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Hard total quality management practices and supply chain digitalization: Evidence of Jordan

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Abstract

This study investigates how hard total quality management practices influence supply chain digitalization, emphasizing four key aspects: process management, continuous improvement, quality tools, and product design. The required primary data had been collected through a structured questionnaire, that had been self-administered to 100 respondents among those occupying various roles in the manufacturing firms of Jordan. Employing both of simple and multiple linear regression methods in data analysis and hypotheses testing, the results showed that each of the four dimensions of hard total quality management, that the study takes into consideration, has a positive significant influence on supply chain digitalization, with quality tools and product design having the most substantial impact. These results indicate that comprehensive hard total quality management practices can advance significant digital transformation in supply chains. The study recommends conducting further research in this issue to identify whether there are other factors affect this relationship.

Keywords: Hard total quality management, Supply chain digitalization, Quality tools, Process management, Continuous improvement, Product design

1. Introduction

Most firms use different techniques to boost its efficiency and create a competitive edge. One among the most important ways is to concentrate on Hard Total Quality Management (TQM) dimensions and their effect on each aspect of the organization (Ali et el,2020), especially on supply chain. The era of technology enforces most firms to focus on Supply Chain Digitalization (SCD) through applying the elements of hard TQM, such as structured tools and methodologies (Ali& Johl,2023). Quality tools such as cause-and-effect diagrams, control charts, failure mode and effect analysis, play a vital role in advancing the transformation towards digital supply chains by offering systematic quality assurance and process improvement approaches (Nguyen et al., 2023).

As supply chains became more complicated and digitally connected, as the application of hard TQM practices enable enhanced data-driven decision-making, consistency of process, and reduction of errors, where each of which is vital for successful digital transformation. Incorporating digital technologies such as, artificial intelligence, the Internet of Things, and big data analytics, with TQM approaches, significantly enhances the capability to monitor, evaluate, and optimize supply chain operations in real time, improving responsiveness and flexibility in dynamic markets (Aichouni at el, 2024). Hard TQM practices, ensure that suppliers consistently provide products meeting established quality standards, reducing errors and variability while maintaining system reliability and efficiency. Consequently, comprehending the interaction between hard TQM dimensions and SCD, is essential for organizations seeking digital solutions to enhance quality, transparency, and overall supply chain performance (Clancy at el., 2023). It reduces mistakes and variations, which keeps the system reliable and effective. Therefore, understanding how hard TQM dimensions interact with SCD is crucial for organizations that leverage digital solutions to boost quality, transparency, and the overall supply chain effectiveness (Babatunde,2021).

In real-manufacturing world, things like process control, using the right quality tools, and always looking for ways of improvement, are not just passing things, but also the backbone of any serious attempt to go for digitalization. These so-called "hard" TQM practices help in creating the kind of structure and consistency that digital systems need to function well (Sastyawan et al., 2025). Automation and analytics

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does not do much good if processes are messy or undocumented, but if the operations are already running on clear standards and by using tracking performance with data, digital tools can amplify that. "Success is not solely regarding possessing advanced technology; it fundamentally depends on having a strong foundational framework that ensures the technology that effectively serves the organization's needs" (Sharma et al, 2023).

Based on the observations from the manufacturing sector of Jordan, attempts to transition to digitalization is often failed because they depend heavily on a firm foundational process, such as maintaining consistent quality, implementing thorough quality checks, using effective problem-solving methods, following clear workflows, and having a skilled workforce. So without these solid foundations, new technology fails to achieve its goals (Jones et al.,2021), but when a business already values consistent tracking and continuous improvements and makes choices based on solid data, digital systems can really shine. Automation, data analytics, and system integration are not magic solutions; they amplify what's already working (McEwan, 2025).

Business organizations, including manufacturers, are looking for success and survival, where to continue in production, those manufacturers are required to employ technological and technical procedures. Success and survival are not easy issues, as some people believe. Survival can be achieved through the adoption of the different developed policy, and attraction of new qualified workforce. Training the staff members for using these new developed technologies is necessary, and should be given enough attention by the managements of firms. Leaving the environment surrounding the firm change, without reaction to that change will lead business organizations to bankruptcy, but the consideration of how the environment is developed may rescue the business, when managements attempt studying the environment. Employing developed technologies and the digitalization of process, services, and activities, will lead the firm to continue smoothly. Many firms went to bankruptcy along the last decade, especially small size enterprises. The problem of the study can be illustrated through the technological development taking place in the World. These developed technologies can be employed in business, and can improve the quality of products and services of those businesses. At the same time neglecting these technologies is dangerous because competitors will attempt to adopt these technologies. Adoptions of technologies and techniques require cost, effort, training of staff, and research. The problem statement of the study, can be summarized and better presented through the following question, does employing hard TQM practices affect the performance of SCD? Four additional detailing questions are stemmed from the key question including, (1) Does the continuous improvement affect SCD? (2) Is an impact of process management on SCD?, (3) Do quality tools influence the performance of SCD?, and (4) Does product design affect the performance od SCD?

The study is important because it provides applicable and beneficial solutions for different business organizations. The study illustrates the relationship between hard TQM practices, and SCD. It illustrates the impact of hard TQM practices on SCD. It shows that SCD, will be more beneficial and efficient, when the firm adopting supply chain and hard TQM, It shows how much necessary the adoption of hard TQM practices, for firms adopt digitalization of its supply chain. The importance of the study increases because it individually investigates the impact of each type of hard TQM on SCD, including process management, continuous improvement, quality tools, and product design. Moreover, theoretically, and far from practice, the study provides a valuable addition to the available literature regarding the relationship between hard TQM and SCD.

The main objective of the study is to determine whether hard practices of TQM affect the SCD. Several secondary objectives the study achieves, such as, determining whether the performance of SCD is influenced by process management, continuous improvement, quality tools, and product design. In addition, the study is an attempt to identify the adoption level of hard TQM practices, and the level of digitalization in supply chain among the manufacturing firms of Jordan.

The remaining of the study is structured to be as follows. Section 2 presents the literature and prior related research. The hypotheses are developed and listed in section 3 in null form of hypotheses. Section 4, shows the methodology that followed by the authors, including the study population, sample selection, data collection, variables, study instrument development, and statistical methods used in analysis and hypotheses testing, while section 4, includes the analysis and discussions, section 5 summarizes the conclusions and findings of the study.

2. Literature Review and Prior Research

is a philosophy of business and production, where some interested people describe this term by doing the right thing, in the right way, at the right time, at the most economical way (Al-Ani and Mashadani, 2004), Some people refer to TQM as “business excellence” According to Oberlender (2000), TCM is defined as “a philosophy, that concentrates on process improvern ent, customer and supplier involvement, team work, and training to achieve customer satisfaction, cost effectiveness, and defect-free quality work”. Two types of practices that the philosophy of TQM consists, soft and hard TQM practices. Soft practices of TQM can be considered as the infrastructure of hard TQM practices.

Despite that there is no consensus among academics, practitioners, and other interested people for he classification of TQM practices into soft and hard, but the majority agree that soft TQM practices include, customer focus, education and training, top management leadership, and supplier relationship, whereas, Hard practices include, continuous improvement, statistical process control, process management, quality tools and techniques, and product design (Saleh, et al, 2018).

The so-called "hard" side of TQM, isn't just about preventing mistakes, but it is what actually prepares a firm to go digital in a meaningful way. It can quickly become an expensive groundwork that yields minimal benefits (Mahindra,2025). Manufacturing experiences a significant transformation today. New technologies contribute to rapid evolving industry by reshaping products in designing, producing, and delivering. This shift, called Industry 4.0, contributing in the creation of highly automated, intelligent, and interconnected production environments. According to Ali & Johl (2022), the intersection of TQM and these advanced digital tools, is driven by utilizing advanced technologies including, cyber-physical systems, IoT, networks, cloud computing platforms, artificial intelligence, big data analytics, robotics that deeply integrate information technologies into engineering, and business processes to create more innovative, efficient, and flexible production systems. In past, they relied entirely on labor and employees to check for defects, but their abilities were limited, especially when they were attempting or under pressure. Now, with the development of AI, the technology spots are defect faster and more accurately. Now, systems can give us a warning when something is not right. This early notification gives teams the time to solve problems before the problems increases. Maintenance has come a long way, too. We used to wait until a machine actually broken down to fix it. It is working on proactive instead of reactive, catching problems early so the operation stays on the right path (Salierno et al., 2021).

The hard dimensions of TQM encompass technical-structural aspects of quality management, which involve using standardized tools, techniques, and systems to oversee and improve processes. It includes activities such as quality planning, process management, data analysis, and performance evaluation, all of these are essential for achieving reliable and measurable quality outcomes (Fotopoulos et al., 2009). Nguyen et al ( ), explained how integrating practices of quality management into supply chain drives digital transformation of supply chains. They stress importance on data-driven decisions in managing production, transportation, warehousing, and providing complete visibility across the supply chain. Logistics 4.0 technologies, sensors, and networked systems allowing machines and products to generate continuous data processed by AI-enabled automatic decision-making systems. This transparency from suppliers to customers, supported by distributed management, defines digital supply chains underpinned by strong TQM. Hard TQM practices focus on strict quality control, exact standards, and management systems are essential for ensuring data, process, and output quality, thus enabling effective SCD (Nguyen et al., 2023).

According to Lambert et al (1998), the supply chain is defined as, “the alignment of firms that bring products or services to market”. Supply chain consists of manufacturer, supplier, transporters, wholesalers and retailers, intermediaries, and customers. It starts by procurement of raw materials through production and delivery and ending with customers. Therefore, suppliers are the starting point, and customers are the ending point. Considering the starting and ending points of supply chain, both of them representing the external parties in supply chan. The internal aspect of supply chain consists of three phases including, purchasing, production, and distribution,

SCD means employing the recent emerged technologies in supply chain to improve the accomplishment of activities with less efforts and costs, and faster time. Recent emerged technologies are various, where each firm is required to adopt the technologies that is considered more appropriate and beneficial to its supply chain activities. Examples of supply chain are internet of things, artificial intelligence, robots, big-data, et al, but firms are required to attract the professional human resources among those who have the ability to maximize the firm benefits as a result of one or more technology adoption.

Converting TQM to supply chain is the urgent necessary action to be taken as soon as possible, by manufacturers and other business organizations because the business can be smoothly and better performed, with less cost and efforts, and with faster timer and higher profitability, ending with better competitive position.

Cloud platforms have become an influential factor for manufacturers. It helps store and process data, monitor remote operations, and connect systems like ERP, MES, and supply chain tools until it spreads across various sites. This system helps firms see the whole picture more clearly and respond faster, using real-time data to make smarter decisions (Sunyaev, 2020). Transforming for digitalization leads to product innovation, exceeding expectations for growing customer needs, stimulating collective engagement, and driving the establishment of alternative business structures without influencing efficiency or quality (Zhao et al, 2022). Firms like Siemens and BMW adopted AI-driven tools to accelerate development cycles, improve operational efficiency, and maintain high standards (Robinson et al, 2024).

Furthermore, the most critical factors for driving digitalization are sustainability and commitment to regulations (Burri, M., & Kugler, K.,2023), renovation that helps in achieving supply chain transparency, and monitoring the use of energy through determining real-time and minimizing emissions and waste to support the global environment. Even with all the technological progress, many manufacturers struggle—whether with uneven digital adoption or lacking the right skills. To move forward, they need to invest in developing the next generation of leaders who understand the industry and the digital tools shaping its future. It's about ensuring that the team can use these new technologies to their full potential (Thrassou et.al, 2020). Pasini and Piazzoni (2024), present digitization as a sophisticated issue, but also essential attempts, and they provide a detailed examination of the benefits of digitization, which includes improved research capabilities and innovative uses of digital tools. Digitalization is mainly described as a socio-technical process encompassing adopting, implementing, and evaluating for digital technologies and their effects on individuals, organizations, and society (Frenzel et al.,2021). Moreover, Frenzel et al. (2021), present digitalization as a comprehensive technological, social, and organizational process. It stresses that digitalization is about adopting new technologies and how social and organizational contexts shape these tools. Gong describes digital transformation with his colleagues as an essential process for change, driven by the creative application of digital technologies with effective management of resources. This process aims to enhance organization. It involves more than simply implementing new technologies; it requires profound organizational and strategic changes that generate sustainable advantages for both internal members and external parties (Gong et al., 2021).

According to Schallmo and Tidd (2021), Digitalization is a complex process that influences every part of society, with a particular impact on the economy. It facilitates new forms of collaboration and connection among various stakeholders. Digitalization goes beyond simply adopting new digital tools; it involves the application of these technologies across products, services, processes, and business models. Organizations engaging in digitalization must assess their capabilities, set strategic goals, and build networks or ecosystems to stay competitive. In addition, Reis, et al ( ) define digitalization as "transforming business operations, activities, products, and services through digital technologies". This process involves technological adoption and significant shifts in strategy, organizational structure, and culture, all of which contribute to innovative approaches for generating value and overseeing business processes. In fact, when we delve into all the definitions, we find that they share one idea: the use of digital technologies. But many researchers have differentiated between two terms, which are: digitization and digitalization:

Gradillas and Thomas (2025) aim to clarify the common confusion between digitization and digitalization. They explain that digitization converts analog information like paper documents into digital form. It's a technical step focused on turning physical data into digital data. Digitalization goes beyond simply implementing new technologies; it involves taking step back to reconsider and ask fundamental questions, such as "How can we do this better?" While digitization is just turning paper or manual info into digital formats, digitalization means using that digital info to change how work gets done. It's about improving day-to-day processes, helping teams work more efficiently, and sometimes changing how a business operates. The authors put it, digitization is really step one. The real impact comes when organizations take that digital information and use this digital information in solving problems with more innovative ways, make decisions faster, and create something new, whether that's a better service, a more efficient process, or a totally new way of doing business.

Think of digitization as simply turning anything physical, like a paper document, an old photo, or a videotape, into a digital file; it's about making information readable by computers so it's easier to store, access, and share, without changing the underlying work process (Clerck,2017; Khan et al., 2018). On the other hand, digitalization involves more than just possessing digital data; it's about actively utilizing that data and technology to drive value in a way that helps a business run more effectively to make customer service faster and easier, keeping track of supplies better, or discovering new opportunities to grow (Calderon et al., 2023; Kaewsaeng et al., 2022). Finally, Digital Transformation is the biggest picture, where an entire organization fundamentally rethinks its whole business model, culture, and customer experience using digital tools, aiming to adapt to new markets and create entirely new value, with both digitization and digitalization serving as crucial steps within this larger strategic evolution towards long-term success (JVrana,, et al., 2022). Other researchers stated that going digital isn't just about using up-to-date technology. Having support systems in organization like good policies and culture that encourages learning, is essential so people can use these tools well. Without that support, organizations might struggle to use technology safely and effectively. In other words, real digital change happens when people and institutions grow together (VL Vasilev, et al.,2020). Akmaeva and his colleagues argue that digitalization is critical in reshaping corporate strategies and business models by changing management structures, enhancing decision-making, fostering innovation, and integrating digital technologies throughout organizational activities to remain competitive and effective in evolving economic environment. It also helps improve processes by enabling more automated, flexible, and responsive management systems (Akmaeva et al.,2020). Moreover, digitalization helps new businesses create and bring products and services faster, allowing them to exceed customer expectations. It also allows firms to expand their operations without increasing costs to improve performance, competitiveness, and innovation. Still, these advantages also depend on digital skills and an environment that fosters and encourages digital ways of working (Proksch et al., 2024; Kashmeeri et al., 2021). Dergachova, et al (2021), declare that digital transformation influences all organizations in all aspects, where it improves access to data about customers and business operations, analysis, facilitating using resources efficiently, preparing smarter predictions, and responding swiftly to market changes. Additionally, shifting to digital environments requires new management approaches and a culture that promotes flexibility and innovative thinking, helping businesses remain competitive and succeed in a rapidly evolving marketplace.

Many scholars have examined how soft and hard TQM practices enhance an organization's preparedness for adopting technologies associated with the fourth industrial revolution and systems. To succeed in the Industry 4.0 era, organizations must adapt. Transform, and balance soft elements such as (leadership and organizational culture) and hard components (like technical procedures and systematic processes) within their TQM approach.

Thus, TQM is a tool for improving quality and an essential, strategic foundation for driving digital transformation (Ali, K., et al. 2022). Other authors examine that supply chain quality practices positively impact supply chain performance but also acknowledges potential adverse effects. The study highlights the crucial role of innovation and flexibility in maximizing the benefits of quality management within supply chains. Although digitalization is not explicitly addressed as a central theme, there is an implicit suggestion that innovation and agility, which often rely on digital technologies, contribute significantly to supply chain improvements (Abdallah et al, 2021). Saleh et al (2018) explored how hard TQM practices applied in Jordanian manufacturers certified under ISO 9001. Their study explored that using these tools, especially continuous improvement, improves operational performance. Considering that the goal of digitization supply chain is improving inventory visibility and quality control, these results highlight how hard TQM practices are essential in driving successful digital transformation within supply chains. Shehadeh et al (2024), examined the relationship between supply chain management practices and key components of TQM, finding a positive correlation. Their findings indicate that supply chain management practices play a significant role in shaping TQM outcomes; however, the study does not specifically explore the effects of digitalization within supply chain management.

Few studies directly explored the relationship between hard TQM practices and SCD, all over the World. While both TQM and supply chain have been widely individually investigated, and gained enough attention in developed countries, a limitation in the context in the Middle East area relates to this topic. Some studies have explored how TQM practices affect innovation and performance in Jordanian manufacturing, without separating hard and soft TQM. For example, a survey by Ghanem et al (2021) found that TQM practices contribute in improving innovation in nursing services of Jordan. Another study has also showed that TQM strongly affects supply chain performance in Jordan's industrial sector (Mohailan, 2022). However, most of these studies focus on the overall supply chain outcomes rather than digitalization of supply chain.

Kadam, et al (2025), carried out a review study purposing for exploring the transformative power of several recently emerged technologies, including IoT, artificial intelligence, machine learning, and block chain. The authors mentioned that these emerged technologies provide the solutions of huge challenges facing globalization management, and provide unprecedented benefits, with high accuracy, and efficient imperatives to supply chain. Authors add that digital innovations is the key tools to reduce risk, optimize processes, and also to maintain high standard of product and service quality. The study examines the integration of these different emerged technologies within supply chain management, and the possibility of driving sustainable competitive advantage. The challenges facing the process of digital transformation was among the issues investigated in the study.

Lu, Taghipour (2025), Carried out a review study of Supply Chain Digitalization and Emerging Research Paradigms. The authors of the study perceived that business organizations face challenges concerning the integration of these technologies because of lack understanding, and because the academic literature of supply chain lacks clear taxonomy and analysis of research paradigms and investigations. Therefore, they carried out this study to address the gap and addressed a comprehensive literature review following the abductive approach in studying issues. In addition, various technologies are examined and assessed in the study, The study proposed new systematic dimensions for the digitalization of supply chain. The study provided valuable insights and a foundation for future research.

Liu and Jiang (2025), investigated the impact of supply chain quality on firm performance, using supply chain quality integration, supply chain strategy management, and supply chain capability as mediators, while digital intelligence is used as moderator. A questionnaire had developed and used as a basis for primary data collection. Emloying the structural equation modeling technique, the study showed that supply chain quality management has a positive indirect significant impact on firm performance, through supply chain quality integration and supply chain strategy. In addition, the results revealed that digital intelligence is found that significantly moderate.

Basha (2025) investigated how adopting digitalization, such as AI, IoT, and e-government, has contributed to the economic recession in Jordan. All the evidence shows that a10% increase in digitization can elevate GDP in Jordan by approximately 0.6%. On the other hand, Basha added that digital transformation in Jordan need for labor-intensive and correlated positively with job growth, but also lacking investment in R&D and innovation outputs and complicated regulations will reduce the ability to convert to digitalization. and makes it more challenging to convert to digitalized supply chain.

Rahamneh, A, et al., (2023) examined the effects of digital supply chains practices such as digital technologies, data integration, automation, and real-time tracking on the implementation and effectiveness of lean manufacturing in organizations, focusing on Jordanian industry and they report positive influence of digital supply chain on lean manufacturing efficiency and reduce waste and improve flow in manufacturing and supports lean principles like Just-In-Time, continuous improvement, and pull-based production

Alhloul (2023), explores the reality that implementation of Industry 4.0 technologies in manufacturing sector continues to be limited because there is a gap in workforce readiness and supportive infrastructure, such as energy, internet, and regulatory standards. Many challenges are related to high cost, high risk from adopting these technologies, lack of required skills and competencies, and most managers hinder progressive technological transitions. Outdated legislation hinders change.

Hughes et al (2022), stated that manufacturers encounter additional barriers through shifting to Industry 4.0 era by adopting new technologies like AI, IoT, and intelligent systems, in their current operations. Many firms, especially smaller ones, struggle of high costs and must train workers in new digital skills. Also, they hold additional pressure from the desire to be more sustainable and profitable. Moreover, they pay attention to the issues related to cybersecurity and make different systems work together smoothly. Medium and small manufacturing firms in developing countries encounter numerous challenges when trying to adopt Industry 4.0 technologies. These challenges include limited financial resources, insufficient research and development teams, and reliance on outdated IT systems. Additionally, there is a shortage of employees with necessary digital skills. In addition, businesses often struggle in integrating new technologies with their existing system. On the other hand, several issues related to data security and resistance to change exist. Limited cooperation with outside partners and unclear government support, make the path to digital transformation and sustainability even more challenging (Jamwal et al, 2025).

Mohailan (2022), examined the effects of quality dimensions on listed firms at Amman Stock Exchange, Jordan, and revealed that TQM extends beyond internal quality circles and generates tangible performance improvements throughout the entire supply chain. By focusing on continuous improvement, leadership, customer-centric thinking, and employee engagement, industrial firms, can improve their work methods, customer responsiveness, and innovation, leading to more resilient and competitive supply chains. There was no mention digitalization, and its use may have been indirect.

Mohailen (2022), investigates how TQM practices affect supply chain performance of industrial firms of Jordan that are publicly traded, focusing on soft and hard TQM dimensions. These encompass a focus on the customer, a strong commitment to quality from senior management, continuous process improvement, and involving employees in decision-making. The study explores how these factors impact supply chain outcomes, including operational efficiency, customer responsiveness, and product innovation. The results revealed that the studied firms exhibit a strong adoption of TQM, which positively affects the entire dimensions of supply chain performance.

Wachira, et al (2021), assessed the impact of TQM on supply chain performance of the manufacturing listed firms at NSE, Kenya. Deming's quality theory, Goldratt's theory of constraints and supply chain operations Reference mode, were used as the basis and guidelines for the study. The required primary data had been collected through a questionnaire, while the secondary data had collected from the financial reports of 9 listed firms consisted the population of the study. The secondary collected secondary data covered two financial periods, 2013-2014, and 2017-2018. Employing the multiple linear regression in hypotheses testing, the results of the study showed that all TQM variables affect supply chain performance. In more details, the study showed that strategic quality planning, supplier relations management, and management commitment, each of which, has a positive significant impact on supply chain performance, and TQM variables explain 76.5 percent of variation in supply chain performance.

Alshourah (2021), investigated the effect of TQM practices on innovation in the manufacturing firms of Jordan. The study assesses how various TQM components contribute in improving innovation in manufacturing firms of Jordan. The findings indicate that most TQM practices positively impact innovation performance, helping firms to develop new products and enhance their processes. The research underscores the value of TQM implementation in enhancing innovation capabilities and boosting the competitiveness of manufacturing firms in Jordan. The study identifies a gap in the research due to limited empirical studies that specifically investigate direct effect of hard TQM dimensions on digital transformation of supply chains within the manufacturing firms of Jordan. The study identifies gap in existing research, as there is a lack of empirical studies that directly examine how hard TQM dimensions influence digital transformation of supply chains in Jordan manufacturing industry. Although previous research has broadly addressed the relationship between TQM and supply chain management, specific role of hard TQM components such as formal quality control mechanisms, process management, and performance measurement in driving SCD has not been investigated in this regional context. Filling this gap would offer valuable insights and actionable recommendations tailored to Jordanian manufacturers, enabling them to utilize hard TQM practices better to advance digital supply chain technologies and improve their competitive position.

Adaileh, and Alshawawreh (2021), developed a national plan for ten years to motivate individuals, industries, and businesses in Jordan for transition to digital technologies by 2025. This plan consists of several components such as public sector innovation, demand driven innovation, entrepreneurial development, and smart digital economy infrastructure. Starting the application of the project, they faced some barriers such as lack of investing in talent development, absence of performance indicators, shortage in Jordan capacity and training efforts, in addition to inadequate infrastructure of Jordan, which restricted achieving the goal of this plan. Moreover, he bureaucratic and traditional policies still exist, making implementing this plan more challenging

Tarigan, et al (2020), investigated and explained the structural relationships among operational capability, TQM, supply chain practices, and operational performance. The survey-based methodology is used in data collection The population of the study included the different manufacturing listed firms at Indonesian stock exchange, and data had collected from the entire population. Employing the regression method in data analysis and hypotheses testing, the results showed that a sustainable competitive advantage can be achieved through supply chain management. The results also revealed that the way to leverage the internal capabilities of managers through establishing relations with partners in supply chain is crucial issue. The results provided support regarding the mediating role of TQM in the relationship between supply chain operations and firm performance.

Modgil and Sharma (2017), identified the soft and hard TQM and investigated the effect of soft TQM on hard TQM, and the impact of both soft and hard TQM on plant level supply chain of pharmaceutical setup. To achieve the objectives of the study, the authors developed a questionnaire, and the this instrument is had been self-administered for executives in 394 pharmaceutical firms, where only 270, and later some of these responses excluded, so 254 responses used in the analysis and hypotheses testing. Employing the SEM method, the study showed that soft TQM practices directly affects supply chain performance, and hard TQM greatly affects supply chain performance.

Chang (2009), discussed the application of the eight TQM principles of ISO 9000, in suplly chain quality management in a review study. In the study, the author focused on implementing the modern eight principles of ISO9000, and stated that these principles are made for the standardization of quality management and quality assurance. The study showed that in supply chain circumstances, the implementation of ISO900 principles is the basic assurance for enterprises to improve the quality of its products in a certain supply chain. The study found that the eight principles of ISO9000 in supply chain quality promotes the improvement in operation efficiency and increasing the ability of the supply chain system as a whole.

Vanichchinchai and Igel (2009), reviewed the the concepts of TQM and supply chain management, and identified the similarities and differences between these applicable concepts. The purpose of the paper was to review the two concepts and determine the similar and different issues between them. The authors reviwied the available literature regarding TQM and supply chain management, and thereafter compared between these two concepts. In order to explore hoe these philosophical perspectives could be further developed. The authors demonstrated that the two concepts have different starting points, and goals, where this complicates the integration of the two philosophical concepts. The results showed that the focus of TQM is internal, while supply chain management involves an external focus, but there is a need to emphasize both to strengthen the emphasis on TQM and thereafter the supply chain in the entire supply chain management, for the purpose to improve the integration between them.

In summary, most empirical research shows that hard dimensions of TQM significantly enhance digitization capabilities of supply chains in the manufacturing industry of Jordan. While numerous studies have explored this relationship globally, it had not been investigated within Jordan or its industrial sectors. A research gap emerges, requiring focused studies to obtain precise findings and practical applications.

3. Hypotheses development

The dimensions of hard TQM can significantly influence SCD, especially within the manufacturing sector of Jordan. Integrating strict quality control systems, process management, and performance measurement, enable firms to enhance their supply chain operations through digitization. These hard TQM practices improve data accuracy, process standardization, real-time monitoring, crucial for effective digital supply chain management. Although studies have confirmed the beneficial effects of TQM on supply chain performance, there remains a need to explore how hard TQM dimensions specifically mediate digital transformation initiatives in Jordanian manufacturing, forming the basis for developing the main hypotheses around this relationship. Therefore, based on this, the first hypothesis is formulated in its null form, as follows.

Ho_1. There is no significant impact at ($\alpha \leq 0.05$) of the entire hard total quality management practices, as one group, on supply chain digitization in the manufacturing firms of Jordan.

The first hypothesis examines whether the structured-technical quality management practices, including quality tools, product design, process management, and continuous improvement, have a meaningful effect on adopting and advancing digital technologies within supply chains in Jordan manufacturing sector. This hypothesis is designed to statistically assess whether these hard TQM practices influence SCD efforts in manufacturing firms of Jordan. Rejecting the hypothesis would suggest that hard TQM significantly supports digitalization initiatives, emphasizing its importance in driving digital transformation in manufacturing, while accepting the hypothesis implies that factors other than hard TQM have a more crucial role in facilitating SCD in these firms.

The second hypothesis had developed to enable examining whether continuous improvement, as an important type of hard TQM practices, affect SCD. The hypothesis is appearing, in its null form, as shown below. The second hypothesis that continuous improvement has no significant effect at ($\alpha \leq 0.05$) on Digitalization of supply chain performance in Jordanian manufacturing firms implies that ongoing process enhancements may not directly affect adoption of digital technologies in supply chains. Nonetheless, studies indicate that when integrated with digital tools, continuous improvement activities help detect and address issues within supply chain operations in real time, thereby boosting efficiency, responsiveness, and operational quality (Buer et al., 2018). This hypothesis suggests that although continuous improvement direct influence on SCD may sometimes lack statistical significance, it plays a vital role within a larger framework of quality management and technology integration, contributing to better overall supply chain performance and flexibility in manufacturing firms.

Ho_2. Continuous improvement has no significant impact at ($\alpha \leq 0.05$) on supply chain digitalization performance in manufacturing firms of Jordan.

The third hypothesis proposes that the organization and optimization of processes within manufacturing firms might not significantly influence adoption or success of digital technologies in supply chains. Process management typically involves planning, controlling, and improving operational workflows to boost efficiency and quality (Imgrund et al,2018). However, in this context, this hypothesis suggests that such management practices do not directly affect the digital transformation of supply chain activities. Testing this hypothesis will determine whether process management contributes meaningfully to SCD. When the null form of the hypothesis id rejected, this would confirm that effective process management supports digitalization efforts, improving supply chain operations, whereas when it is accepted, it implies that other elements might have a more significant role in driving digital transformation within these firms.

Ho_3. Process management has no significant impact at ($\alpha \leq 0.05$) on the digitalization of supply chain performance in manufacturing firms of Jordan.

The 4th hypothesis of the study proposes that the organized, technical, and systematic quality practices do not significantly affect integration of digital technologies and processes within supply chains of these firms at a 0.05 significance level or lower. This Hypothesis serves as a foundation for statistical analysis to assess whether quality tools play a role in advancing supply chain digitalization in this particular industrial setting. If the null form of the hypothesis is rejected, it would imply that quality tools positively affect SCD, highlighting their significance in facilitating digital transformation efforts in manufacturing operations.

Ho_4. There is no significant impact at ($\alpha \leq 0.05$) of quality tools on supply chain digitization in manufacturing firms of Jordan.

The fifth hypothesis is developed to investigate whether product design-related decisions and activities affect adoption and success of digital technologies in supply chains of the manufacturing firms of Jordan. Product design plays a crucial role in supply chain operations by influencing aspects such as material procurement, complexity of production, transportation expenses, and overall supply chain efficiency. Digitalization amplifies these impacts by incorporating tools that support real-time collaboration, simulation, and enhancement of the product design process, leading to more efficient, quicker, and cost-effective supply chain management (Cantamessa et al., 2020). Examining this hypothesis will clarify if product design significantly influences these firm digital transformation of supply chains, while the rejection of the hypothesis would suggest that product design is a key factor in driving SCD, while acceptance would indicate that other elements may hold greater influence.

Ho_5. There is no significant impact at ($\alpha \leq 0.05$) of product design on supply chain digitization in the manufacturing firms of Jordan.

4. Methodology

This research employs a quantitative methodology to examine how hard dimensions of TQM influence the digitization of supply chains in the manufacturing industry of Jordan. The population of the study encompasses all manufacturing firms operating in Jordan, regardless of their size or legal structure, including shareholding and non-shareholding firms. Respondents from the manufacturing sector in Jordan were selected using purposive sampling. This approach chosen to guarantee that participants had direct knowledge and experience in quality management and supply chain practices, allowing for informed and relevant input. Data was gathered from 120 participants within the manufacturing sector, drawn from CEOs, department managers, and employees working in key departments related to supply chain management, specifically production, purchasing-logistics, and human resources, ensuring the inclusion of individuals directly involved in implementing and managing TQM and digitization initiatives. Ultimately, a total of 100 completed and valid responses were received, yielding a response rate of 83.3%. The number of respondents was considered adequate to perform the necessary statistical analyses. From the total sample, 105 participants completed the questionnaire over three to four weeks. Nevertheless, after evaluating the returned questionnaires, five responses were discarded due to incomplete or careless answers. As a result, data from the remaining 100 valid responses were utilized for the final analysis and hypothesis testing.

Data had been gathered using a structured 5-Likert scale questionnaire, based on well-established scales from the literature, focusing on hard TQM dimensions including, process management, technology management, quality planning, and supply chain digitization. The questionnaire was pilot tested to ensure reliability and validity before full distribution. Data were analyzed using SPSS, with descriptive statistics summarizing respondents' profiles and key variables. Inferential analyses, including correlation and regression, examined the relationships between hard TQM dimensions and SCD. Ethical standards were upheld by informing participants of the study's purpose, ensuring confidentiality and anonymity, and obtaining informed consent.

The developed questionnaire consists of 3 sections. Section 1 consists of 5 items. It had designed to acquire demographic data regarding the respondents, including age, number of years of experience, department, administrative level, etc. Section 2 consists of four dimensions of TQM in 21 Items; these items are dedicated to collecting the required data for measuring TQM practices with its four dimensions. The third section also consists of 8 items used to collect data enabling the SCD measurement. The hypotheses were tested at 95% confidence level, corresponding to 0.05 (1 – 0.95) coefficient of significance. Simple and multiple linear regression analyses are utilized to examine the hypotheses, relying on the computed t-values and significance coefficients. The p-value (0,05) served as the criterion for accepting or rejecting the null hypothesis, where underline this rule, when p-value is greater than 0.05, the null hypothesis is accepted, while when it is less than 0.05, the null hypothesis is rejected.

Furthermore, decisions are made by comparing the calculated t-value with the critical (tabulated) t-value. According to this rule, the null hypothesis is accepted when the computed t-value is less than the tabulated, and rejected when the computed t-vale is higher than its corresponding tabulated one. Figure 1 illustrates the model of the study, showing the variables involved and their organizational framework.

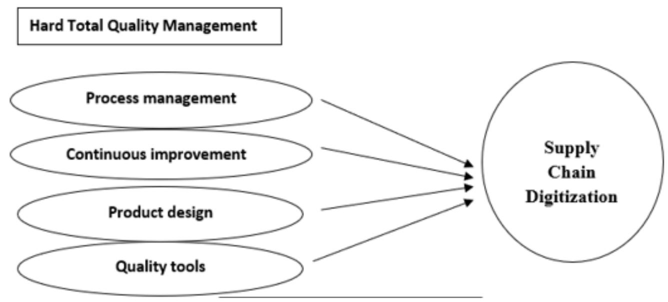

Figure2. Study model

5. Results and Analysis

5.1 Sample description

The study examines various demographic factors of the respondents, such as gender, age, years of experience, job role in the company, and the industry size. Detailed information about each of these demographic variables is presented in Table 1.

Table 1, shows that the sample consisted of 49% male respondents and 51 females, demonstrating a balanced gender representation. This balance suggests that the findings are unlikely to be biased toward either gender, thereby improving the ability to generalize the study results by reflecting nearly equal participation from both males and females. Moreover, respondents were spread across various age groups, with 25% under 27 year-old, 23% from 28 and less than 38 years, 25% of respondents have 39 and less than 49 years, 19% from 50 and less than 59 years, and 8% aged 60 and above. This fairly even distribution across age categories allows the data to represent viewpoints from younger and older employees, increasing the sample representativeness. This diversity supports the generalization of the results by including perspectives from different age groups within the manufacturing sector.

Furthermore, the participating organizations were relatively evenly divided by size, with 36% categorized as large (over 200 employees), 31% as medium-sized (50 to 200 employees), and 33% as small (fewer than 50 employees). This almost equal distribution across these categories suggests that the sample includes viewpoints from firms of various sizes, enhancing the overall comprehensiveness of the findings. Such a balanced representation helps avoid the dominance of any group and ensures that the results accurately reflect the conditions of both small and large manufacturing organizations.

On the other hand, the distribution of respondents according to their organizational roles shows a reasonable and logical spread across different managerial levels. Specifically, 14% of participants were senior managers, reflecting strategic-level perspectives within the large firms, 25%, were middle managers, while 30% were operational managers, representing those directly involved in day-to-day process oversight. Interestingly, 31% of respondents were categorized as "other," which may include supervisors, technical staff, or administrative roles not formally classified under management levels. This balanced distribution is logical for the manufacturing sector, where operational and mid-level roles typically constitute most of the workforce, while fewer individuals occupy senior management positions.

Table (1). Respondents' demographic Data

Variable	Class	Number	Percent
Gender	Male	49	49%
	Female	51	51%
Age	Less than 27	25	25%
	28 and less than 38 years	23	23%
	39 and less than 49 years	25	25%
	50 and less than 59 years	19	19%
	60 and above	8	8%
Year-Experience	more than 20years	27	27%
	16 and less than 20 years	16	16%
	11 and less than 15 years	19	19%
	5 and less than 10 years	16	16%
	Less than 5 years	22	22%
Role of the organization	Senior manager	14	14%
	Middle manager	25	25%
	Operational manager	30	30%
	Other please specify	31	31%
Size of organization	Large(more than200 employee)	36	36%
	Medium (50 to 200)	31	31%
	Small (less than 50)	33	33%

5.2 Data reliability

Cronbach's Alpha is used to assess data reliability and verify whether the collected data is dependable enough for hypothesis testing. The test applied to each section of items, measuring individual variables in the study and questionnaire items in its entirety. Results indicated that the values of Cronbach's Alpha were sufficiently high for each group of items. Additionally, when all items were assessed collectively as one group, the reliability score was even higher, reaching a value of 0.959. Table 2 presents the detailed outcomes of Cronbach's Alpha reliability test. The results indicated acceptable of data reliability across the different dimensions. Table 2, reveals the Cronbach Alfa of the different dimensions, and it reveals a Cronbach Alfa of 0.743, 0.852, 0.878, 0.908, 0.943 for process management, continuous improvement, quality tools, product Design, and SCD, respectively. Because all values were above the suggested cutoff of 0.70, the measurement scales are deemed reliable and appropriate for subsequent statistical analysis.

Table (2). Cronbach alfa

Section No.	Variable	No. of Items	Cronbach Alfa
Section 1	Process management	6	.743
Section 2	Continuous improvement	5	.852
Section 3	Quality tools	5	.878
Section 4	Product design	5	.908
Section5	Smart Supply Chain Digitization	8	.943
Total Items	The Entire Questionnaire	34	.959

5.3 Descriptive statistics

Different descriptive statistics were utilized, such as the mean, selected as the primary measure of central tendency, and the standard deviation, regarded as the most effective indicator of data variability. Moreover, the minimum and maximum values were computed for each questionnaire item. The data required to measure hard TQM, the unique independent variable, had collected through 21 items shown in Table 3. Therefore, Table 3 displays the mean and standard deviation of the entire items used in measuring hard TQM of the manufacturing firms of Jordan.

Table 3 shows the mean and standard deviation of the different items used in data collection to enable the measurement of hard independent TQB variables. The table shows that that the means ranges from 2.35 to 2.79, indicating a moderate level of hard TQM implementation across various aspects. The highest mean equals 2.79, and it is attributed to item number one in the table, where item one states that “Process management is in line with strategy”, with 1.336 standard deviation, followed closely item number 2, which states that “Well-documented guidelines exist in the company” which records 2.77 mean and 1.136 standard deviation. In opposite, the least mean equals 2.35, which is due to item number 16, which states that “Employees receive training on using relevant quality tools in their roles”, with 1.009 standard deviation. highlighting weaker emphasis on employee development and staff participation in innovation. Standard deviations, ranging between about 0.92 and 1.33, indicate some variation in responses but no extreme differences. Overall, the findings suggest that while foundational practices like documentation and alignment are well-established, there remains significant potential to improve training, employee engagement, and more advanced quality management activities.

Table (3). Descriptive statistics of hard TQM dimensions

Item Ser. No	Item Text	No.	Mean	Std. Deviation
1.	Process management is in line with strategy. (PM)	100	2.79	1.336
2.	Well-documented guidelines exist in the company (PM)	100	2.77	1.136
3.	Guidelines are regularly reviewed and updated (PM	100	2.75	1.077
4.	Standard operating procedures are implemented. (PM}	100	2.43	1.066
5.	Employees have a clear understanding of workflows (PM)	100	2.252	1.114
6.	Process management applied in industry (PM)	100	2.49	1.068
7.	process monitored always (PM)	100	2.41	1.045
8.	Employees are motivated to propose suggestions for improvements. (CI)	100	2.49	1.059
9.	Management is constantly seeking methods to boost product quality. (CI)	100	2.49	1.068
10.	Insights gained from past mistakes are applied to better future outcomes. (CI)	100	2.51	1.150
11.	Improvement efforts are integrated into our everyday tasks. (CI)	100	2.49	1.059
12.	Quality control instruments, like check sheets are consistently utilized. (QT)	100	2.42	1.112
13.	Data examined to detect quality issues and their underlying causes. (QT)	100	2.64	1.106
14.	Our company applies statistical methods to manage manufacturing processes. (QT)	100	2.41	0.922
15.	Utilizing quality tools aids in resolving problems related to quality. (QT)	100	2.51	1.087
16.	Employees receive training on using relevant quality tools in their roles. (QT)	100	2.35	1.009
17.	Product design choices are guided by customer needs (PD)	100	2.48	1.114
18.	Manufacturing staff are involved in developing new product designs. (PD)	100	2.36	1.097

19.	The company employs up-to-date techniques or software for product design. (PD)	100	2.45	1.158
20.	Quality is taken into account throughout all phases of product design. (PD)	100	2.45	1.158
21.	Design tasks are organized and synchronized across various departments. (PD)	100	2.45	1.158
	Valid Number (Listwise)	100		

The descriptive statistics of SCD are shown in table 4, revealing low to moderate mean scores, ranging between 2.33 and 2.52, and indicating that respondents only partially agree with statements about the adoption of digital technologies in their supply chain processes. The highest mean within the group equals 2.52, attributed to item 6, which states that "Digital systems allow us to react swiftly to disruptions in the supply chain.", where this highest item records 1.114 standard deviation. In the other hand, the least mean equals 2.33, with 1.146 standard deviation. The least mean is attributed to item 2, which states that "Real-time information applied in managing supply chain activities).

Table (4). Descriptive statistics of supply SCD

Item Ser. No	**Item Text**	**No.**	**Mean**	**Std. Deviation**
1.	Our company utilizes digital platforms to share information with suppliers.	100	2.42	1.130
2.	Real-time information applied in managing supply chain activities	100	2.33	1.146
3.	We employ technologies like ERP and cloud-based systems to unify supply chain processes	100	2.37	1.089
4.	Communication with supply chain partners is conducted through digital platforms.	100	2.33	1.064
5.	Implementation of digital technologies has improved supply chain performance.	100	2-39	1.053
6.	Digital systems allow us to react swiftly to disruptions in the supply chain.	100	2.52	1.144
7.	Data from suppliers and customers is leveraged to improve decision-making.	100	2.44	1.155
8.	Our company invests in advanced digital technologies to optimize supply chain operations	100	2.48	1.292
	Valid N (listwise			

5.4 Hypotheses testing

Except for the first hypothesis, where it had tested using the multiple linear regression method, the remaining are tested using the simple linear regression method. Two criteria to determine whether to accept or reject the null hypothesis. The first criterion is based on a comparison between the computed t-value and its corresponding tabulated one, where the null hypothesis is accepted in case where the computed t-value is less than the tabulated, and rejected when the computed t-value is higher. The second criterion is based on a comparison between the computed and the predetermined coefficients of significance (p-value), where following this criterion, the null hypothesis is accepted when the computed coefficient of significance is greater than the predetermined, that equals 0.05, and in opposite, when the computed coefficient of significance is less than the predetermined, the null hypothesis is rejected.

5.4.1 Testing the 1st hypothesis

The first hypothesis is developed to enable examining whether hard TQM management directly affects SCD of the manufacturing firms of Jordan. The Hypothesis is shown again, in null form, as follows.

Ho_1. There is no significant impact ($\alpha \leq 0.05$) of hard total quality management on supply chain digitization in manufacturing firms of Jordan

The descriptive statistics show that the surveyed firms demonstrated moderate-high hard TQM practices (M = 2.60, SD = 0.84). In contrast, the average level of SCD. was somewhat lower (M = 2.42, SD = 1.02). Correlation analysis showed a strong, positive, and statistically significant association between hard TQM and supply chain digitalization. ($r = 0.913$, $p < 0.001$), indicating that firms with stronger TQM practices tend to adopt digital technologies more extensively in their supply chain operations. Regression analysis supported this finding, showing that hard TQM significantly predicts SCD. These results emphasize the important role of TQM practices in promoting digital transformation in supply chains in the manufacturing industry of Jordan. The regression analysis demonstrated that hard TQM has a substantial and statistically significant impact on supply chain digitalization. The model indicates a strong correlation (R =0.913) between hard TQM and SCD, and that TQM explains 83.3 percent (R^2 = 0.83,3) of the change or variation occurs in SCD.

The ANOVA table shows that f-vale equals 354.531, and the coefficient of significance equals zero. Or a very closed value to zero. The test also reveals that the sum of squares 62.492, and it exceeds the residual sum of squares, that equals 12.531, showing that most of variation in SCD is explained by Hard TQM. The coefficients table further emphasizes this strong relationship, revealing significant positive effect of hard TQM ($\beta = 0.913$, $t = 18.817$, $p < 0.001$), where this refers that an increase of one unit in hard TQM corresponds to an estimated 1.107 ($b = 1.107$)-unit rise in SCD. These results support the conclusion that hard TQM is a key factor driving the digitalization in supply chains. These findings are consistent with earlier research highlighting that implementing hard quality practices such as process measurement, process standardization, and decisions based on data directly improve organizations capacity to drive digital transformation in their supply chains. Thus, the results validate prior studies and offer strong empirical evidence that investing in hard TQM practices is a practical approach to accelerate digitalization and boosting the performance of smart supply chains, especially within the manufacturing firms of Jordan. In summary, the null form of the first hypothesis is rejected because the computed f-vale is higher than the corresponding tabulated one, and because the computed coefficient of significance is less that the predetermined one, that equals 0.05, whereas the alternative form of the hypothesis is the one that it is accepted. This result means that hard TQM affects SCD. Table 5, shows the related coefficients and statistical values.

Table (5). The related coefficients and statistics to the first hypothesis

Model		Unstandardized Coe.		Sta. Coefficients		
		B	Std. Error	Beta	F-Vale	Sig.
	Hard TQM	1.107	0.059	0.913	354.531	Zero

5.4.2 Testing the 2nd hypothesis

The second hypothesis is developed to enable testing whether continuous improvement affects the SCD in the manufacturing firms of Jordan. The listed items (8 -11) in table (3), are used in data collection regarding the continuous improvement. The Hypothesis is listed again, in its null form, as follows.

Ho_2. Continuous improvement has no significant impact at ($\alpha \leq 0.05$) on the Digitalization of supply chain performance of manufacturing firms in Jordan.
The results of analysis offer strong evidence of the impact of continuous improvement on SCD. Table 6, shows the results of the test employed to determine whether continuous improvement affect SCD. Descriptive statistics (Table 1) showed that the average level of supply chain digitalization was 2.42 (SD = 1.02). At the same time, continuous improvement had a slightly higher mean of 2.55 (SD = 0.97), indicating a moderate level of both among respondents. The test reveals a significant positive correlation between ongoing continuous improvement efforts and the digitalization of supply chains ($r = 0.780$, $p < 0.001$), suggesting that enhancements in continuous improvement practices are linked to greater digitalization. Table 3 identified continuous improvement as the independent

variable in the regression model predicting SCD. The model summary (Table 4) showed a strong correlation (R = 0.780), with continuous improvement explaining about 60.9% of variance in supply chain digitalization ($R^2 = 0.609$; Adjusted $R^2 = 0.603$), and ANOVA results confirmed model's statistical significance (F = 110.559, p < 0.001).

Table 6 further demonstrated that continuous improvement exerts a strong and significant positive effect (β = 0.780, t = 10.515, p < 0.001), where a one-unit increase in continuous improvement corresponds to an estimated 0.823-unit rise in SCD. Overall, these findings provide solid empirical support that continuous improvement, as a fundamental aspect of hard TQM, significantly drives the Digitalization within supply chains. Because the computed t-value is higher than its corresponding one, that equals 1.96, and because the computed coefficient of significance (p-value) is less than the predetermined, that equals 0.05, the null hypothesis is rejected and, instead, its alternative is accepted. This result means that continuous improvement has a significant impact on SCD.

Table (6). The related coefficients and statistics to the second hypothesis

Model		Unstandardized Coe.		Sta. Coefficients		
		B	Std. Error	Beta	F-Vale	Sig.
	Continuous Improvement	0.823	0.078	0.78	10.515	<0.001

5.4.3 Testing the 3nd hypothesis

The third Hypothesis had developed to enable testing whether process management affects SCD in the manufacturing firms of Jordan. Items (1- 7), that are included in table 3, are used in data collection regarding process management. The third hypothesis is shown again, in null form, as follows.

Ho_3. Process management has no significant impact at (α ≤ 0.05) on the Digitalization of supply chain performance in manufacturing firms in Jordan.

The statistical analysis strongly supports the proposed relationship between process management and SCD. Table 7, shows the main results of the test. Descriptive statistics (Table 1) indicate a moderate mean level for both SCD (M = 2.42, SD = 1.02) and process management (M = 2.71, SD = 0.75). The test reveals a strong positive correlation (R = 0.755) between process management and SCD. This connection is confirmed by the regression results, with the model summary (Table 4) revealing that process management accounts for 57.0% of variance in SCD ($R^2 = 0.564$) . ANOVA table indicates high significant (F = 93.967, p < 0.001), demonstrating predictive strength of process management. The regression coefficients are expected to show a significant positive impact, with a standardized beta of β ≈ 0.755 and a highly substantial t-value (p < 0.001). These findings provide robust empirical evidence that effective process management is vital in promoting supply chain digitalization. Therefore, because the computed t-value (9.694) is higher than the tabulated (1.96), and because the computed coefficient of significance (<.001), is less than the predetermined (0.05), the null hypothesis is rejected, and the alternative one is accepted. This result refers for a positive significant impact of process management on SCD, in the manufacturing firms of Jordan. Table 7, shows the most important coefficients of the regression test.

Table (7). The related coefficients and statistics to the third hypothesis

Model		Unstandardized Coe.		Sta. Coefficients		
		B	Std. Error	Beta	F-Vale	Sig.
	Process Management	1.032	0.106	0.755	9.694	<0.001

5.4.4 Testing the 4th hypothesis

The 4th hypothesis had been developed to enable examining whether quality tools affect the SCD. The listed items (12-16) in table 3, are used in data collection from respondents for the measurement of quality tools. The hypothesis is listed again, in null, as follows.

H04. There is no significant impact (α ≤ 0.05) of quality tools on supply chain digitization in manufacturing firms of Jordan.

The findings of the test refer for strong empirical evidence supporting positive impact of quality tools on SCD. Descriptive statistics show moderate average scores for supply chain digitalization (M = 2.42, SD = 1.02) and quality tools (M = 2.56, SD = 0.95). The correlation analysis demonstrated a significant positive correlation (R = 0.915) between quality tools and SCD. Regression results further confirm this link, where quality tools explain 83.8% of the variance in SCD ($R^2 = 0.838$), and the model demonstrates a high significance (F = 367.192, p < 0.001). Coefficients indicate strong positive effect, where a one-unit increase in quality tools corresponds to an estimated 0.98-unit rise in supply chain digitalization. Overall, these results underscore crucial role of quality tools, as a key hard TQM practice, in advancing SCD. Table 8 provides more details regarding this issue. Therefore, because the computed t-value (19,162), is higher than the predetermined one, that equals 1.96, and since the computed coefficient of significance (< 0.001), is less than the predetermined (0.05), the null form of the hypothesis is accepted, and the alternative one is accepted. This result means that quality tools affect SCD in the manufacturing firms of Jordan. Table 8, shows the most important statistical results.

Table (8). The related coefficients and statistics to the fourth hypothesis

Model		Unstandardized Coe.		Sta. Coefficients		
		B	Std. Error	Beta	F-Vale	Sig.
	Quality Tools	0.98	0.051	0.915	19.162	<0.001

5.4.5 Testing the 5th hypothesis

The fifth Hypothesis had been developed test whether product design affects SCD in the manufacturing firms of Jordan. The listed items (17-21) in table 3, are used in data collection for the measurement of product design. The text of the hypothesis is repeated again, in its null form, as follows.

Ho_5. There is no significant impact at (α ≤ 0.05) of product design on supply chain digitalization in the manufacturing firms of Jordan.

Table (9). The related coefficients and statistics to the third hypothesis

Model		Unstandardized Coe.		Sta. Coefficients		
		B	Std. Error	Beta	F-Vale	Sig.
	Product design	0.877	0.064	0.909	18.34	<0.001

The results offer strong empirical evidence supporting the positive impact of product design on SCD. Descriptive statistics show moderate average scores for digitalization of supply chain (M = 2.42, SD = 1.02) and product design (M = 2.51, SD = 1.06). Correlation analysis reveals powerful, significant positive relationship between product design and SCD (R = 0.909, P < 0.001). Regression analysis confirms product design as a powerful predictor, explaining 82.6% of the variance in SCD (R = 0.909, $R^2 = 0.826$), with model showing high statistical significance (F = 336.366, p < 0.001). The coefficients indicate a strong positive effect where a one-unit increase in product design corresponds to an estimated 0.877-unit rise in supply chain digitalization. These findings highlight product design as a key hard TQM practice and a crucial factor in advancing Digitalization within supply chains. In brief, the null form of the hypothesis cannot be accepted, and the alternative one is accepted because the computed t-value (t = 18.340), is higher than its corresponding one (1.96), and because the computed coefficient of significance (p < 0.001), is less than the predetermined (0.05). Table 10 summarizes the results of different hypotheses.

Table (10). The results of the third hypothesis test

Hypothesis	B-value	t-value	Sig.
Impact of Continuous Improvement on Supply Chain Digitization	0.823	10.515	001.<
Impact of Process Management on Supply Chain Digitization	0.755	9.692	001.<
Impact of Quality Tools on Supply Chain Digitization	0.98	19.162	001.<
Impact of Product Design on Supply Chain Digitization	0.877	18.34	001.<

6. Findings and Conclusions

The study explored the impact of hard TQM practices on SCD, concentrating on four key areas including, process management, continuous improvement, quality tools, and product design. Secondary data collected through a structured questionnaire completed by 100 respondents among those occupying different official roles in the manufacturing firms of Jordan. Employing the simple and multiple linear regression methods in hypotheses testing, the results demonstrated that TQM practices involve a direct positive significant impact SCD, and these practices explain a large degree in the variation in the performance of SCD. The results revealed that hard TQM practices play a crucial role in enabling supply chain digitalization, with continuous improvement. On an individual basis, process management, quality tools, and product design, each of which, has a positive significant impact on SCD, and contributes in explaining the change takes place in its performance. With regard to organizations seeking successful digital transformation within their supply chains, systematic integrating hard TQM practices is essential and beneficial, ensuring alignment between process management, continuous improvement, quality tools, product design, and digital initiatives. The high explanatory power of these practices (with R^2 values ranging from 57% to 83.8%) demonstrates their reliability as strategic drivers for enhancing digital performance, providing managers with robust levers to advance supply chain digitalization.

No identical prior research to the current study had found, making the identification of prior studies that showed similar or different findings, an impossible issue. The authors of the study recommend more and more studies of the idea of the current study, to be applied on different industries.

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