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SUPPLY CHAIN QUALITY MANAGEMENT (SCQM) LITERATURE REVIEW AND MODEL PROPOSAL IN THE ERA OF INDUSTRY 4.0

Abstract: *The article aims to review the literature on the issue of quality management in supply chains in the era of Industry 4.0 and to propose general assumptions of the model supporting the implementation of the SCQM concept. The developed model stands out from the other concepts presented in the literature in several respects. Firstly, it is based on instruments and concepts often proposed as separate solutions to problems without showing their interrelationship. Secondly, it exposes the importance of IT system management and its role in SCQM. In addition, the developed model has a high universality, which allows it to be implemented (at least incomplete) in almost any supply chain that wants to improve the implementation of key processes.*

Keywords: *SCQM, Industry 4.0, Supply chain, Quality.*

1. Introduction

Supply Chain Management is a fundamental concept of the current economy, which has evolved to enable organizations to improve efficiency and effectiveness in the twenty-first century's global and highly competitive environment. This comprises processes connected with planning, completion, and evaluation related to the flow of materials, equipment, information, and human resources among organizations to ensure effective and fast delivery of tangible products and services between the supplier and the customer. Building a competitive advantage in the manufacturing sector is, in particular, subject to shaping long-term partner relationships between companies. An individualized, trust-based approach toward establishing contacts, interests, and possibilities of cooperation allows the negotiation and execution of transactions with parties, guaranteeing their equal standing (called win-win). A positive evaluation of these activities, through which each party can see several measurable benefits, is essential in maintaining relationships and a sign of readiness for further cooperation (Katiyar, Meena, Barua, Tibrewal, Kumar, 2018; Neutzling, Land, Seuring, do Nascimento, 2018, Zimon et al., 2018; Cyprian Nwasuka et al., 2022). Quality management (QM) and supply chain management (SCM) are the most critical strategic approaches in business management and are considered a prerequisite for companies' success and competitive advantage. Both approaches share common goals, such as the organization's performance improvement and stakeholder satisfaction. However, the study of their integration in terms of management practices is still limited (Fernandes et al., 2022). Industry 4.0 concept uses automation as well as processing and exchange of data, as well as a variety of new technologies (mainly digital) to create the so-called cyber-physical systems, changes in production methods, the possibility of

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personalizing products, and changing the rules of operation value creation chains; in terms of technology, it is a conceptual aggregate covering several technologies such as industrial Internet of Things, cloud computing, Big Data Analytics, artificial intelligence, and also additive printing, augmented reality and collaborative robots (Santos et al., 2021). Given the above considerations and the research gap that exists in the literature on the subject, the article aims to review the literature on the issue of quality management in supply chains in the era of Industry 4.0 and to propose general assumptions of the model supporting the implementation of the SCQM concept.

2. The role of quality in supply chain management literature review

First of all, scientific articles covering SCQM topics were searched in the Scopus scientific database. Two hundred two papers in the Scopus database contain the phrase „supply chain quality management“ or „SCQM“. Figure 1 shows their distribution. The first article was published in 2001. In the next few years, the topic of SCQM increased continually. The growing trend can be shown by the moving average, which is also shown in this figure.

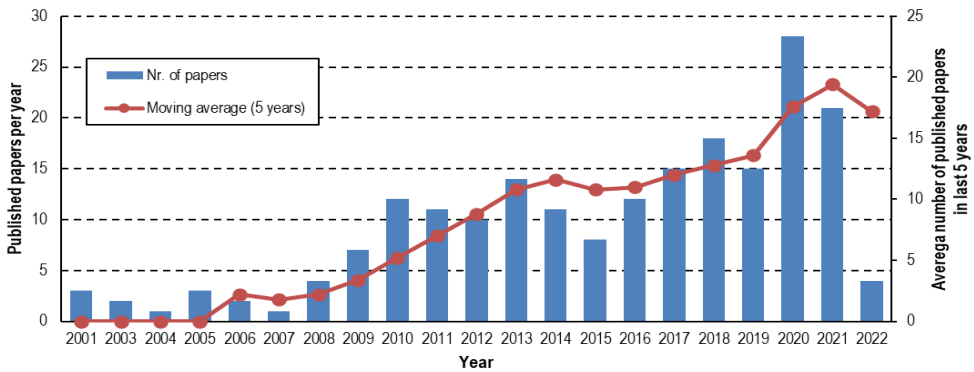

Figure 1. The number of scientific articles related to SCQM from 2001

The topics related to SCQM were mainly published in six journals, narrowly related to quality management and supply chain management. Table 1 shows more detailed information about them. There were 4772 citations related to these 202 papers.

The majority of published papers fall into four subject areas: Business, Management and Accounting (BUSI), Engineering (ENGI), Decision Sciences (DECI), and Computer Science (COMP). Figure 2 shows the distribution of published papers in these subject areas between years 2016 and 2022.

Based on the analysis of Figure 2, it can be concluded that the problems of SCQM are interdisciplinary and complex. In addition, it cannot be analyzed today without the influence of the latest IT solutions. It is, therefore, necessary to investigate the reflections on SCQM undertaken in the scientific community. The subject of Kaynak's and Hartley's research was the relationship between quality management and supply chain actors. Kaynak and Hartley (2008) argue that quality management concepts perceived as management tools within an organization should also be applied to suppliers and customers. The most important aspects of Supply Chain Quality Management include managerial leadership, employee relations, customer orientation, process management, and quality management among suppliers.

Table 1. Journals related to SCQM research

Journal	Publisher	Published papers on SCQM	Sum of citations	Published papers (2017-2021)	Top paper
International Journal of Quality and Reliability Management	Emerald	12	363	4	Kuee, Madu and Lin, 2001: 133 citations
International Journal of Supply Chain Management	ExcelingTech	8	11	7	Ahmad et al., 2019: 5 citations
Supply Chain Management	Emerald	8	276	8	Sila, Ebrahimpour and Birkholz: 134 citations
International Journal of Production Research	Taylor & Francis	6	530	0	Xu, 2011: 233 citations
TQM Journal	Emerald	6	25	6	Sharma and Joshi, 2020: 7 citations
International Journal of Production Economics	Elsevier	5	722	3	Robinson and Malhotra, 2005: 336 citations

Researchers observe the need to implement Quality Management in organizations as a system, rather than selected methods and tools, which should bring companies a long-term effect. They also suggest that poor supply chain management can result in poor quality products, high operating costs, delivery delays, and excess inventory. A high level of quality in the supply chain can be achieved through the integration and cooperation of all its links. Effective implementation of the SCQM concept can improve the quality of products. Tracey et al., (2004) believe that the implementation of internal evaluation systems, which allow companies to select suppliers and their active participation in the supply chain, significantly impacts product quality and company efficiency. In addition, by implementing efficient logistics systems, companies can improve product quality by eliminating damage and losses and reducing inventory and maintenance costs. Ross (1988) defined quality management in the supply chain (SCQM) as the participation of all supply chain members in the continuous and synchronized improvement of all processes, products, services, and organizational culture focused on increasing productivity and competitiveness that shape customer satisfaction. Ross (1988) also suggested that during the flow of a product between different links in the supply chain, all these links affect the quality of the product, as well as the quality of the information flow and the processes occurring in the supply chain. There is, therefore, a need to integrate the supply chain and to implement a systematic quality management approach by the different members of the supply chain. Carmignani, in his research "Supply chain and quality management", attempted to define quality standards in the supply chain based on the requirements of ISO 9001. The author emphasizes that the ISO 9001 standard relates to aspects of quality management within a single organization's supply chain as a whole.

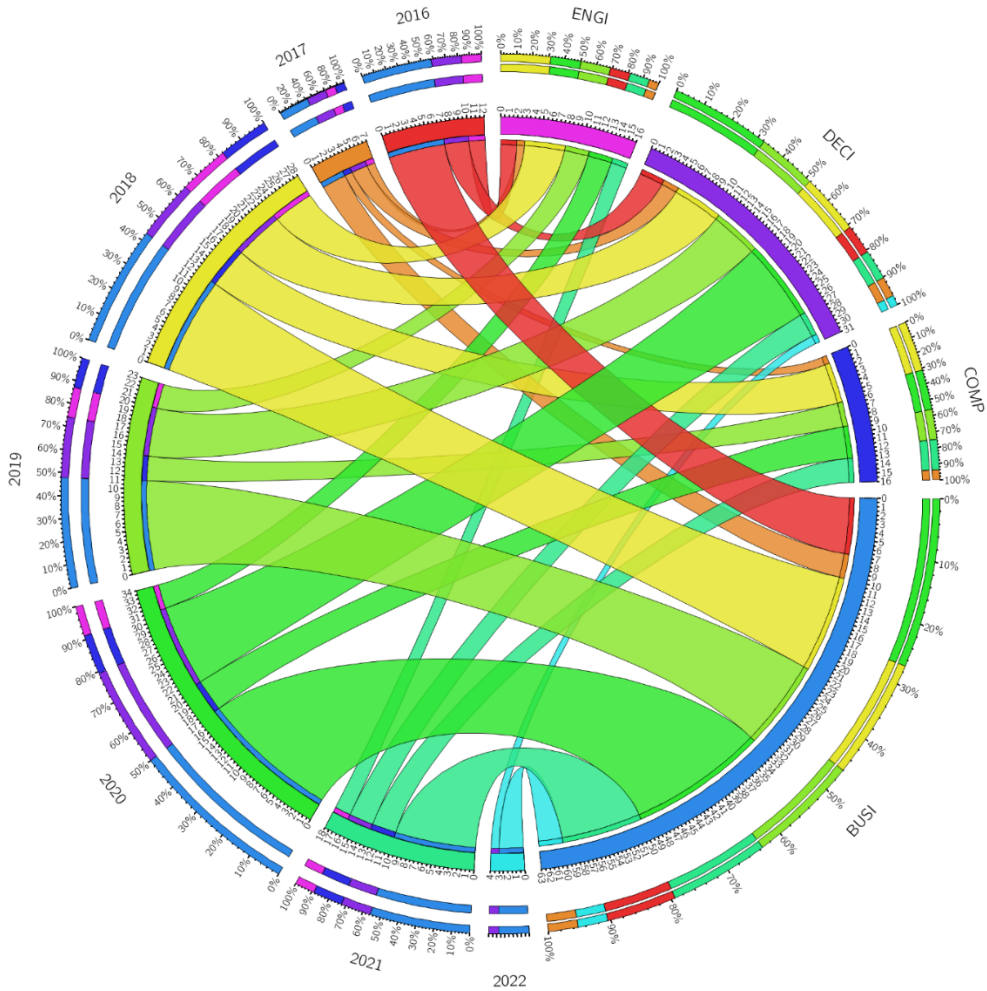

Figure 2. Relationships between research areas and years

To define standards in the supply chain, Carmignani (2009) identified four key processes- customer requirements and demand analysis, information management, inventory management, and transport management. According to Carmignani (2009), not only information, inventory and transport are essential, but also customer requirements are a crucial element of quality management since they are the primary input to every process. A properly executed demand analysis will avoid a bullwhip effect that has a negative impact on the efficient functioning of the supply chain. Carmignani (2009) also focuses on the fact that in manufacturing companies, the main aspect of quality concerns products, not processes - in other words, the quality of the result of the process and not the process itself as a set of actions. A quality management system's development, implementation, and improvement require a process approach to meet buyers' needs. Implementing this approach in the supply chain as one of the ways of quality management emphasizes the importance of understanding customer expectations, the perception of processes in the context of creating added value for the

customer, and continuous improvement of processes.

The problematics of the impact of the normalized management systems on the functioning of the supply chains are considered in the research of Zimon (Zimon et al., 2022; Zimon et al., 2020) and Dellana (Dellana & Kros, 2018, Dellana et al., 2021) and co-authors. An in-depth analysis of their publications allows concluding that standardized quality management systems have an important role in SCQM and support the implementation of this concept on many levels. Ahmad et al. (2019) emphasize that the implementation of quality management concepts in supply chains helps to reduce operational costs, improves cooperation in the supply chain, and has an impact on improving the reputation of the entire supply chain. Sila et al. (2006) suggest that the process of supply chain management should be integrated with the philosophy of comprehensive quality management, which will improve the competitive position of the supply chain, increase market share and increase customer satisfaction. Dhamija and Bag (2020) consider that decision-making processes in supplier selection, demand planning, production, and logistics activities also significantly impact quality levels in supply chains. Wrong decisions and inappropriate design of the supply chain harm the functioning and efficiency of the supply chain. The cooperation of supply chain actors is essential to ensure the integration of processes to improve supply chain efficiency. Beamon and Ware (1988) proposed a model for controlling and improving quality in the supply chain. This is another study that highlights the importance of process management. Chau et al. (2021) recognized the need to identify critical success factors for quality management in supply chains. Five key factors have been identified-customer orientation, supplier quality management, IT system quality, process integration, and leadership. The primary objective of quality management is customer satisfaction. Customer orientation will allow the company to create lasting relationships with its customers. Forza and Filippini (1988) believe that customers should participate in the design of quality programs in companies. Supplier quality management throughout the supply chain directly contributes to better performance of the supply chain and improves the quality level of the product or service from the supplier. This approach focuses primarily on the quality of the products and services, not their price. Kuei and Madu (2001) mentioned that quality in the supply chain is also determined by the quality of the relationships of all participants in the supply chain. Liao et al. (2021) emphasize that implementing quality management principles in the supply chain contributes to developing cooperation between its various links.

Another factor determining quality throughout the supply chain is the IT system. An adequately designed information management system improves the efficiency and performance of the supply chain (Xu, 2011). The data analysis results from such a system are used for resource planning and product lifecycle management. (Ka-Yin et al., 2021). Rajeb et al. (2019) emphasize that in the digital era, quality management in the supply chain has been recognized as one of the most significant ways to respond quickly and effectively to market needs. In the same way, Sharma and Joshi (2022) claim that SCQM includes quality strategy, leadership, and integration that are implemented in SCs to improve operational quality and customer satisfaction. Robinson and Malhotra (2005) recognize that SCQM is the formal coordination and integration of business processes involving all partner organizations in the supply channel to measure, analyze and continually improve products, services, and processes to create value and achieve the satisfaction of intermediate and final customers in the marketplace. In addition, the same authors argue that managers need to emphasize stimulating their suppliers to implement quality programs. Although this generates additional costs, it is a cost-

effective investment in the long term, contributing to the development of supply chains. Bui et al. (2022) claim that disruptive technologies have increased rapidly with the development of Industry 4.0. Technology 4.0 has created business ecosystems, improving quality and performance in supply chain operations.

3. Proposal of the SCQM model in the era of industry 4.0

Based on the considerations made in the previous chapters, it can be concluded that the integration of quality management and supply chain management is necessary, especially in today's times when the latest information technologies support the implementation of the underlying concepts (Ben-Daya et al., 2020). The same suggestion was made by Lin (2022), recognizing that attention to the quality of IT systems is key to increasing the efficiency and competitiveness of supply chains. The aim of this part of the article will be to develop a general IT-driven SCQM model that can be used as a basis for implementing this concept across different supply chains. The starting point for the development of the model was the models developed by Fernandes et al. (2022), Bui et al. (2022), and Sharme and Joshi (2022). Figure 3 presents a proposal of the author's model.

Figure 3. Proposed IT-driven SCQM

The model developed is ancillary and should closely support the implementation of the mission and the strategy adopted in the supply chain. It is important not to lead to a situation where the whole of the model or some parts of it start to play a vital role in the design of the supply chain strategy. The starting point is the development of an overall strategy for supply chain management, strategic objectives, and the different parts of the model should be shaped on this basis in such a way as to contribute as much as possible to the achievement of the intended strategic objectives through the gradual implementation of operational and tactical objectives. The main objectives must cover all aspects of the model. They must not focus on specific elements without leaving out others. The next step is to formulate a quality policy and culture, considering the concepts of improvement and using the IT infrastructure.

The model is based on integration processes in the supply chain. This is not about integration with first-tier suppliers; integration must encompass all links in the supply chain. As Gimenez and Tachizawa (2012) rightly suggest, supplier evaluation and control are insufficient for supply chains to be competitive. It is based on an integrated and collaborative approach that extends to all links in the supply chain. Large manufacturing corporations are increasingly offering support through joint ventures, such as deployment projects, operational improvement tools (quality, environmental, and safety management systems, or developing concepts for new products. Building partnerships with industrial customers and suppliers can bring the supply chain many important benefits, such as:

- shortening the time for new products (thereby reducing associated costs);
- ensuring business continuity, together with the methodology developed for identification, analysis, and hazard mitigation (associated with the product and the processes implemented in the supply chain);
- increased flexibility, efficiency, and effectiveness of the processes through efficient and rapid communication (aimed at forecasting demand, joint planning of resource use; use of a compatible infrastructure, and the use of operational improvement tools like quality management systems (Aboelmaged, 2010; Su et al., 2015).

A partnership comprises a process in which the customer and the supplier gradually build strong and extensive social, economic, and technical relations. Creating partnerships usually results from some evolution, beginning with repeated transactions, based on loyalty to the source of purchase, and related to the positive image of a particular partner. These repeated transactions often transform into long-term connections in which agreements regulate relations. Suppose parties are content to keep to the agreements' arrangements. In that case, their cooperation may transform into a close partnership (Wagner, 2011, Zimon 2016), which has the potential to produce many benefits for the partners. These are: improved quality of products and services, prompter processing of orders, preferential prices, improved communication between the supplier and the recipient (quicker and more complete exchange of information), joint research and development (Quigley, Walls, Demirel, MacCarthy, Parsa, 2018).

A particularly important element in the SCQM is to guarantee the products' technical quality. Guaranteeing this quality requires strict compliance with legal requirements relating to ensuring safety (included, among other things, in European Union directives and technical standards), special supervision over operational processes associated with the implementation of the product, and over the resources necessary for this implementation. An essential role in ensuring product safety is played by the effectiveness of the processes of monitoring and measuring

their parameters. To guarantee product safety, partners in the supply chain must exercise special supervision over the production processes and the provision of services. Following the latest requirements of ISO 9001, this supervision should include, among others:

- documented information specifying the properties of the products;
- availability and use of adequate resources for monitoring and measuring products and processes;
- using appropriate infrastructure (buildings and related installations [utilities], equipment, including computer hardware and software, means of transport, communication technologies),
- supervision over the environment for the safe functioning of processes;
- designation of appropriate personnel with the required qualifications.

It is particularly important for the efficient functioning of the supply chain to avoid the negative consequences of potential threats. Examples of this type of threat include:

- delivery of defective materials/infrastructure by sub-suppliers;
- inconsistencies related to product defects or errors in operational processes, resulting in the need for repairs and replacements, increased costs, and delays;
- shortage of employees with the required qualifications;
- ineffectiveness of supervision over infrastructure elements (resulting in its failure rate and damage);
- failure to achieve the required process objectives (efficiency, effectiveness, timeliness, technical parameters);
- accidents/breakdowns caused by working conditions or non-compliance with health and safety rules;
- theft and damage to goods in logistic processes (related to transport or storage);
- late deliveries to customers;
- customer complaints (quantitative, qualitative goods delivered), or
- natural events such as floods, hurricanes, and earthquake.

SCQM should be understood as the planned and organized impact of the management system (representatives of the coordination links) on the managed system (supply chain and environment), which includes all activities leading directly to the fulfillment of quality requirements. In quality management, management decisions cover processes, resources, and organizations that are important in creating quality. At the same time, the primary task is the continuous improvement of processes, products, services, and key processes (Kuei et al., 2008). Therefore, the implementation of the requirements of individual systems in the supply chain is currently insufficient, and it is necessary to implement different standards and their integration (quality, risk, safety, and environmental management). Flynn and co-author (2005) strongly emphasize the need to implement integrated supply chain management systems, suggesting that there are strong interdependencies between quality management and supply chain management, and their proper use will result in a stronger competitive position. IT systems become the driving force behind properly functioning these two management concepts. Eryarsoy et al. (2022) recognize that modern solutions such as IoT and Big Data deployed in supply chains have huge untapped potential and can significantly reduce uncertainty and risk in SCM. The primary motivation for integrating management systems in the supply chain is to develop a comprehensive approach to process management (Hernandez-Vivanco et al., 2019. Kuei et al., 2011). If the systems operated separately, the focus would be on different aspects of management. The essence of integration is, therefore, the coherent management of many aspects of the supply

chain, which means that quality, safety, environmental management, or other tasks arising from the supply chain's specificities must be managed simultaneously.

In order to effectively create an integrated system in the supply chain, it is necessary to identify its activities and processes through its individual links (suppliers, subcontractors, distributors, etc.). In addition to identifying processes that affect the organization of product flow and comprehensive customer service in the supply chain, management processes should be identified and reviewed and corrective actions implemented (Zimon & Dellana, 2020; Shalij et al., 2009). Identifying these processes and then including them in an integrated management system will allow them to be properly implemented and compromises to implement the best solutions developed based on a combination of sometimes contradictory goals formulated in individual systems. The achievement and coordination of these tasks would not be possible thanks to the achievements in the field of information technology and the development of Industry 4.0. Industry 4.0 is the fourth industrial revolution characterized by decentralization, digitization, automation, virtualization, machine-2-machine communication, and real-time data acquisition and processing (Woźniak et al., 2021). Industry 4.0 technologies can make SCQM more intelligent, smart, integrated, data-driven, agile, autonomous, and connected system (Yadav et al., 2022). The technologies under digital transformation, such as the Industrial Internet of Things (IoT) and cyber-physical systems (CPS), help improve SCQM performance by bridging the gap between the digital and physical worlds. Industry 4.0 significantly changes SCQM behavior towards achieving smarter and more flexible processes, driving automation and optimization measures, resources efficiency, and overall welfare of the customer and the society (Vujovic et al., 2019; Chen et al., 2021). The digitization of an industrial plant in the context of Industry 4.0 is about sourcing as much as possible the amount of data on production processes, machine condition, inventory, media consumption, costs, energy, production quality, personnel availability, number and terms of orders, indicators flowing out from the company's market strategy. The Industry 4.0 concept uses many production management methods, such as:

- Optimizing production processes;
- Quality management;
- Six Sigma;
- Lean Management;
- Supply Chain Management), in particular the implementation of Just-in-Time deliveries,
- Demand Driven Manufacturing.

The idea and activities under Smart Industry allow companies to transfer market competition from offering a simple product to delivering products for added value and compete with process excellence.

4. Conclusion

The developed model stands out from the other concepts presented in the literature in several respects. Firstly, it is based on instruments and concepts often proposed as separate solutions to problems without showing their interrelationship. Secondly, it exposes the importance of IT system management and its role in SCQM. In addition, the developed model has a high universality, which allows it to be implemented (at least incomplete) in almost any supply chain that wants to improve the implementation of key processes. It is also worth mentioning some limitations that should be considered when deciding to implement the guidelines presented in the model. Implementing the model is costly, requiring investments related to improving infrastructure, implementing certified management systems, training crews, hiring specialists, etc. However, it is worth noting that the costs incurred can be classified as so-called "good quality costs", which will

gradually be reimbursed by increasing the effectiveness of the activities carried out and minimizing errors and irregularities.

Smaller organizations with ancillary functions in the supply chain will not be able to implement all the proposals presented in the model. This requires a great deal of flexibility and adapting some fragmented rules to the capabilities of such enterprises. Implementing the model requires the involvement and coordination of many links in the supply chain, which can significantly impede the implementation of the assumptions presented in the model.

In conclusion, the future of quality management systems and the supply chain is information technology, particularly its innovation level and ability to counteract the negative effects associated with its improvement. The latest developments in this area combine the level of operational technology with the level of information technology. The data obtained can be easily read and processed and used as the basis for sustainable business decisions. Undoubtedly, the attempt to integrate quality management and technology in the supply chain requires a systematic approach to this issue. The system approach demands a logical analysis of the actions carried out in the enterprise and obliges in practice to define and consistently develop and use the rules that must accompany these actions.

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