by existing and prospective customers (Ramdass & Masithulela, 2018) and can be crucial for the business. However, some research indicates that the primary barrier to adopting standards-based management systems is often the lack of clear customer demand for such certifications (Sanchez-Lizarraga et al., 2020).

Successful implementation of standards-based quality management systems allows companies to adopt the TQM philosophy (Mohanraj & Kumar, 2019). Standards-based QMS put the requirements for established consistent processes, document procedures, continuous performance monitoring and improvement, customer orientation, and employee involvement (Hoyle, 2009). This systematic approach aligns with TQM principles, such as continual improvement, customer-focused organization, total employee involvement, and a process-centred, strategic, and systematic approach (ASQ, 2024; Zairi, 1991). By implementing standards-based quality management systems, companies create a foundation on which TQM principles can be built.

The studies also confirm that manufacturing companies become more internationally competitive when introducing standards-based quality management systems (Ramdass & Masithulela, 2018). However, traditional management practices are insufficient to compete and sustain in the contemporary business environment as operations become more complicated (Javaid et al., 2022). The survival and sustainability of manufacturing companies in the highly competitive environment are related to their ability to coordinate their efforts across various functions and to adopt and integrate advanced technologies in manufacturing. These technologies ensure flexibility and enhance quality in production (Dangayach & Deshmukh, 2006). Traditional methods of production control often lack the flexibility to adapt quickly to the changes in the market, demand uncertainty, and product variety (Weckenborg et al., 2023).

Among the factors affecting the implementation and integration of digital technologies in manufacturing companies, the previous research highlights data usage and legal aspects, such as legislation and IT standards, IT infrastructure, workforce commitment, collaboration, and teamwork (Zhao et al., 2022). The role of external support from the government, research institutions, and consultants is also underlined. The literature also mentions the factors that may negatively affect technology

implementation – workers' acceptance of technology, fear of job loss, and occupational health and safety issues (Kopp et al., 2020).

It is also assumed that the motivation and success of digital technology implementation depend on the experience and the efficiency of current methods and systems used in manufacturing. The study within American manufacturing companies implementing ERP systems demonstrated that those companies that want to improve external market and supply chain performance must first achieve foundational improvements in internal operational performance to enhance customer satisfaction and supply chain benefits. (Stratman, 2009). A study by Jung et al. (2023) demonstrated that the expectations of adopting smart factories depend on the performance of current production systems. If the current production methods, systems, and tools are well established and effective, they improve the overall performance of manufacturing companies; therefore, digital technology implementation is expected to enhance the performance further, thus creating motivation for smart technology adoption.

Nonetheless, despite numerous benefits, many companies still struggle with the integration of digital technologies (Tortorella et al., 2019). Therefore, companies look for solutions how to implement the technologies in a more efficient and effective way. Quality management within organizational contexts is critically important for enhancing operational efficiency, customer satisfaction, competitive advantage, and aligning business objectives with customer needs (Fadilasari et al., 2024). Thus, traditional methods for quality assurance and management, including standards-based management systems, may serve as the solid foundation for the adoption and integration of digital technologies in manufacturing.

Technology Adoption and Company Performance

Research and practical applications are increasingly focusing on the automation and digitalization of manufacturing processes, as the manufacturing industry is an important production sector of the national economy of many countries (Guo & Su, 2023). Industry 4.0, with its technologies, is a technological revolution based on the advancement of technology to increase the efficiency of business, engineering, and production processes, improve quality, and ensure sustainability (Ali & Johl, 2022). Industry 4.0 technologies corresponding to success factors offer a variety of economic advantages (Bhatia & Kumar, 2022).

Manufacturing companies are forced to become more flexible, resilient, and cost-efficient to respond faster to increasing customer demands and changes in the external environment, offering a better product and service quality at lower prices and minimizing resource utilization. Industry 4.0 technologies assist companies in conquering such challenges by the increase in productivity, efficiency, and flexibility of manufacturing processes, reduction of equipment downtime, better visibility and control of processes, collaboration, improved product quality and customization, faster response to customer demands, shorter product launch and delivery times, flexibility increase regarding production volumes, optimization of resource consumption leading to reduction of costs and enhanced information exchange (Bhatia & Kumar, 2022). Industry 4.0 presents manufacturing companies with answers to the challenges of how to enhance their current operations and practices (Rahardjo et al., 2023).

Rapid technological advances have the potential to transform production management and control within the manufacturing sector, leading to the creation of smart factories (Rahmani et al., 2022; Sony & Naik, 2020). The concept of the "factory of the future," powered by digitalization and automation, is considered crucial for gaining a competitive edge in the global market (Anumbe et al., 2022). Adopting Industry 4.0 technologies is necessary to ensure flexibility and customization, leading to improved organizational performance (Javaid et al., 2022).

The implementation of advanced technologies facilitates better integration of customers and suppliers in supply chains, which leads to significant improvements in operational performance through increased profits, sales growth, and increased customer satisfaction and loyalty (Soesetyo et al., 2024). The research of Saad et al. (2023) also indicates that technology adoption positively impacts customer satisfaction. Adopting RFID technology can enhance organizational agility, leading to improved overall performance (Zelbst et al., 2011). ERP system implementation can improve operational performance (Stratman, 2009). Digital technologies may facilitate cost reduction, improve product quality, and enrich

customer experience (Wan et al., 2023). Based on the results of the literature overview, the following hypotheses have been forwarded:

H1: Companies that have certified QMS and methods of assuring quality in production in place also adopt technologies for production control.

H2: The implementation of production control technologies has a positive impact on product quality.

H3: The implementation of production control technologies has a positive impact on customer satisfaction.

The conceptual model of the research is shown in Figure 1.

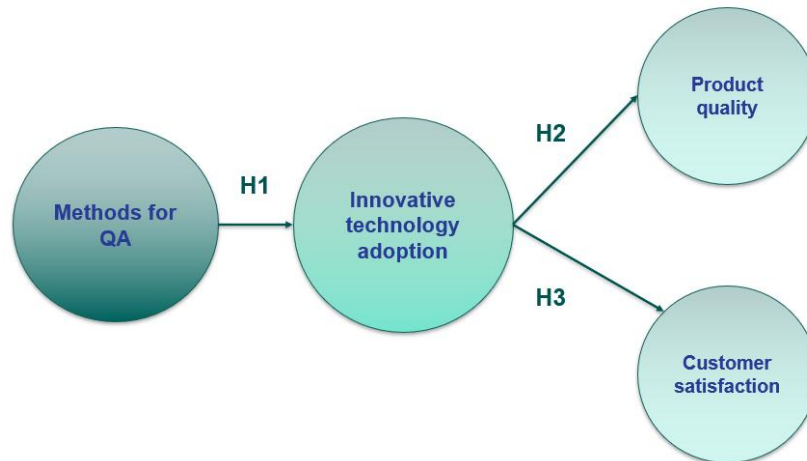


Fig. 1. Conceptual model of the research (Source: Created by the authors)

The authors propose that integrating quality management practices with advanced technologies is essential for manufacturing companies to maintain competitiveness and sustainability in the contemporary business environment. Adopting digital technologies enhances operational efficiency, contributes to improving product quality, and increases customer satisfaction. As manufacturing companies continue to navigate the challenges of globalization and market volatility, the synergistic relationship between quality management systems and technology adoption will be increasingly critical in driving performance and ensuring long-term success.

Research Methodology

For the current study, the multivariable analysis technique was applied based on data corresponding to the Latvian and Finnish sub-samples of the European Manufacturing Survey 2022 (EMS, 2022) edition data collection. European Manufacturing Survey is organized every three years and is managed by a consortium of 19 European universities and research institutes. The Fraunhofer Institute for Systems and Innovation Research (ISI) coordinates the survey.

The survey period is October 2022 – March 2023. The online questionnaire was sent to 2500 manufacturing companies in Finland and 548 manufacturing companies in Latvia. The target group of the respondents consisted of companies' Chief Executive Officers, Plant directors, and Production managers. The response rate in Finland is 5%, with 123 companies participating in the survey; in Latvia, it is 13 %, with 71 manufacturing companies' respondents. In terms of industries (Figure 2), the survey covers metal, machinery and equipment, textile, food, drink, manufacture of computers and electronics, electrical equipment, pharmaceutical, chemical, rubber and plastic, wood products, and furniture production.

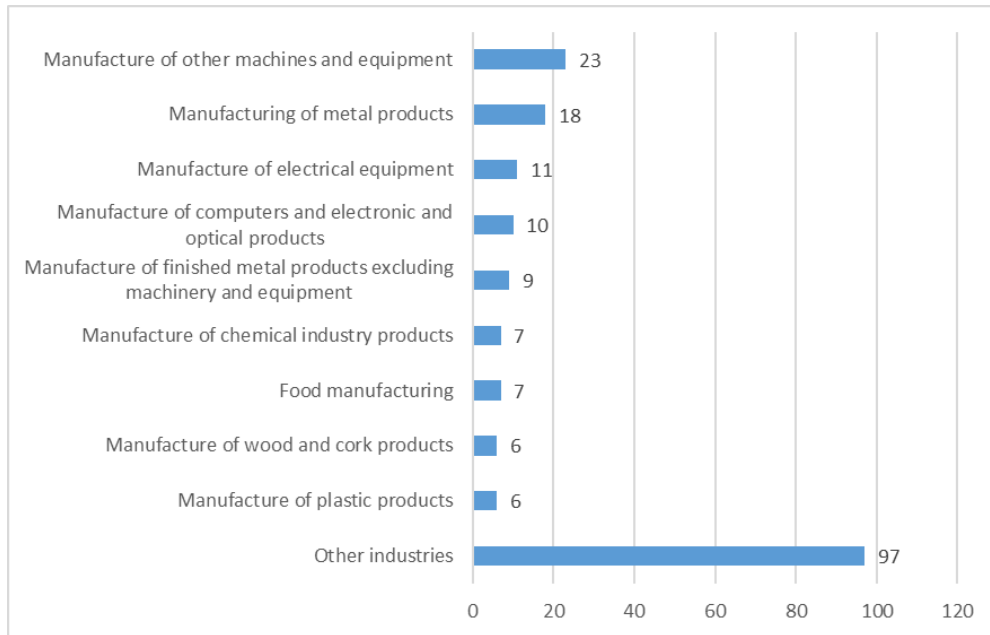


Fig. 2. The distribution of companies by industries (Source: Created by the authors)

Companies' distribution by size by number of people employed, shown in Figure 3, is categorized as Small (up to 49 employees), Medium-sized (50 to 249 employees), and Large (employ 250 or more people) (OECD, 2024).

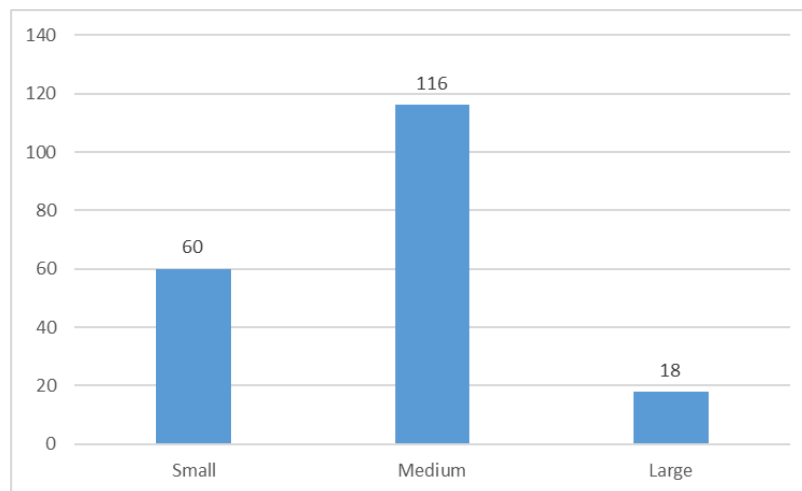


Fig. 3. The distribution of companies by size (Source: Created by the authors)

Company performance was measured by two variables: Product quality and Customer satisfaction. In the survey, the question related to product quality was "What is the percentage of products or semi-finished products that have to be scrapped or reworked due to quality issues?." Customer satisfaction was measured by the number of customer complaints in the percentage of delivered orders ("Client complaints about quality were received for what percentage of delivered orders?").

The independent variable was measured by asking the question, "Which of the following organizational concepts are currently used in your factory?" and the Yes/No option for the "Methods of assuring quality in production (e.g., Total Quality Management procedures, certificates, continuous improvement of production processes)."

Innovative technology adoption was measured by asking the question in the survey: "Which of the following technologies for production control are currently used in your factory?" and the following answer options:

- Mobile/wireless devices for programming and controlling machinery and facilities, e.g., tablets;
- Digital solutions to provide drawings, work schedules, or work instructions directly on the shop floor;
- Software for production planning and scheduling, e.g., ERP or APS system;
- Techniques for automation and management of internal logistics, e.g., Warehouse management systems, RFID;
- Digital exchange of product/process data with suppliers and customers (Electronic Data Interchange (EDI));
- Product-Lifecycle-Management-Systems (PLM) or Product/Process Data Management;
- Near real-time production control system, e.g., Systems of centralized operating and machine data acquisition;
- Industrial robots for manufacturing processes, e.g., welding, painting, and cutting;
- Industrial robots for handling processes, e.g., depositing, inserting, sorting, and packing processes.

These variables are dichotomous, with a value of 1 if the technology is present and a value of 0 if otherwise.

The data was compiled using Microsoft Excel. The data was standardized for comparison purposes, and Pearson's correlation coefficient was used to determine the relationships between different variables. Correlation analysis was performed using the programming language Python and functions provided in the "pandas", "statsmodels", and "scipy.stats" libraries. The "matplotlib.pyplot" library was used to visualize the results. The software solution was written as code in the Python programming language by the authors.

Research Results

The correlation data shows that the essence of Methods of assuring quality in production, e.g., TQM, procedures, certification, and continuous improvement of production processes, has a moderate positive statistically significant association with the adoption of the following technologies as shown in Figure 3: Software for production planning and scheduling, e.g., ERP or APS system, Product-Lifecycle-Management-Systems (PLM) or Product/Process Data Management, Techniques for automation and management of internal logistics, e.g., Warehouse management systems, RFID, and Mobile/wireless devices for programming and controlling machinery and facilities, e.g., tablets,. Digital solutions to provide drawings, work schedules, or work instructions directly on the shop floor), Digital exchange of product/process data with suppliers and customers (Electronic Data Interchange (EDI)), Near real-time production control systems, e.g., Systems of centralized operating and machine data acquisition, have a weak positive correlation with the Methods of assuring quality in production. There is no correlation or insignificant negative correlation with Industrial robots for manufacturing processes, e.g., welding, painting, and cutting, and Industrial robots for handling processes, e.g., depositing, inserting, sorting, and packing processes. However, these results are not statistically significant, indicating the necessity for further and deeper analysis.



Fig. 4. The impact of methods of assuring production quality on adopting production control technologies
(Source: Created by the authors)

The strongest correlation ($r=0.41$, $p=0.0004$) is observed with the Software for production planning and scheduling, e.g., ERP or APS system. This can be explained by the fact that production planning and scheduling are essential to increase manufacturing efficiency. Companies that have implemented methods for quality assurance, certified management systems, and TQM in production would seek ways to increase efficiency and reduce waste and errors by using these technologies.

Comparing Latvia and Finland, it is found that in Latvia, 72% of companies reported having methods of assuring quality in production. In Finland, this figure is slightly higher at 74%.

The impact of technology implementation on product quality is shown in Figure 5. Product quality is measured by the percentage of products or semi-finished products that must be scrapped or reworked due to quality issues. As can be seen, there is a weak negative correlation, which is statistically significant at $p=0.0499$ with Digital exchange of product/process data with suppliers and customers. This means that with the adoption of this technology, the number of products needing to be scrapped or reworked decreases slightly, albeit weakly. The correlation between adopting other technologies and product quality is not statistically significant.

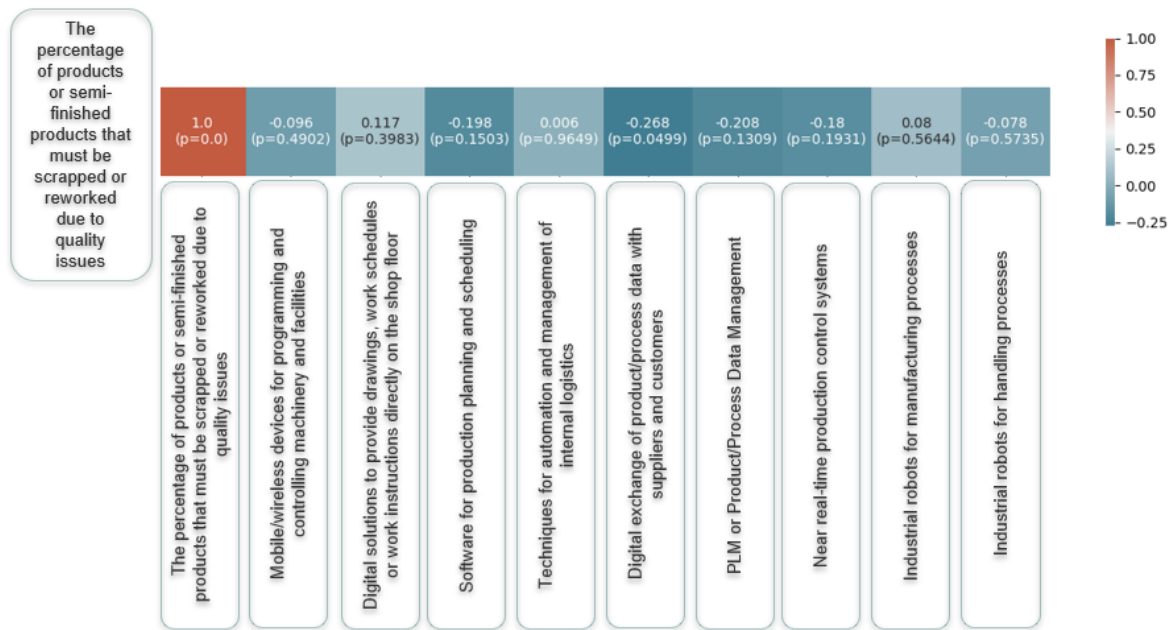


Fig. 5. Technologies impact on product quality (Source: created by the authors)

The similar findings shown in Figure 6 are related to the technology implementation and customer satisfaction measured in terms of customer complaints about quality in the percentage of orders delivered. Without the Digital Exchange of product/process data with suppliers and customer systems, this would become highly disadvantageous since process control is evident in the equivalence level of advanced planning and scheduling systems.



Fig. 6. Technologies' impact on customer satisfaction (Source: Created by the authors)

Digital Exchange of product/process data with suppliers and customers and Software for production planning and scheduling (ERP) show a minor negative correlation with customer complaints, meaning the number of complaints decreases with the implementation of these technologies. However, with $p=0.0592$, only Digital Exchange of product/process data with suppliers and customers can be considered statistically valid. The close integration of software-customer-interface (SCI) into production planning and control can be a powerful technology that can reduce negative customer feedback.

Thus, while H1 was implicitly supported, hypotheses H2 and H3 were only partially confirmed. While current research does not fully address the coincidence delineation interval (or confidence interval), this remains an important area for future investigation.

Discussion and Conclusions

The relationships highlighted by these correlations emphasize the crucial role a robust organizational foundation plays across diverse aspects of a business, ranging from internal operations to external customer satisfaction. Previous studies demonstrated positive direct and indirect impacts of technology implementation on the overall and operational performance of the companies, including product quality improvement and increased customer satisfaction and loyalty (Javaid et al., 2022; Saad et al., 2023; Soesetyo et al., 2024; Stratman, 2009; Wan et al., 2023; Zelbst et al., 2011), current research demonstrates that the technology alone does not have a significant positive impact on product quality improvement, the reduction of failures and customer complaints, as H2 and H3 were only partially confirmed.

Companies that have implemented quality assurance methods such as TQM, continuous improvement, and certified management systems are more likely to adopt ERP systems or similar production planning and scheduling technologies due to the complementary nature of these tools. TQM and similar quality management practices focus on improving processes, reducing waste, and enhancing overall organizational efficiency—objectives that align closely with the goals of ERP systems and the reasons why companies invest in them. With the joint effect of TQM, ERP, and organizational performance, organizations can achieve maximum strong excellence and remain in a competitive market. Companies can achieve maximum excellence through TQM, ERP, and organizational effectiveness and remain competitive in the market (Al-Dhaafri & Alosani, 2021).

ERP systems are designed to integrate various business processes effectively and efficiently across an organization, ensuring real-time data flow and streamlined operations. Companies already committed to quality assurance practices are well-prepared for the organizational change required to implement ERP systems, as both demand high levels of management commitment, employee involvement, and a focus on continuous improvement (Schniederjans & Kim, 2003).

The absence of or slight negative, although not statistically significant, correlation between Methods for quality assurance in production and implementation of industrial robots for manufacturing and handling processes can be explained by the fact that Quality assurance practices are generally aimed at enhancing process quality, reducing defects, and improving customer satisfaction through continuous improvement and adherence to standardized practices (Ramdass & Masithulela, 2018). The adoption of industrial robots is primarily driven by the need for automation to increase production speed and productivity, reduce labour costs, and handle recurring or monotonous tasks more efficiently. Industrial robots are often associated with substantial investments, the need for significant infrastructure modifications, and the complexity of integrating them into existing workflows. The strategic decision to implement robots is often related to the desire to enhance production flexibility, expand the scale of production, or respond to labour shortages (Guo & Su, 2023), which are not the primary purposes of quality assurance methods implementation in production.

The presented research results also underscore the need for a systemic approach, suggesting that improvements in one area often lead to benefits in others. The multisystem relationship between digital technology adoption and traditional quality assurance and management practices (H1) underscores its spotted light on technological integration. Correlations also emphasize the value of a client-centred approach, specifically in digital data exchange with suppliers and customers. These insights spotlight

the multifactorial dynamics of organizational quality in the modern business environment. However, further research is needed to validate these findings, mainly due to the limited geographical scope and sample size.

The pursuit of improved quality management and production control systems is paramount in modern industries, exerting direct influence on the sustainability and profitability of operations. The research findings underscore the importance of well-designed organizational concepts in achieving operational efficiency, product quality, customer satisfaction, and technological innovation. However, these insights should be considered in the context of the specific organizational circumstances and industry dynamics. Furthermore, strategies should be tailored to address the unique challenges and opportunities identified by thoroughly analysing these variables. The positive impact of digitalization on manufacturing will be seen over time, while exploration of long-term competitiveness and sustainable growth in the manufacturing sector is the question of the expansion of quality and environmental management systems in combination with the adoption of digital technologies.

A limitation of the present research is that it relies on a questionnaire survey conducted in the manufacturing companies of just two countries, and the number of respondents is relatively small.

The correlations found in this study suggest that there are complex relationships between different factors within a company that can affect the adoption of digital technologies for production control. Understanding these relationships can help companies make more informed decisions about where to invest resources and what strategies to pursue when adopting new technologies. Further, the study contributes to starting the discussion of traditional management methods and technology adoption, providing valuable insights for companies planning to navigate their digital transformation.

Future research can focus on expanding the dataset and using machine learning models to extend the inquiries into the contracting type of manufacturer to provide a more in-depth understanding of the relationships and their potential causal factors. In addition, a qualitative study could complement the quantitative data, providing insights into the practical challenges and strategies related to production control, quality and environmental management, and advanced digital technologies in the industries of Latvia and Finland.

Finally, implementing a comparative analysis with other countries that have participated in the EMS 2022 survey could provide a richer, more contextual understanding of the factors influencing technology adoption by manufacturing companies and its further impact on performance.

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