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Investigating the Impact of 4IR Technologies on Supply Chain Performance: A Literature Review

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Abstract:- Supply chain performance measurement is an integral part of supply chain management that reveals the efficiency, health and success of the supply chain and offers areas for improvement in this regard. Nowadays, new ways maintain to be sought to realise the highest possible potential of supply chains. The Fourth Industrial Revolution enabled limitless benefits to supply chains and created a transformation that alters the entire supply chain and business models. This study aims to reveal the contributions of this industrial revolution's technologies to supply chain performance and to ensure superior performance is achieved thanks to these technologies. In this study, the fourth industrial revolution was examined in light of the stages of industrial revolutions and the concept of supply chain performance was explained by considering the historical development of performance management. Afterwards, the dimensions of supply chain performance in the literature and the SCOR model version 13.0 attributes and their metrics, which are considered as dimensions of supply chain performance in this study, are elaborated. The contributions of these technologies to supply chain performance were investigated. The study ended with the evaluation of the findings.

I. INTRODUCTİON

"*Industry 4.0 (4IR) refers to The Fourth Industrial Revolution*" (Kolberg & Zühlke, 2015, p. 1870). There have been four industrial revolutions (IRs) until now, and the discussions of the fifth industrial revolution (5IR) have continued (Elangovan, 2022, p. 39). The word "*revolution*" means abrupt and radical change (Schwab, 2017, p. 3). The concept '*industrial revolution*' signifies the alteration of industry's technological, social, and economic systems (Dombrowski & Wagner, 2014, p. 100). The nature of modern life is about comprehending the pros and cons of IRs. For this reason, understanding industrial history is crucial not only for comprehending its impacts on SCs but also for understanding today's dynamic politics and the world around us (Stearns, 2021, p. 1).

Investigating the history of IRs, the first IR was launched at the end of the 18th century with the publicity of mechanical production equipment. The second IR launched with the emergence of electrical machines, with the need to switch to mass manufacturing held on the division of labour. The need for information technologies and the utilisation of electronics emerged to automate manufacturing processes in the 1970s. That revealed the necessity of performing several intellectual tasks in addition to the manual tasks of the machines. That launched the third IR (Bauernhansl, 2014, p.7; Brynjolfsson & McAfee, 2014, p. 10; Heng, 2020, p. 46). Figure 1 illustrates alterations in IRs over time.

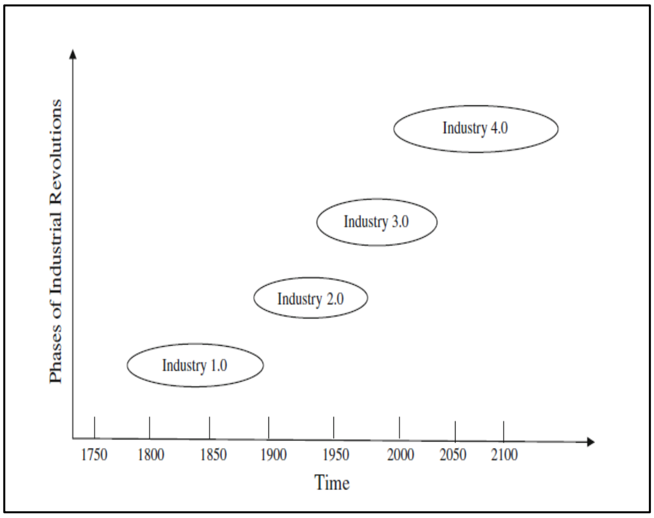

Fig 1 Phases of IRs from 1800 Until Present

* *Note.* Garbie, I. (2016). *Sustainability in manufacturing enterprises: concepts, analyses, and assessments for Industry 4.0*. Springer Nature. doi: 10.1007/978-3-319-29306-6. p. 2.

The main force that drives 4IR is expectations about the future. 4IR can also be expressed as a scheming phase of the industrialisation process. The constant change in global consumer demands and the orientation of that situation to global competition have caused a radical alteration in the production process. In this direction, Germany, the leading country in the production industry, has initiated the

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'Industrie 4.0' initiative as a part of its high-tech strategy, therefore revealing the thought of a "completely" integrated industry (Brettel et al., 2014, p. 38). That initiative was promoted as a "*strategic initiative*" by the German government in January 2011 and was initiated by the Communications Supporters Group of the Industry-Science Research Association. The suggestions for initial applications were developed by the Industry 4.0 Working Group. They were performed between January and October 2012 under the coordination of the National Academy of Science and Engineering (Kagermann et al., 2013, p. 81).

4IR is a digital revolution that intends to digitise the whole production process with the lowest possible human or manual interference. The purpose of it is to comprise as many industries as possible and to settle and evolve current technologies to comply with the necessities of digital production (Kumar & Nayyar, 2020, p. 1). It is still relatively in development, and there are more than a hundred descriptions in the prevailing literature (Moeuf et al., 2017, p. 1119). Shafiq et al. (2015) defined 4IR in three different ways. First, it incorporates complicated physical machines and tools with networked sensors, and software utilised to anticipate, check, and intend more desirable business and social outcomes. Also, it is a novel degree of organisation and management of the SC along the life cycle of goods. Moreover, it is a common expression for SC technologies and concepts. The 4IR concept can also be defined based on primary design principles and technology inclinations (Gilchrist, 2016, p. 207). To exemplify, 4IR is the assemblage of technologies ranging from various digital technologies (e.g. internet of things, 3D printing, advanced robotics) to new materials and new processes (OECD, 2016, p. 3).

The technologies offered by 4IR have the potential to revolutionise operations and SCM. However, it is much more than the integration of technologies. It consists of various positive effects on a product or service in terms of velocity, price, sustainability, data collection, data sharing, data utilisation, reproduction, and recycling. Therefore, it requires rethinking how goods or services are supplied, produced, distributed, sold, and utilised in the SC (Koh et al., 2019, pp. 817-818).

4IR significantly affects SC activities, models, and business processes (Luthra & Mangla, 2018, p. 7). It boosts the integration of SC as well as enhancing collaborative production and enabling member companies to knuckle down core competencies and so companies can work up more value-added goods and complementary services or assets (Frank et al., 2019, p. 3). SCs are becoming more flexible. In this way, they can respond to alterations in the market easily (Immerman, 2017). 4IR enables an extraordinary enhancement in productivity and efficiency in SC operations. It ensures this thanks to manufacturing ecosystems directed by smart systems with autonomous characteristics. Moreover, it ensures novel types of advanced manufacturing and industrial operations arise (Thames & Schaefer, 2017, p. 2).

4IR also provides mass customisation. Customisation permits companies to recompense the demands of clients and constantly acquaint novel services and products with the SC market. It enhances transparency in SC operations. Additionally, the main contributions of 4IR are reduction in cost, improvement in quality and enabling competitive advantage (Masood & Sonntag, 2020, pp. 1-3; Kusiak, 2023, p. 974; Tjahjono et al., 2017, p. 1181). It enables competitive advantage through the dynamic structure it ensures in company processes. It lessens SC risks. It is also eco-friendly in addition to the contributions of price and time. In this context, it augments environmental, social, and economic sustainability. It does away with faults, enables end-to-end visibility, and optimises decision-making (Mrugalska & Wyrwicka, 2017, p. 468). It ensures better operating conditions for employees thanks to the cooperation of the workforce and technology (Tjahjono et al., 2017, p. 1181). However, implementing new technologies requires constant employee training (Nnaji & Karakhan, 2020, p. 8; Smith & Carayon, 1995, p. 102). New skills will be required for employees. Furthermore, there are long-standing discussions that unemployment among large parts of the population will rise, and new socio-economic and political issues will emerge (Majumdar et al., 2018, p. 1247).

Implementing technologies enabling 4IR leads to crucial performance enhancements in SCM with a totalitarian approach stemming from information sharing, transparency, and SC integration. Moreover, these technologies ensure important performance advancements in SC processes by providing integration, digitization, automation and acquiring new analytical skills (Fatorachian & Kazemi, 2021, p.63). As can be understood from all these contributions, 4IR technologies have considerable potential in the way of operations and SCM (Kagermann et al., 2011). With 4IR, the transformation of SCM through these technologies has come to the fore (Hofmann & Rüsch, 2017, p. 33). Companies must leverage the digital technologies offered when collaborating with their suppliers, partners, distributors, and customers to take full advantage of 4IR adoption and stay competitive (Wu et al., 2016, p. 411).

How companies should digitally integrate their SCs is a significant issue to consider. Technologies will be implemented in a new environment with employees. Therefore, legal aspects, obligations, insurance, and ethical issues must be considered (Tjahjono et al., 2017, p. 1181). While businesses incorporate various existing and emerging technologies into the existing production process, they must successfully integrate and adapt their production processes with these technologies. Several complex and time-consuming procedures need to be implemented to adapt the concepts and strategies of this IR to current methodologies and techniques before they can be put into practice. It should be discussed in terms of maturity and feasibility. This IR requires significant changes in innovation, production, logistics and service processes, as it includes technologies from a wide variety of fields (Kumar & Nayyar, 2020, p. 1). In addition to the advantages of 4IR, implementation challenges should also be investigated. These challenges relate to technologies, management paradigms, systems, and workforce capabilities (Handfield, 2016, p. 1). The *'Fourth Industrial Revolution'* (4IR) is the conversion of industries, economies, and so SCs by a fusion related to technological, business, and social disruptive forces (Manners-Bell & Lyon, 2019, p. 1). The disruptive forces that cause the conversion discourse are 4IR technologies. This industrial revolution has a crucial impact on all industries, especially manufacturing, and this effect maintains exponentially (Abdelmajied, 2022, p.1). Companies and SCs that want to enhance their competitiveness and SC performance need to use these technologies to benefit from 4IR's contributions (Raji et al., 2021, p. 1153).

II. SUPPLY CHAIN PERFORMANCE

SCM has critical importance in the global competitive environment in terms of creating value and maintaining a sustainable competitive advantage for whole SC members (Ellinger, 2000, p. 86; Gashti et al., 2012, p. 11024), and its effective realisation enables many contributions to companies, regions, and countries (Silvestre, 2015, p. 156). Therefore, in today's world, where competition is no longer between businesses but between SCs (Christopher, 2000, p. 38; Lambert & Cooper, 2000, p. 67), the analysis and improvement of SC are vitally significant and inevitable (Beamon, 1999, p. 276; Saleheen & Habib, 2023, p. 2). Performance measurement is defined as "*the process of quantifying effectiveness and efficiency of actions*" (Neely, 1999, p. 207) and a critical process that measures efficiency and effectiveness in a certain activity (Gunasekaran & Kobu, 2007, p. 2820). It defines success or failure and, therefore, identifies process problems that need to be resolved. Due to the growing significance of SCM, the scope of performance measurement has expanded from a single company level to the SC level, covering all SC member companies (Guersola et al., 2018, p. 111). The historical evolution of performance measurement is given in Table 1 below (Neely, 2005, p. 1271):

Table 1 Historical Evolution of Performance Measurement

Stage I: 1980-1990	**Stage II: 1990-1995**	**Stage III: 1996-2000**	**Stage IV: 2000-2005**	**Stage V: 2005-Today**
Discussing and evaluating performance measurement systems and their operational impacts.	Suggesting possible solutions to identified problems.	Discussion on ways in which the put forward frameworks and methodologies can be utilised.	Restructuring and strengthening previous performance measurement frameworks and methodologies.	Transition from firm-based performance measurement to SCPM of which firms are members.

- *Note.* Reproduced from Neely, A. (2005). The evolution of performance measurement research: Developments in the last decade and a research agenda for the next. *International Journal of Operations & Production Management*, *25*(12), 1264–1277. https://doi.org/10.1108/01443570510633648

Supply chain performance (SCP) is a result of SCM and is based on measuring and monitoring appropriate factors that benefit the SC. Unsurprisingly, world-class companies' success depends on their SCPs (Avelar-Sosa et al., 2019, p. 70; Kurien & Qureshi, 2011, p. 20). Supply chain performance measurement (SCPM) is defined as "*a set of metrics used to quantify the efficiency and effectiveness of supply chain processes and relationships, spanning multiple organizational functions and multiple firms and enabling supply chain orchestration*" (Maestrini et al., 2017). It enables decision-makers to have information about how efficient the SC is in a certain period, understand the SC better, and evaluate it in depth (Ambe, 2014; Avelar-Sosa et al., 2019, p. 70; Ilkka, 2015, p. 292). In this way, potential problems can be identified, and performance improvement actions and opportunities can be identified (Ahi & Searcy, 2015, p. 361). Weaknesses and strengths of the SC process can be determined (Pretorius et al., 2013, p. 2). SCPM enables current performance to be compared with past performance or to identify future performance trends. Whole SC members are responsible for establishing performance measures and contributing to performance measurement (Avelar-Sosa et al., 2019, p. 69).

SCPM is performed by assigning the most relevant performance measures to SC processes (Sürie & Reuter, 2014, pp. 39-40). Since it is an activity that supports organizations in achieving their strategic goals and objectives, it is significant that the criteria determined are compatible with SCM targets and contain effective information that ensures continuous improvement of the SC (Pretorius et al., 2013, p. 2). Additionally, the correct performance measurement system should be determined by SC managers (Lehyani et al., 2021, p. 283). During the measurement and evaluation of performance, possible situations that may prevent the achievement of the SC's objectives should be considered. Lack of communication among SC members and lack of connectivity and measurement are examples of these barriers (Jalali Naini et al., 2011, p. 594). Performance measures should be understandable to whole SC members (Gunasekaran et al., 2004, p. 335; Schroeder et al., 1986, p. 5). Lastly, the findings obtained because of performance measurement should be evaluated by whole SC members (Chan & Qi, 2003, p. 213).

III. DIMENSIONS OF SUPPLY CHAIN PERFORMANCE

➢ *Dimensions in the Literature*

Until the 1980s, performance measurement focused mainly on using financial measurements such as ROI, return on sales, profit, and sales per employee (Da Silveria & Cagliano, 2006, p. 232; Tracey & Lim, 2005, p. 180). It was understood that financial performance indicators were not

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sufficient for SCPM in the following years. Nowadays, SCPM is a comprehensive issue that needs to be addressed in whole aspects of the SC (Balfaqih & Yunus, 2014, p. 634). There is no generally accepted dimensioning of the SCP structure. It has been defined in various dimensions by various researchers from the past to the present. Some of the SCP dimensions in the extant literature are illustrated in Table 2 below:

Table 2 The Dimensions of the SCP in the Literature

Source	Categories/Dimensions
Stewart (1995)	Delivery performance, flexibility and responsiveness, logistics cost, asset management.
Neely et al., (1995)	Quality, time, cost, flexibility.
van Hoek (1998)	Integration, customer service, cost-effectiveness.
Beamon (1999)	Resources, output, flexibility.
De Toni & Tonchia (2001)	Cost, non-cost.
Agarwal & Shankar (2002)	Lead time, cost, service level.
Hieber (2002)	Supply chain collaboration efficiency, coordination efficiency, configuration.
Chan et al. (2003)	Qualitative, quantitative.
Gunasekaran et al. (2004)	Strategical, tactical, operational.
Park et al. (2005); Saad & Patel (2006)	Tangible, intangible.
Chae (2009)	Plan, source, production, deliver.
Tao (2009)	Satisfaction degree of the customer, information sharing degree, logistics level, financial conditions.
Shepherd & Günter (2006)	Cost, time, quality, flexibility, innovativeness.
Cirtita & Glaser-Segura (2012)	Supply chain delivery reliability, supply chain responsiveness, supply chain flexibility, supply chain costs, supply chain asset management efficiency.
Elrod et al., (2013)	Cost, quality, time, flexibility.
Anand & Grover (2015)	Resource optimization, transport optimization, inventory optimization, information technology.
Chopra et al. (2016)	Facilities, inventory, transportation, information, sourcing, pricing.
Xie et al. (2020)	Visibility, legality, personalization, information governance, supply chain warning, green, innovation and learning.
Qader et al., (2022)	Operational performance, financial performance.

- *Note*. Author.

SCM is a dynamic process, and the performance measurement systems must be compatible with it (Bourne et al., 2000, p. 755; Kennerley & Neely, 2003, p. 214; Surana et al., 2005, p. 4236). SCs have evolved in line with the usage of ISs and 4IR technologies and the enhancing importance of sustainability in recent years (Gunasekaran et al., 2017, p. 474; Kamble et al., 2020, p. 3; Romagnoli et al., 2023, p. 2). Xie et al. (2020) included visibility and green in the dimensions of the SCP; this is an example of this situation (Table 2). They adapted the SCP structure to the dynamic structure of the SC. Undoubtedly, the SCP dimensions that will be defined in the SCs of the future will differ from today's. The SCP structure can be defined in diverse ways in line with new concepts to be introduced to the existing literature, current developments, research agenda and researchers' horizons.

- *The SCOR Model Version 13.0 Performance Attributes and Metrics*

The performance measurement model, introduced by the Supply Chain Council (now a part of ASCM) in 1996, is defined as a "*systematic approach for identifying, evaluating and monitoring supply chain performance*" (Stephens, 2001, p. 472). The SCOR model, which stands for Supply Chain Operations Reference, forms the basis of performance measurement, and is widely utilised by many companies (Hwang et al., 2008, p. 412; Lockamy & McCormack, 2004, p. 1193). The main reasons for its widespread use are that it provides universally accepted standard performance measures (Cohen & Roussel, 2013, p. 68; Khan et al., 2023, p. 2) and creates a common language for decision-making, organization, and implementation of SC procedures. It not only improves performance but also enables a competitive advantage (Delipinar & Kocaoglu, 2016, p. 399; Ntabe et al., 2015, p. 311). Moreover, it offers a rapid performance assessment, allowing performance gaps to be clearly identified and the competitive basis to be analysed, contributing to the structuring of the SC (Lohtia et al., p. 307; Pretorius et al., 2013, p. 2). Another important contribution is to support managers in making strategic decisions (Huang et al., 2004, p. 24). Implementation of the model to SCPM enables better understanding and improvement of the SC (Fawcett et al., 2007, p. 225).

The SCOR model demonstrates how well SC processes work and contributes to SCP achieving that of the industry's best SCs (Bolstorff & Rosenbaum, 2012, pp. 9-12). It is compatible with the company's information flows, workflows, materials, and operational strategies (Blanchard, 2021, p. 38) and covers whole physical material processes, customer interactions and market interactions in SCs (Millet et al., 2013, p. 171). Nowadays, the SCOR model is based on the plan, order, source, transform, fulfil, and return processes (ASCM, 2023). It includes many performance

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measures (or metrics) and is associated with performance measures that correspond to SC best practices (Avelar-Sosa et al., 2019, p. 83). SCOR model performance metrics consist of three levels. Information regarding the general status and health of the SC is obtained with Level-1 metrics. In addition to these performance measures being defined as key performance indicators (KPIs), they are considered strategic metrics in performance measurement. This level of metrics contributes to setting realistic goals and supports strategic goals. Diagnosis of Level-1 metrics is performed with Level-2 metrics. They reveal the reasons for performance gaps at Level-1. Diagnosis of Level-2 metrics is enabled by Level-3 metrics (Roe et al., 2015, p. 14).

Table 3 SCOR Model v13.0 Performance Metrics at Level-1 and Level-2

Performance Attribute	**Level-1 Performance Measurements**	**Level-2 Performance Measurements**
Reliability	Perfect order fulfilment	Percentage of orders delivered in full
		Delivery performance to customer commit date
		Documentation accuracy
		Perfect condition
Responsiveness	Order fulfilment cycle time	Source cycle time
		Make cycle time
		Deliver cycle time
		Delivery retail cycle time
		Return cycle time
Agility	Upside supply chain adaptability	Upside adaptability (Source)
		Upside adaptability (Make)
		Upside adaptability (Deliver)
		Upside return adaptability (Source)
		Upside return adaptability (Deliver)
	Downside supply chain adaptability	Downside adaptability (Source)
		Downside adaptability (Make)
		Downside adaptability (Deliver)
	Overall value at risk	Supplier's, customer's, or product's risk rating
		Value at risk (Plan)
		Value at risk (Source)
		Value at risk (Make)
		Value at risk (Deliver)
		Value at risk (Return)
		Time to recovery (TTR)
Cost	Total supply chain management costs	Cost to plan
		Cost to source
		Cost to make
		Cost to deliver
		Cost to return
		Mitigation costs
	Cost of goods sold	Direct material cost
		Direct labour cost
		Indirect cost related to production
Asset Management	Cash-to-cash cycle time	Days sales outstanding
		Inventory days of supply
		Days payable outstanding
	Return on supply chain fixed assets	Supply chain revenue
		Supply chain fixed assets
	Return on working capital	Accounts payable
		Accounts receivable
		Inventory

- *Note*. Özkanlısoy, Ö., & Bulutlar, F. (2023c). Measuring supply chain performance as SCOR v13. 0-based in disruptive technology era: Scale development and validation. *Logistics,* *7*(3), 1-35. https://doi.org/10.3390/logistics7030065

The performance metrics of SCOR model v13.0 were not published as a separate list by ASCM, updates on the previous version were reported in an official document (ASCM, 2020, p. 19). For this reason, the SCOR model v13.0 performance metrics have been compiled into a list by taking into account the previous version, v12.0 metrics, and the updates made for v13.0 (APICS, 2022; Özkanlısoy & Bulutlar, 2023, p. 24).

IV. IMPACT OF 4IR TECHNOLOGIES ON SUPPLY CHAIN PERFORMANCE

➢ *Overall Performance*

The extant literature has highlighted that the utilisation of the 4IR technologies, ensures a significant increase in SCP (Fatorachian & Kazemi, 2021, p. 63). CPS offers automation and enhanced connectivity through advanced information sharing. This situation significantly enhances SCP (Wiengarten & Longoni, 2015, p. 26; Blome et al., 2014, p. 640). IoT technology enables advanced connectivity by providing real-time reaching to information. It is claimed to enable enhanced SCV (Kache & Seuring, 2017, p. 12) and significantly contribute to SCM (Wamba et al., 2015, p.935). The incoming advanced automation of the IoT is one of these contributions. Productivity and efficiency increase, and this technology ensures quality control with automation (Yu et al., 2015, p. 1055). Therefore, it's a technology that improves the whole SC. BDA technology is another technology that makes significant contributions to SCP. It ensures the optimisation of SCP with its simultaneous and systematic data collection and analysis characteristics. Additionally, this technology provides a competitive advantage. It also contributes to real-time problem resolution and crucial cost reduction by enabling real-time data flow analysis (Davenport, 2006, p. 99). Cloud computing technology ensures the forming of novel communication platforms, collaborations, and coordination forms at the institutional level (Helo & Hao, 2017, p. 525). Real-time information sharing and high-level integration are other contributions. Furthermore, this technology is important for planning and decision-making (Helo & Hao, 2017, p. 526; Tan et al., 2017, p. 4998). Consequently, using 4IR technologies has a positive impact on SCP.

Fatorachian & Kazemi (2021) brought new perspectives to improving SCP. In this direction, they performed exploratory research. The study investigated the effect of 4IR on SCP, and the findings were presented in four groups. They were CPS, IoT, BDA and cloud computing technologies. The effects of them were explained separately in that study. Xi et al. (2020) analysed key features of smart SC and then proposed a performance measurement framework including various indicators to determine the impact of 4IR on SCs. The authors assumed the framework to contribute to the evolution of the OP of smart SCM. The indicators in the study were visibility, flexibility, personalisation, information management, SC warning, green, innovation, and learning. Wamba et al. (2020) developed two separate models to close the gap in inquiring about the effect of utilisation of blockchain technology on SCP in the literature. The study applied surveys from SCs that implement that technology in the SC. Jum'a (2023) investigated the effect of blockchain technology adoption on SCP by utilising structural equation modelling. The findings of the study revealed that blockchain adoption enhances SCP (β= 0.368; t-value=5.942; $p<.05$). Al-Khatib & Ramayah (2023) examined the effect of BDA capability on SCP to evaluate the mediating effect of SC innovation and the moderating effect of a data-driven culture by utilising structural equation modelling. The study revealed that BDA ability statistically affected SCP (β= 0.378; t-value= 7.101; $p<.05$).

➢ *SCOR Model v13.0 Performance Attributes*

Since the current SCOR model version was 13 when this study was carried out, the attributes and metrics of this model were taken into account. Its performance attributes are reliability, responsiveness, agility, cost, and asset management. The contributions of the relevant technologies to these performance attributes are respectively discussed below:

- *Reliability Performance*

The relationship between SC reliability and SCP is not a new fact. It dates to the Defense Production Act, enacted in 1950 to keep supply lines running smoothly and prevent hoarding in the event of a national emergency. The importance of SC reliability performance has been re-emphasised by the COVID-19 crisis. Disruptions in the provision of adequate medical equipment, transportation interruptions and problems with reliable food supply have brought the significance of SCV and SC reliability performance to the agenda again (Goel, 2020, p. 3).

SC reliability performance relates to situations encountered by customers. The most fundamental criteria are perfect order fulfilment, delivery performance and order fulfilment performance (Lai et al., 2002, p. 442). The notion of reliability pertains to the ability to perform tasks properly in SC processes. Reliability performance enhances the predictability of the outputs of a process. Reliability measures are based on documentation accuracy, quantity, and time. They relate to delivering a service or product on time, in the accurate quantity, and with accurate documentation. SC reliability performance is a customer-oriented attribute (APICS, 2022). It is the quality of SC activities as perceived by customers. The main aim of an organisation is to engender customer value and create value for stakeholders, so it is not difficult to predict the primary purpose of SCM (Iansiti & Lakhani, 2020, p. 61). Since SC reliability performance is also a customer-oriented performance attribute (Hamada & Jarrell, 2009, p. 254), it is crucial for its contribution to the primary purpose of SCM.

4IR technologies have a significant effect on SCP. They improve operations, enhance SC revenue, develop new business models in companies and enable significant opportunities for SCs that add value to customers, stakeholders, and society. In terms of SC reliability, customer expectations are better met, and delivery efficiency is increased. Therefore, 4IR technologies positively affect SC reliability performance. For example, all parameters in traditional SCM can be affected positively thanks to the ability of machines to perceive, interpret, act, and improve. Companies can turn into data-driven organisations over time (Sinha et al., 2020). Using these technologies in SCs enhances customer satisfaction (Guarraia et al., 2015, p. 2). Supply quantity and delivery times can be controlled with

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them (Oh & Jeong, 2019, p. 219). Improving communication between SC members (Korpela et al., 2017) is also essential for reliability performance. This performance is more about reducing errors in all processes, delivering on time, increasing forecast accuracy, ensuring accurate quantity, and being at an accurate place in the SC. Since 4IR technologies enable the benefits mentioned above, the using 4IR technology and reliability performance are closely related. 4IR technologies improve SC reliability performance (Zhu & Kouhizadeh, 2019, pp. 37-38).

Fatorachian & Kazemi (2021) reviewed the extant literature to investigate the effect of 4IR technologies on SCP. The technologies formed the basis of integrated and end-to-end SCs with superior flexibility, transparency, connectivity, collaboration, and autonomy. Therefore, they also affect reliability and performance. Kayıkci et al. (2022) performed a literature review and case analysis. The advantages and difficulties of blockchain technology were presented with the findings obtained from the study. The human, process, and technology models were utilised in the study. The study also presented the opportunities and threats of blockchain and revealed that blockchain ensures that data, transparency, and cooperation between stakeholders are not manipulated. Forslund & Jonsson (2007) developed a theoretical measurement tool for estimation information quality to explain the sensed quality of customer forecast information and the effect of estimation information quality on SCP. The study found that the biggest lack of information quality is that the estimation is seen as unreliable. When examining suppliers with forecast access and stock without forecast access, the only significant difference between them regarding SCP was the utilisation of safety stock in the completed goods inventory.

Moeuf et al. (2017) investigated the observed performance benefits of 4IR implementation by conducting a literature review of extant implemented research, including various 4IR topics related to small and medium enterprises. The study revealed that the most prevalent performance advantage is the increased productivity advantage, and 4IR implementations in small and medium enterprises have many advantages, such as lower cost, lower delivery time, and improved quality. Alkış et al. (2020) collected data by conducting in-depth interviews, observations, and document reviews with competent senior and mid-level managers of logistics companies that used 4IR effectively and tested the reliability of that data with Kappa Analysis. The findings revealed that 4IR technologies influence operational efficiency in transportation management, which is one of the logistics activities. They also affect fuel consumption, route and route planning, transportation and delivery speed, vehicle occupancy rates, fleet management, and vehicle and driver performance.

Tang & Veelenturf (2019) investigated the role of logistics activities in the 4IR era to create value as social, environmental, and economic. The value that logistics activities can create through digital transformation was examined. The study revealed that using 4IR technologies is economically beneficial; they enable faster delivery, higher reliability in storage and access systems, lower operational costs, and enhanced productivity. The findings demonstrated in terms of social value that they enable faster and safer response and rescue operations as well as enabling benefits such as improvement in diagnostic care and medication application with wearable devices, increasing farmer productivity by using drones and smart sensors, improving provenance using blockchain, and improving mobility through smart transportation. The study revealed that environmental value, protecting endangered species, lessening water consumption, and reducing emissions are some of the contributions of 4IR technologies. Ghadge et al. (2020) formed a simulation model that relied on the extant literature to initially specify the effects of 4IR technologies usage on SCs. The benefits and challenges of related technologies were discussed to designate their impact on SCP. Using simulation analysis enabled the effects of the implementation of 4IR technologies to be examined on the SCP. Moreover, the study proposed a new conceptual framework for 4IR application in SCs.

Kamble & Gunasekaran (2019) comprehensively reviewed a total of sixty-six articles to determine the performance measures of SCs based on BDA. The performance measures obtained were separated into two groups. While the first related to the performance of BDA quality, the second group related to the process performance of SCs based on that technology. The study introduced new performance metrics based on prediction and social analytics. The identified measures included SC reliability performance. Frederico et al. (2021) presented a balanced scorecard-based theoretical approach for SCPM in the 4IR era. In the study, performance measures in the extant literature and balanced scorecard measures were combined in the context of 4IR. The study examined performance measurements from four different perspectives, and a SC 4.0 scorecard was proposed. Since measurements such as process efficiency, transparency, and process integration were included in the study, SC also included reliability performance.

- *Responsiveness Performance*

The primary determinant of the firms' performance is their capability to react expeditiously to alterations in the external surroundings. Notwithstanding, it can be only possible when the entire SC responds (Singh, 2015, p. 868). From an SC responsiveness perspective, it can be described as the speed at which duties are accomplished or the repetitive speed of doing business in SC. Cycle time measures relevant to the speed at which service or goods can be supplied, produced, and delivered are instances of responsiveness performance measures. Responsiveness performance is also a customer-oriented attribute like reliability performance (APICS, 2022).

Raw materials are converted into ultimate goods and subsequently delivered to end clients in SC. This process, which begins with purchasing unprocessed materials, expands with the delivery of the ultimate goods to the end client, and the SC integrates the process (Janvier-James, 2012, pp. 194-195). Accordingly, SC integration is the

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ability of companies that are suppliers and customers of each other to integrate their activities and between their departments (Xie et al., 2020, p. 713). The responsiveness of the SC network and SC operations are related to internal integration (Sukati et al., 2012, p. 2). SC integration has a mediating role on the relationship between using 4IR technology and SCP (Bruque Cámara et al., 2015, p. 428). Therefore, the utilisation of 4IR technologies affects SC responsiveness performance because they enable integration in SCs. Singh (2015) reviewed the extant literature to identify key factors for SC responsiveness.

The study identified seventeen critical factors. The factors were grouped as process-oriented and result-oriented. The main success factors of responsiveness were the commitment of the top management, utilisation of technology, risk, strategy development, resource development, and reward sharing. The study showed that companies could also be useful in inventory management, reducing lead time and agility by implementing the enablers.

Zekhnini et al. (2021) investigated a hundred of the most relevant articles to investigate the current literature on digital SCM. The academic studies from 2005 to 2020 were considered as the date range. The study revealed the effects of 4IR technologies on SCP by distinguishing between digital SCs and traditional SCs. The status of digital SCs was also evaluated using SWOT analysis. The study revealed a roadmap framework for further studies. The findings demonstrated that all 4IR technologies included in the study support the responsiveness dimension of the SCP. Choudhury et al. (2021) reviewed the literature comprehensively and identified and analysed many key achievement factors that can enhance the performance of digital SC. The hierarchical structure was constructed utilising total interpretive structural modelling, which considered expert opinion. The study revealed that SC responsiveness performance is significant in the relationship between using 4IR technologies and SCP, as reducing lead times is among the twelve success factors.

Erboz et al. (2022) investigated how 4IR technologies affect SC integration and SCP and analysed it utilising structural equation modelling. The study revealed that 4IR positively affects SC integration and SCP. It also demonstrated that SC integration has a partial mediation role in the relationship between 4IR and SCP. The SCP scale included on-time delivery, customer reaction time, and production lead time items. In that respect, the scale had SC reliability performance measures. However, the study discussed the sub-dimensions of the scale in three groups: resource utilisation, output, and flexibility.

- *Agility Performance*

Agility is described as “*the ability to react to external influences*”. External influences consist of situations such as unpredictable enhancement or decline in demand, unemployed suppliers or partners, natural disasters, availability of financial resources and labour problems, and cyber and physical terrorism acts that may depend on the state of the economy. Agility is a customer-oriented attribute, like reliability and responsiveness (APICS, 2022), and is also defined as the capability to respond effectively and efficiently to market alterations and turbulence. It is also a crucial issue in the survival of companies (Altay et al., 2018, p. 1159). Using 4IR technology significantly affects companies and their SCs to focus on dynamic capabilities such as agility (Warner & Wäger, 2019, p. 346).

Dhaigude & Kapoor (2017) proposed a model linking SC orientation and SC agility with SCP to fill the gap in the extant literature on SC agility and SCP. A cross-sectional survey was implemented for Indian manufacturers in the study. The findings illustrated that SC orientation and SC agility are significantly related to SCP. Furthermore, it revealed that agility has a mediating role between orientation and performance. Eslami et al. (2021) examined whether 4IR technologies moderate the relationships between SC integration and SC agility and between SC agility and financial performance. The study revealed that 4IR technologies enhance the impact of SC agility on financial performance. The study also demonstrated that the technologies do not affect the relationship between SC integration and SC agility. Raji et al. (2021) investigated how 4IR technologies contribute to implementing lean and agile applications. Moreover, it evaluated the probable performance implications of integrating them with SC operations. An exploratory case study was conducted using the data obtained through interviews. The study revealed that 4IR technologies enable and develop lean and agile applications in SC.

- *Cost Performance*

SCM is defined as "*the management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at lower cost to the SC as a whole*" (Rana & Sharma, 2019, p. 89). Using 4IR technology contributes to one of the objectives of SCM, enabling higher customer value at a low cost. Using 4IR technology enables significant cost advantages for countries, businesses and SCs, especially in the industrial field (Sabri et al., 2020).

SCs have reached lower inventory levels, demand uncertainties, and shorter lead times thanks to using 4IR technology. All of them allow for the reduction of costs in the SCs (Naslund & Williamson, 2010, p. 12). The benefits of using 4IR technology are not limited to the cost-cutting effect. It also reduces transaction costs, which are the costs related to completing a transaction (Amit & Zott, 2001, p. 494; Dyer, 1997, p. 536). Processes are long and complex in the physical world, and there are many intermediaries between buyers and sellers. Therefore, transaction costs are high. These intermediaries are greatly reduced due to new 4IR technologies (Williamson, 1980). Using 4IR technology also affects marginal costs, which represent the costs incurred to manufacture one more unit of products or services (Shapiro & Varian, 1998, p. 86). Basic costs generally arise from production activity. The cost of producing, duplicating, and distributing digital information products is so low as to be counted as zero since duplication of the same products does not create additional costs.

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Therefore, using 4IR technologies has a lowering effect on information costs.

Üstündağ & Tanyaş (2009) investigated the effect of Radio Frequency Identification (RFID) technologies on SC costs with a simulation model. The RFID-applied model and the non-RFID model were compared in that simulation. The study revealed that the total cost gain is mostly at the retailer level compared to the average values in terms of the distribution of RFID applied SC total cost gain between the retailer, distributor, and manufacturer, and that was followed by the manufacturer and distributor. Therefore, it would be appropriate to comment that RFID technology provides cost savings that cover the entire SC. Emelogu et al. (2016) researched the economic practicability of 3D printing technology. They introduced a stochastic cost model to measure the SC-level costs related to manufacturing biomedical implants utilising the technology. The study concluded that the cost of 3D printing machinery must be lessened by almost 60% to make it profitable to manufacture biomedical implants using them.

Tekin et al. (2005) researched the impact of information technology use on business performance in the logistics industry. The study evaluated the criteria regarding technologies' usage purposes. The findings revealed that information technologies have the effect of decreasing inventory costs. The study was not about 4IR technologies, it was about information technology. Shnaiderman & Ouardighi (2014) discussed partial information sharing. Unlike other studies in the literature, it knuckled down the impacts of sharing demand alterations on the SC, which distinguishes it from previous studies. They investigated the effects of sharing demand information at various levels between the manufacturer and the retailer on the cost of the SC with the theoretical models they developed. The study revealed that SC costs decrease with the increase in the level of sharing.

As using 4IR technologies enhances and facilitates information sharing, it is also essential to address studies addressing the effect of information sharing on SC cost performance (Rodríguez-Espíndola et al., 2020, p. 4621; Ye & Wang, 2013, p. 375). Premus & Sanders (2008) revealed that the enhancement in the quality of the level of shared knowledge is efficacious in improving SCP. The study also showed that it reduces total costs and enhances the level of client service. Davis et al. (2011) compared two situations. While one could not enable information sharing, the other ensured full information sharing. The study revealed that performance indicators such as cost, and inventory level are positively affected when shared. The cost-related part of the study illustrated that if the coefficient of variation is high, supplier capacity is high, and supplier penalty costs are low, the cost-benefit enabled by information will be low.

- *Asset Management Performance*

Companies are established by systematically and consciously bringing together factors such as equipment, money, personnel, materials, securities, and raw materials, and maintain their operations in this way. These factors are necessary for the existence of the company and constitute the assets of the company (Srivastava et al., 1998, p. 5). The concept of asset management has various definitions in the current literature. It can be explained as the effective and appropriate management of assets throughout their entire life cycle, such as procurement, manufacturing, acceptance, placement, maintenance, operation, and all subsequent processes (Baskarada et al., 2006, p. 487). It is also described as the process of achieving the highest ROI in assets by maximising their performance and minimising their costs throughout the life cycle of assets (Shahidehpour & Ferrero, 2005, p. 33). Since strategies related to investment and business plans are implemented at every stage of the process in asset management (Mohseni, 2003), it is a systematic process (Guler et al., 2004, p. 23).

According to the Association for Supply Chain Management (ASCM) 's shorter, more precise, and more understandable definition, asset management is "*the capability to utilise assets efficiently*". Its SC strategies consist of inventory reduction and internal sourcing rather than outsourcing (APICS, 2022). It deals with the life cycle of physical assets with a holistic approach, enabling the right decisions, optimisation of related processes, and evolving maintenance management (Katicic & Susnjar, 2011, p.717). Additionally, asset management is a value-creating process among customers and the company, as well as among customers and competitors. It enables cost differentiation among businesses and their competitors, thus providing both businesses and the SC to gain a competitive advantage (Christopher, 2023, p. 5).

Assets in 4IR are categorised as physical, virtual, and human (Teoh et al., 2021, pp. 1-8). Thanks to using IoT technology, control of many operations such as precision and accuracy of physical assets, stock orders and controls, depreciation periods and amounts for physical assets, counts and controls of the warehouse, and prosecution of acquisitions and sales can be performed without human contribution as a part of inventory activities (Özcan & Akkaya, 2020, p. 149). This technology is used to identify and track assets. With BDA technology, the failure of production equipment can be predicted. Predictive maintenance enables the company to make decisions, such as replacing or repairing the component before an actual failure affects the manufacturing process (Teoh et al., 2021, pp. 1-8). 4IR technologies enable to prohibit or expeditiously solve process flaws and equipment malfunction (Tao et al., 2018, p. 159).

SCM and physical asset management are automated thanks to 4IR technologies. Unnecessary purchases can be prevented, and business and personnel performance analyses can be made automatically with them. This situation helps to save money. Problems and bottlenecks related to assets can be eliminated automatically with them (Jasperneite et al., 2020, p. 34). 4IR enables significant advantages in designating the locations and quantities of assets, enabling communication between internal and external assets, and determining the effectiveness and efficiency of assets with the 4IR technologies and implementations it offers

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(Demirkol & İkvan, 2020, p. 57). Therefore, using 4IR technology and asset management performance are expected to be closely related. In this context, some of the studies carried out in this field so far are given below:

Cirtita & Glaser-Segura (2012) revealed a measurement tool that determines whether performance metric systems are used to determine whether the observed performance measurements are compatible with the literature and to improve inter-firm performance. The tool was created to address the SCOR model features that were valid at that time. They were asset management efficiency, delivery reliability, costs, responsiveness, and flexibility. The study revealed the one-dimensional structure as the internal metric system. However, there was no convincing evidence for the idea that outward performance measures are utilised to coordinate downstream SCs. Mattioli et al. (2020) investigated how AI technology can improve some of the issues of the asset management lifecycle, including asset acquisition, performance analysis and forecasting, asset tracking, and predictive and prescriptive maintenance. The study relied on the literature review. The findings showed that processes such as asset-related decisions, analytical, and predictive and prescriptive maintenance activities for asset performance monitoring, SC planning, spare parts optimisation, and conversion to end-of-life asset management can be optimised thanks to using AI. Erboz et al. (2022) applied a questionnaire to investigate the 4IR's effect on SC integration and SCP, and structural equation modelling was utilised for analysing the data. It illustrated that 4IR has a positive effect on SC integration. The study also demonstrated that SC integration has a positive effect on SCP, and SC integration has a partial mediation role between 4IR and SCP. The sub-dimensions of the SCP scale were resource utilisation, output, and flexibility in that paper. The content of questions regarding resource utilisation overlapped with asset management.

V. DISCUSSION

This study examined the impact of using 4IR technologies on SCP. There are various studies in the extant literature investigating the relationship between using 4IR technology and overall SCP. Wamba et al. (2020) developed two separate models to close the gap in researching the impact of blockchain utilisation on SCP. The study revealed that the relevant technology had a positive contribution to SCP (β=0.253; t-value= 2.757; $p < .05$). Fatorachian & Kazemi (2021) conducted exploratory studies to investigate the impact of 4IR on SCP. The findings were collected in four groups: CPS, IoT, BDA and cloud computing technology's contributions to SCP. The study revealed that those technologies improved SCP and explained their contributions separately. Jum'a (2023) investigated the effect of blockchain adoption on SCP by using structural equation modelling. The findings of study demonstrated that blockchain adoption enhances SCP (β= 0.368; t-value=5.942; $p<.05$). Al-Khatib & Ramayah (2023) revealed that BDA ability had a statistically significant effect on SCP by utilising structural equation modelling (β= 0.378; t-value= 7.101; $p<.05$). The relevant studies have been conducted on a single technology basis but confirmed the relationship between using 4IR technology and SCP.

SCP was addressed in four dimensions regarding the SCOR model v13.0 attributes. There are many examples in the relevant literature regarding the contributions of 4IR technologies to SCP dimensions. CPS enables reliable data on the SC and the monitoring, control, and coordination of processes (Bonilla et al., 2018; p. 2; Rajkumar et al., 2010, p. 731). In this way, it contributes to SC reliability performance by lessening errors in SC processes and ensuring the accuracy of processes. Furthermore, it enhances responsiveness by shortening cycle times in the SC. It contributes to cost performance by significantly reducing SC costs thanks to optimisation of processes, reduced machinery and energy costs, less investment in production resources, improved quality monitoring and lower quality management costs (Klötzer, 2018, p. 96).

IoT enables fruitful stock counting and decreases the risks of accidents in warehouses (Lee, 2016). What is more, it lessens production errors by controlling production lines. It reduces the transportation cycle time and errors during the transportation period by tracking and controlling the location of the transported goods (Witkowski, 2017, p. 765). Accordingly, it contributes to both SC reliability and responsiveness performance. This technology enhances the efficiency of handling operations and reduces energy losses (Chen et al., 2018, p. 957; Kumar et al., 2022, p. 2). Besides, it raises productivity and efficiency and decreases operating costs thanks to interconnected devices. Therefore, it could enhance cost performance and asset management performance by creating revenue opportunities (Kumar et al., 2021, p. 866).

AI has been utilised in miscellaneous fields in the SC (Aylak et al., 2021, p. 80). Storage costs can be lessened by estimating the company's demand for the next six months in demand forecasting by using machine learning which is a type of AI and allows these implementations to be carried out more meticulously (Wenzel et al., 2019, p. 415). AI is also utilised as an early warning tool for potential customer churn (Chen et al., 2015, p. 476). It alleviates transportation distance and time by carrying out route optimisation in transportation activities with its algorithms, which provides remarkable savings in transportation costs (Dauvergne, 2022, p. 701). It contributes to the accuracy of information on the movement of goods throughout the SC (Mahroof, 2019, p. 177). Moreover, it helps to cope with the problems of material supply delays, inadequate planning, and lack of forecasting in SC processes (Dhamija & Bag, 2020, p. 870). It is also crucial for quickly assessing risks and minimising their effects to the lowest possible level (Riahi et al., 2021, pp. 2-3). Operator movements can be detected at an early stage by utilising a combination of RFID technology and machine learning methods to prevent potential order-picking errors (Geigl et al., 2017, p. 74). It ensures efficient utilisation of assets by detecting maintenance and malfunctions of assets used in operations ahead of time and prohibiting possible damage and malfunctions (IBM, 2018).

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Accordingly, it is obvious that AI is a vital technology for all SCP dimensions.

Autonomous robots contribute to SCP by being utilised in warehouses, distribution centres, and factories (Rüßmann et al., 2015, p. 56). They can boost efficiency and security in warehouses as well as enable the wane of operational faults human-based (Görçün, 2022, p. 84). They could provide the reduction of labour costs, the number of raw materials and waste, and the margin of error of the operators they work with. Besides, it enhances production quality, efficiency, and flexibility (Dalmarco & Barros, 2018, p. 304; Bugmann et al., 2011, p. 2). They also could curtail production cycle times (Hofmann & Wenzel, 2021, p. 896). BDA is another technology that makes pivotal contributions to SCP dimensions. It enables tasks to be completed in minutes and at a speed never before possible compared to traditional data infrastructures (Pellicelli, 2023, p. 109); hence, it accelerates SC processes (Höchtl et al., 2016, p. 148) and is considered one of the game changers of SCM (Fawcett & Waller, 2014, p. 157). It enables supplier risk to be managed by allowing detailed evaluation of supplier performance. Moreover, it reduces SC risks in general and plays a role in creating emergency plans. It could reduce sourcing costs (Xu et al., 2023, pp. 2-3) and enhance SCP by enabling data-driven decision-making. It also provides faster access to relevant data and trends to be used in analysis, thereby speeding up the search process and increasing operational efficiency. When implemented to identify current trends and pattern recognition, it enables faster and more accurate demand forecasting based on historical databases. This ensures purchasing activity to be transformed from a reactive to a proactive process (Lamba & Singh, 2017, pp. 881-882).

BDA is considered a critical technology for manufacturing operations thanks to its contributions such as better forecasting of product demand and production, better plant performance and faster after-sales service and customer support (Bi & Cochran, 2014, p. 250). Furthermore, it enables faster production, predicts malfunctions, reduces costs and production defects (Belhadi et al., 2023, p. 769; Park & Singh, 2023, p. 1438). Optimising route planning and refuelling, minimising waiting times for drivers, optimising maintenance times, and identifying accident-prone drivers are some of its benefits in the transportation process (Sabet & Farooq, 2023, p. 2004; Shoman et al., 2023, p. 2). BDA has emerged as a remarkably lower-cost option compared to traditional databases (Jeble et al., 2018, p. 41) and is vital for whole SCP dimensions.

The immutable nature of blockchain technology allows the creation of a complete SC from the point of origin to the point of sale for all items stored in the ledger, thus enhancing SC reliability. Data stored in this technology cannot be modified or deleted, ensuring high data security (Korepin et al., 2021, p. 2). It contributes to reliability and responsiveness performance by shortening operational processes and ensuring that processes are carried out correctly (Tieman & Darun, 2017, p. 548; Wang & Beynon-Davies, 2019, p. 63). Additionally, it positively contributes to asset management performance by enhancing traceability, security, and control of assets (Correa Tavares et al., 2021, p. 580).

The use of cloud computing has significantly transformed SCs by providing real-time access to data from any location and improving collaboration (Dallasega et al., 2018, pp. 208-210). It enhances product customisation, market flexibility and global collaboration and helps companies to meet growing demand (Ren et al., 2017, p. 502). This technology, which enables networked smart production, contributes to control and planning by enabling the creation of metadata flow in a controlled manner; what is more, it provides processes to be carried out quicker and shortens cycle times (Piyathanavong et al., 2022, p. 2; Vazquez-Martinez et al., 2018, p. 92). It also boosts SC collaboration, delivers cost savings, and raises revenues (Gowda & Subramanya, 2016, p. 56). It increases trust between SC members. Additionally, it is pivotal for optimising resources, ensuring more efficient service delivery, lessening risks, and enhancing resilience (Gammelgaard & Nowicka, 2023, p. 8; Giannakis et al., 2019, p. 585; Lin et al., 2021, p. 98; Nan et al., 2020, p. 2780).

3D printers are technologies that allow on-demand and rapid production of customised products. They can reduce lead time, inventory and waste, warehouse costs and process inefficiencies while improving product quality. Therefore, it has a positive impact on cost performance as well as responsiveness performance (Pagano & Liotine, 2019, p. 21). The utilisation of augmented reality boosts efficiency and, reduces fault rates in warehouses (Glockner, 2014), and raises asset uptime (Büyüközkan & Güler, 2019, p. 23). Therefore, they improve reliability and asset management performance. It can be utilised in order picking in warehouses, enhancing the efficiency of warehouse operations (Pagano & Liotine, 2019, p. 29). The utilisation of this technology allows for a more comprehensive and in-depth comprehension of business processes (Mohsen, 2023, p. 788). It also could provide visualisation of workflows, production optimisation, and real-time collaboration in production processes. Moreover, it can be utilised to guide workers through assembly, maintenance, and repair tasks. When incorporated into production processes, it can be used to enable workers to receive step-by-step instructions, visualise real-time data, and generate virtual models. When utilised in production maintenance, it lessens the likelihood of machine failure, diminishes production costs and raises equipment availability. SC member companies can more easily cope with problems related to planning, process integration and resource utilisation by using augmented reality (Mishra, 2023, pp. 93-98).

Virtual reality has the potential to dramatically transform many aspects of the SC and customer experiences (Druehl et al., 2018, p. 267). It makes various contributions to SCP. To exemplify, it can lessen product time to market and product costs. It can also facilitate new product development, enhance product quality, and reduce risks and uncertainty (Choi et al., 2015, p. 566; Mujber et al., 2004, p.

1836). Autonomous (driverless) vehicles are utilised in passenger and freight transportation. They could reduce traffic accidents, delivery time and delivery costs by lessening traffic congestion in freight transportation (Pietras, 2015, pp. 64-67). They make it easier to transport large loads, decrease operational costs, boost load traceability, and diminish maintenance costs (Perussi et al., 2019, p. 34). Thanks to their contributions, it is significant for reliability, responsiveness, and cost performance.

Digital twin technology is a virtual copy of a physical item or system that can be monitored, analysed, and controlled in real-time (Menon et al., 2023, p. 75152). It allows analysis of data and monitoring of systems to predict problems before they occur, prevent downtime and waste of time, and even plan for the future using simulations (Mashaly, 2021, p. 299). It also enables easy and accurate organisation and optimisation of product designs, inventory management, material usage, shipping, and delivery time (Lam et al., 2023, p. 2). In other words, it is a model that lessens traffic congestion and prevents accidents in warehouses and possible delays by optimising processes, enhances agility and resilience, and can ensure end-to-end visibility to test emergency plans in the SC (Ivanov et al., 2019c, p. 310). It makes critical contributions to reliability and responsiveness performance by reducing cycle times and accidents related to processes as well as enhancing agility (Leng et al., 2021, p. 2; Wang et al., 2022, p. 56). Furthermore, it offers many opportunities for innovation and improvement in SC processes. It enables time and cost savings by facilitating the testing process of scenarios and cases during production; hence, it is a key technology in terms of SC cost performance (Li et al., 2021).

5G technology integrates suppliers, customers and intra-organizational processes and facilitates communication within the organisation and among SC members (Taboada & Shee, 2020, p. 394). While it reduces handling times, human errors, and accidents in storage activities, it reduces traffic congestion, accidents, and economic loss risks in transportation activities. It also shortens the transportation and waiting times of trucks. This technology enables augmented security thanks to more precise data transfer and enhances operational efficiency across SC (Cavalli et al., 2021, pp. 10-11). Accordingly, it contributes remarkably to reliable and responsive performance. It also contributes to cost performance due to significant energy savings (Agiwal et al., 2019, p. 2). Simulation is a technology that contributes to achieving better operations, reducing waste of time and resources, and increasing efficiency (Gunal, 2019, p. 276). Thanks to these characteristics, it significantly contributes to responsiveness and cost performance. Horizontal and vertical systems contribute to establishing information and connections and realising cooperation in the SC (Saucedo Martínez et al., 2018, p. 781). They reduce production, labour, transaction, and marketing costs (Brettel et al., 2014, p. 38; Phung & Pham, 2018, p. 665). In addition, it enables more efficient utilisation of assets (Besanko, 2000, p. 425) and enhances profitability (Burns et al., 2014, p. 62). Nearly all 4IR technolgies contribute critically to the cash conversion cycle and the return on working capital (Soni et al., 2022, pp. 2-4), so using 4IR technologies is significant for SC asset management performance.

Overall, the study's findings are compatible with the existing literature. Moreover, it is obvious that 4IR technologies remarkably contribute to SC reliability, responsiveness, agility, cost, and asset management performance.

VI. CONCLUSION

SCM is described as "*the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole*." (Mentzer et al., 2001, p. 18). Nowadays, new ways maintain to be sought to realise the highest possible potential of SCs (Ramezankhani et al., 2018, p. 531**).** SCP measurement is an integral part of SCM that reveals the efficiency, health and success of the SC and offers fields for improvement in this regard (Charan et al., 2008, p. 512). 4IRs are the revolutionary novel technologies of the modern era (Tushman & Anderson, 2018, p. 346) and makes critical contributions to improving SCP (Fatorachian & Kazemi, 2021, p. 64). Accordingly, utilising 4IR technologies is a crucial way to achieve higher performance in SCs. This study provides a guide to enhancing SCP utilising relavent technologies by presenting the contributions of 4IR technologies to both the overall SCP and its dimensions.

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