

THE IMPACT OF HORIZONTAL AND VERTICAL SYSTEM INTEGRATION ON QUALITY 4.0

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ABSTRACT

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The era of Industry 4.0 insists on the necessity of understanding the connection between the strategy of horizontal and vertical system integration with Quality 4.0. A key segment for the effective implementation of Quality 4.0 is the creation of an organizational system that combines vertical and horizontal integration. In the paper, an overview of the literature related to Quality 4.0 and the mentioned integration in Industry 4.0 was given, and the importance of their understanding in Industry 4.0 was pointed out. Also, the focus of the work is on pointing out advantages, challenges and presenting solutions to overcome these challenges. The motive of writing the paper lies in the fact that there is no paper in which these concepts are combined. The aim of the paper is to consolidate in one place a review of the available literature from these areas in order to achieve progress towards Industry 4.0.



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1. INTRODUCTION

The development of Industry 4.0 technologies had an identical and parallel impact on quality management practices that changed quality management methods and practices (Sader, S., Husti, I., & Daroczi, M., 2022). New technologies of Industry 4.0 enable the minimization of complications and errors, the improvement of process effectiveness through a significant increase in the quality of the final product (Javaid, M., Haleem, A., Singh, R. P., & Suman, R., 2021), productivity, standardization of processes (Zaidin, N. H. M., Diah, M. N. M., Yee, P. H., & Sorooshian, S., 2018), transformation of culture, leadership, cooperation and compliance (Jacob, 2017).

Globalization, turbulent conditions on the market, rapid development of information and communication technologies and digital networks are causing a change in the classic business models of organizations. This creates a completely new world of functioning systems for horizontal and vertical integration (Chukalov, 2017) and conditions the application of new business trends called Industry 4.0, i.e. the introduction of a new quality management practice known as Quality 4.0. In order to adapt, managers and then employees must change their awareness and culture to a great extent, but also improve their skills in using Industry 4.0 technologies (Chiarini & Kumar, 2022).

By integrating the quality management system and the basic technologies of Industry 4.0, organizations are

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given the opportunity to effectively and adequately respond to the numerous challenges they face, such as the struggle for survival in the market and maintaining a competitive advantage. For this reason, there is an increased need to understand the connection of horizontal and vertical integration with quality 4.0 in order to better protect the intellectual property of the organization (Subramaniam, 2021).

Due to the extremely small number of available literature sources that connect Quality 4.0 and horizontal and vertical integration, the author's idea was to unite in one place the advantages and challenges related to horizontal and vertical integration in the new era of business. This is where the motive for writing this work comes from.

The paper pointed out the importance of the connection between horizontal and vertical integration and Quality 4.0, as a central and key element of Industry 4.0. This integration with quality 4.0 achieves a positive influence with each other. Also, the paper pointed out the importance of the relationship between horizontal and vertical integration and Quality 4.0.

The contribution of the work is reflected in a tabular representation of the advantages and challenges of horizontal and vertical integration and Quality 4.0, with a proposal for possible solutions to those challenges.

The work is organized as follows: Section 2 refers to the basics of the concept of Quality 4.0 and horizontal and vertical integration of the organization's system. Section 3 of the work describes the research methodology - method, sources and methods of collected samples of published works and tabular presentation of research results and discussion. The last part of the paper contains the conclusion.

2. IMPACT OF HORIZONTAL AND VERTICAL INTEGRATION ON QUALITY 4.0

In Industry 4.0, there is a need to increase the understanding of horizontal and vertical integration in which to better protect the intellectual property of the industry (Finance, 2015; Subramaniam, 2021), due to the emergence of a new value network, as well as new business models (Sony, M., Antony, J., & Douglas, J. A., 2020). Accordingly, the interaction of implemented systems integrated into digital networks creates a completely new world. The interaction between machine and machine, machine and Internet, machine and person in the value chain, in real time forms the basis of the modern manufacturing cyber system (Chukalov, 2017) and has a long-term impact on the company's business strategy (Sewak, 2022).

The use of certain Industry 4.0 technologies could have a positive effect on quality control and management, and therefore on improving the horizontal and vertical integration of the system. Also, the quality management

system in the concept of Industry 4.0 could, on the one hand, contribute to better horizontal and vertical integration, while on the other hand, it could benefit from the use of technologies such as Data Mining, analytics, cloud systems and feedback in decision-making. based on the evidence. Node.js®, Node Package Manager (NPM), MongoDB, Angular, Laravel and MySQL can be used to develop and maintain quality system documentation in the Industry 4.0 concept (Stefanović, M., Đorđević, A., Puškarić, H. & Petronijević, M., 2019).

2.1 Quality 4.0

Given the lack of a generally accepted definition of quality 4.0, some authors define the concept of quality 4.0 in different ways (Aldag, M. & Eker, B., 2018). The term "Quality 4.0" was first used by the analytical company LNS Research in 2017, which defines Quality 4.0 as a set of the latest quality management practices and tools that are applicable for use in the context of Industry 4.0 (Akhmatova, M. S., Deniskina, A., Akhmatova, D. M., & Prykina, L., 2022) state that quality 4.0 combines new technologies with traditional quality methods in order to reach new optimums in operational excellence, performance and innovation. (Sader et al., 2022) defines quality 4.0 as an expanded approach to quality management, where the latest technologies are integrated with traditional quality practices to expand the scope of quality management and improve quality management. (Salimova, T., Vatolkina, N., Makolov, V., & Anikina, N., 2020) defines quality 4.0 as a new understanding of the relationship and responsibility of stakeholders, the transformation of the basic principles on which decision-making in companies is based. In addition to the confirmation of the importance of combining innovative methods of quality management and digital technologies, it has been shown that this process implies the transformation of managerial thinking itself.

The digital transformation of traditional quality cannot be carried out without the implementation of quality 4.0 tools (Richnák, 2022) and therefore, Industry 4.0 technologies are a key factor for understanding how to manage and improve quality processes in the Industry 4.0 era (Carvalho, A. V., Enrique, D. V., Chouchene, A., & Charrua-Santos, F., 2021). Quality management practices are proposed to identify technological progress as a key factor for the successful implementation of quality standards in the era of quality 4.0 (Sader et al., 2022), (Table 1).

Table 1 shows the relationship between quality management practices and seven tools and technologies that can be used to improve quality, in order to facilitate the decision of the type of tool that is most adequate for certain quality management practices.

Table 1. Quality management practices and technology relationship in Industry 4.0 (Carvalho et al., 2021)

I4.0 Tools and Technologies	Quality management practices							
	Management of obligations	Customer involvement	Supplier participation	Employee involvement	Benchmarking techniques	Process management	Information and analysis	Formal strategic planning
Data Science and Statistics	X					X	X	X
Enabling Technologies (IoT, IIoT, Integrated Systems, VR, AR, Cloud Computing (CC))	X	X	X	X	X	X	X	X
Big Data	X	X	X			X	X	
Blockchain	X			X		X		X
Artificial intelligence - AI	X			X			X	
Machine learning - ML	X						X	X
Neural Networks and Deep Learning	X					X	X	

2.2 Horizontal integration

In order to efficiently produce products and services, inter-organizational horizontal integration should be formed, which is made up of related corporations. In this way, an efficient system is formed, in which there is a smooth flow of materials, information and finances between these organizations. In the sub-module of horizontal integration, activities such as planning, control and quality improvement are oriented towards all organizations that collaborate within the value creation process to produce products and services (Sony et al., 2020).

In Industry 4.0, horizontal integration implies the integration of information technologies and production systems with the established exchange of data and information between companies in geographically distant locations throughout the value chain (Chukalov, 2017). This is achieved through the provision of networking through cyber-physical systems, from inbound logistics through warehousing, manufacturing, marketing and sales to outbound logistics (Finance, 2015).

Horizontal integration takes place on several levels (Schuldenfrei, 2019):

- At the production level - connected machines and production units constantly communicate their status and respond autonomously to production demands.
- In multiple production plants - through production execution systems (MES) data about production plants (eg inventory levels, unexpected delays) is shared throughout the company.
- Throughout the supply chain - Suppliers and service providers must be firmly integrated horizontally into the company's production

control and logistics systems.

Examples of successful horizontal integration include Microsoft - Activision Blizzard, Anheuser-Busch InBev and SABMiller, Walt Disney Company and 21st Century Fox (Moltz, 2022; Traver, 2022).

2.3 Vertical integration

Vertical integration occurs when organizations decide to expand by purchasing a company that occupies a critical place in their supply chain process (Moltz, 2022) in order to gain control over the entire production process by integrating different levels of the organization ("Horizontal and Vertical System Integration in Industry 4.0", 2023), minimizing or eliminating the need for external subjects (Amadeo, 2022).

This type of integration in Industry 4.0 uses cyber-physical production systems (CPPS) to enable rapid response to changes in demand or inventory levels and to errors (Finance, 2015). Vertical integration of hierarchical subsystems such as different departments within the factory implies that physical (sensors, control) and informational subsystems (ERP and SAP) are integrated at different levels within the production system in order to create a flexible production system. Quality 4.0 as a sub-module for vertical integration deals with all activities of quality improvement, control and planning, within the organization (Sony et al., 2020).

Examples of vertical integration can be cited (Cook, n.d.; Traver, 2022): Walmart - JoiRun, NVIDIA - Bright Computing, Google and Motorola - Alphabet's Google (GOOG), Ikea and forests in Romania, Netflix (NFLX).

3. THE IMPORTANCE OF QUALITY 4.0 ON HORIZONTAL AND VERTICAL INTEGRATION

3.1 Research methodology

This paper is based on a systematic review of the available literature. Available literature sources from Google scholar, researchgate, springer, science direct were used. Manual search was performed in Google Scholar and Google Chrome, and automated search in Science Direct and Springer.

The search at the mentioned locations was performed by entering keywords into the search engine. Various combinations of keywords were used to search for articles, such as: Quality 4.0, quality 4.0 and industry 4.0, horizontal and vertical integration and quality 4.0, horizontal and vertical integration in industry 4.0.

Papers were reviewed and selected, which, based on the analyzed titles, keywords and abstracts, were relevant to the main research topic of this paper. 23 relevant literary sources were used in writing this paper. The articles that

were used for this paper were mostly published after 2018. with certain exceptions.

3.2 Research results and discussion

In this part of the work in table 2, based on the available literature in this area (Amadeo, 2022; Chukalov, 2017; Cook, n.d.; Finance, 2015; “Horizontal and Vertical System Integration in Industry 4.0”,2022; Moltz, 2022; Pipiy, G. T., Chernenkaya, L. V., & Mager, V. E., 2021; Schuldenfrei, 2019; Sewak, 2022; Traver, 2022) the challenges of horizontal and vertical integration are shown and suggestions are given for overcoming these challenges and the advantages of those solutions are shown in Quality 4.0. Table 3 shows the advantages of horizontal and vertical integration to quality 4.0. In this way, topics from this area are united in one place. Based on a detailed analysis of the presented tables, it is easier to make a decision within the organization whether to choose one type of integration or both in accordance with the specifics of each company and in accordance with the needs and goals of the organization.

Table 2. Presentation of the challenges of horizontal and vertical integration with their solutions and the demonstrated advantages of those solutions to quality 4.0

Challenges	Integration	The solution
Data management - Analysis of accumulated data and knowledge in all sectors of the organization	Vertical and horizontal	Changing the organizational culture, the way of working and the awareness of employees for the use of intelligent systems, the use of digital technologies, such as IoT devices and blockchain, for the collection and sharing of quality data, production units equipped with a wide range of sensors, the establishment of a meta-network
Improvement of IT systems and infrastructure	Vertical and horizontal	Moving to cloud-based IT
Adopting a strong platform for managing and coordinating multiple computer systems and applications	Vertical and horizontal	Investing in the acquisition and updating of a suitable strong platform
Data security and availability	Horizontal	Moving to cloud-based IT
Standardization	Vertical	Implement a quality management system (QMS) that integrates quality management processes in various departments and functions
	Horizontal	Establishing clear quality standards and requirements for suppliers and regular monitoring and evaluation of supplier performance.
Cultural barriers	Vertical	Developing cross-functional teams that include representatives from different departments and functions.
	Horizontal	Developing partnerships and collaboration with other organizations in the supply chain to improve communication and collaboration
Costs	Vertical and horizontal	Using analytics and predictive modeling, continuous improvement that includes regular review and evaluation of quality management practices.

Table 3. Advantages of horizontal and vertical integration on quality 4.0

Quality 4.0 and horizontal integration	Quality 4.0 and vertical integration
Consistent quality throughout the supply chain	Consistent quality across functions within the organization
Improved cooperation and communication with other organizations	Improved communication and collaboration within the organization
Increased efficiency and productivity (Automation, flexibility and operational efficiency in production processes)	Increased efficiency (Quick resolution of change orders, fluctuations in quality or machine failure, reducing waste)
Resource efficiency in terms of efficient use of materials, energy and human resources	
Reducing downtime	
Dynamic management of quality, time, risk in real time	
Improved visibility and traceability	
Improved quality control (more efficient and accurate)	
More efficient decision-making (accuracy, systematicity and agility)	

In order to lead the organization towards industry 4.0, in addition to understanding its tools, it is necessary to understand and successfully implement quality 4.0 and establish connections with horizontal and vertical integration, which serve as key business strategies of the organization towards the key goal.

Industry 4.0, and therefore the quality of 4.0, is characterized by new tools and technologies, and the problems they carry due to insufficient knowledge in the sense of using the right technology in the right place, in this case, is also an advantage, with their proper use, which can be solved by understanding horizontal and vertical integration strategies, by adopting new knowledge and changing culture and awareness in order to achieve sustainability on the market and achieve progress towards industry 4.0.

Among the major problems of the successful introduction of these concepts are problems with large amounts of information, data and their processing (Pipipay et al., 2021), which are successfully solved with the help of modern tools and industry 4.0 practices and quality 4.0. Also, costs can be high due to the acquisition of Industry 4.0 and Quality 4.0 technologies, additional investments in employee training, but in the long run it is profitable. In order to avoid costs related to the inadequate implementation of horizontal and vertical integration and the introduction of inadequate new technologies for a certain organization, it is necessary to change the culture, understand the strategies of horizontal and vertical integration and provide the necessary knowledge about new technologies.

What characterizes Industry 4.0, and therefore also Quality 4.0, are decision-making agility, successful integration with new technologies, and analysis of large amounts of data. With the proper implementation of horizontal and vertical integration in the new era of industry, quality has been improved and its control and

management has been facilitated in all sectors. Also, efficiency in the use of resources and productivity are increased, costs are reduced, communication within and outside the organization is improved, which automatically leads to a reduction in costs and waste.

4. CONCLUSION

For the successful implementation of Quality 4.0, proper selection of business strategies that will lead the organization towards Industry 4.0 and maintaining competitive advantage is necessary.

Correct understanding of the use of horizontal and vertical integration in the era of Industry 4.0 and their impact on aspects of Quality 4.0 is of key importance for the future successful operation of the organization. If implemented correctly, each of the integrations will bring benefits to the organization.

The motivation for writing the paper lies in the fact that there is not a large number of scientific research papers dealing with this topic.

In order to better understand the advantages of each integration, the paper first gives an overview of the literature in the field of Quality 4.0 and horizontal and vertical system integration. After defining the key concepts, the advantages of each of the integrations are tabulated so that organizations can decide which type of integration is best for them based on the goals and strategy of the organization. An overview of the advantages and challenges of horizontal and vertical integration of systems related to Quality 4.0 is given in the form of a tabular presentation, with proposed solutions to these challenges.

Further research will be focused on barriers related to the introduction of quality 4.0 in organizations and ways to overcome these challenges.

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