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A Research on Identifying Intertwined 4IR Technologies in the Supply Chain Context

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Abstract:- The Fourth Industrial Revolution is the conversion of industries, economies, and so supply chains by a fusion related to technological, business, and social disruptive forces. The disruptive forces that cause the conversion discourse are the technologies it has enabled. This industrial revolution has a crucial impact on all industries, especially the manufacturing industry, and this effect sustains exponentially. The utilisation of The Fourth Industrial Revolution technologies and the digital transformation of supply chains is a pivotal step today towards enhancing their competitiveness and their supply chain performance and being able to follow the supply chains of the future. However, implementing them alone is not enough; new ways to get the most benefit from them must be inquired. The combined utilisation of certain industrial revolution technologies boosts their efficiency and their contributions to companies and supply chains. This study investigated the correlational relationships of the eight most used The Fourth Industrial Revolution technologies in the supply chain context and determined the technologies with the highest relationship with each other and called them intertwined technologies. The sample size consists of 393 companies. The study is a guide for companies and supply chains that will implement these technologies or invest in a novel one.

Keywords:- *The Fourth Industrial Revolution, Intertwined Technologies, Supply Chain Management.*

I. INTRODUCTION

The Fourth Industrial Revolution (4IR) can be described simply as the integration of physical manufacturing and cyber by novel technologies or the digitalization of industry [1]. The utilisation of 4IR technologies has demonstrated that the entire SC, as well as factories, must be made intelligent [2], and has realised a digital transformation that alters entire business models and SC [3]. The internal dynamics of an organization cover resources, business models and processes [4]. Transformational alterations in internal dynamics affect the performance of both SCs and companies [5].

A massive alteration has occurred in professional life thanks to the contributions of 4IR technologies and digital transformation, and it has proceeded to progress. 4IR technologies assure lower costs and numerous opportunities, and they are convenient for all-size companies today. 4IR has conceived limitless occasions for companies and connected SCs with these technologies [6]. When the COVID-19 pandemic period is examined, the significance of digital transformation and using 4IR technologies has enhanced even more. The significance of the issue has been emphasized once again in the early investigations on the effects of the pandemic on the SC. Digital transformation is dramatically effective in increasing SC resilience and controlling the ripple effect. Companies that have digital manufacturing networks can take better positions in case of crisis and recovery in terms of digital control and visibility [7].

While digitalization includes technologies that are accessible to everyone [8], digital transformation is a process related to "the world where everything is interconnected" [9]. Therefore, this transformation relates to the utilisation of 4IR technologies. Although some companies have achieved digital transformation in SC, some have still not acted on it. The implementations of many companies that do not realise digital transformation are at the digitalization level. Choosing the accurate technology challenge, high cost and implementation challenges are the fundamental reasons for this situation. The extant studies have revealed that there will be a critical enhancement in the utilisation of 4IR technologies for the next five years. The actual utilisation levels of some 4IR technologies in 2020 and their estimated utilisation levels in 2025 are illustrated in Figure 1 below [10]:

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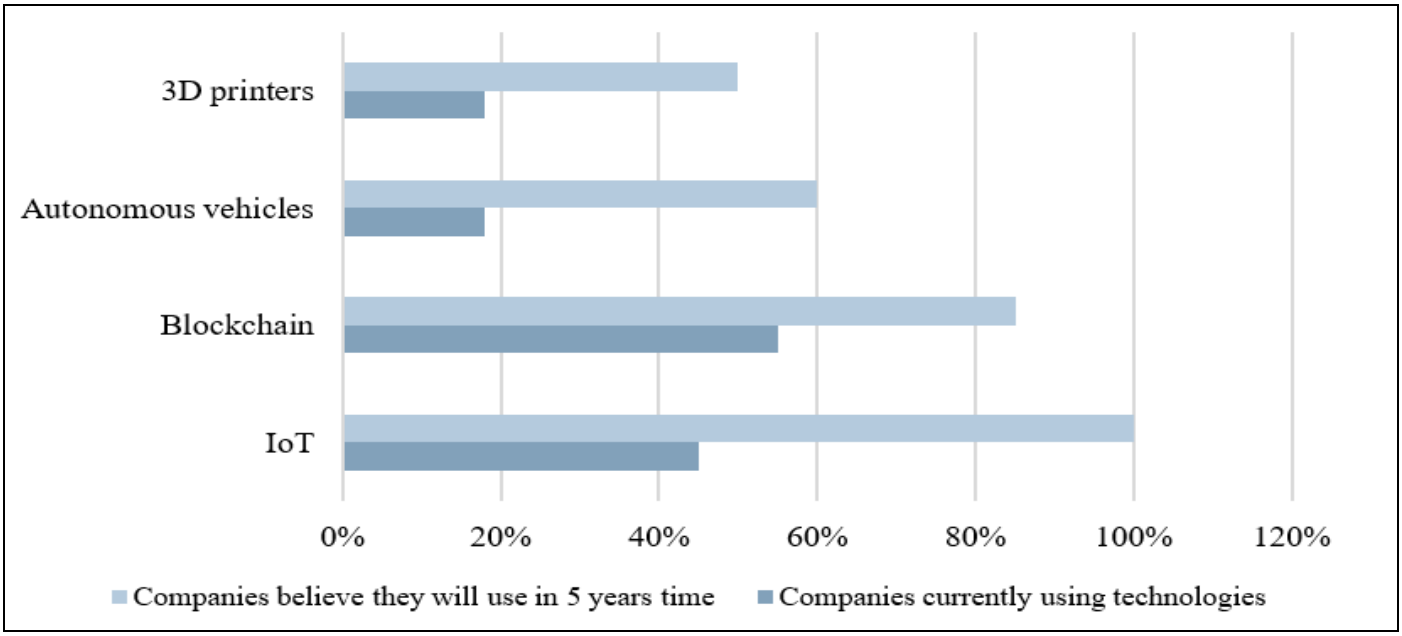

Fig 1 Utilisation levels of some 4IR Technologies for SC about Today and Future
Source: [10].

It is expected that not only the transformation levels of companies will rise, but also, that companies that have not yet decided to transform will make a transformation decision in the future as seen in Figure 1 above. Furthermore, the COVID-19 era underlined that the utilisation of 4IR technologies should be enhanced. According to the "Global COVID-19 Effects of Different Categories of Outbreaks in Turkey" report published by Deloitte (2020), companies need to focus on digital transformation implementations during the pandemic. This situation suggests that the technological infrastructure of companies and their SCs may be one of the crucial competitive tools in terms of recovery [11]. New trends will emerge in the SC as a new normal in the models to be built with digital transformation, and it will be necessary to make decisions on these matters.

Keeping up with the technologies enabled by the current era is not a necessity but an obligation for companies and SCs [12]. The positive effect of using 4IR technologies on SCs will be an incentive for companies to make digital transformation decisions. However, ensuring that the highest efficiency is obtained from these technologies allows superior SCPs to be achieved. The aim of this study is to determine the technologies commonly used together in supply chains by revealing the correlation relationships of the eight most prevalently used technologies in the SC context. Thanks to this study, companies will be aware of which technologies they will use together in their technology investments to achieve higher benefits. While the study enables that the contributions of 4IR technologies to SCs are enhanced in terms of managerial contributions, it has quantitatively revealed the relationships between these technologies in terms of theoretical contributions.

The remainder of this paper is designated as follows: Section 2 uncovered contributions of utilising single 4IR technology regarding prevailing literature. Section 3 investigated the correlations of 4IR technologies in the supply chain context. They were named as "*intertwined 4IR technologies*". Section 4 discusses the findings, and Section 5 outlines the most significant insights of this study.

II. SINGLE CONTRIBUTIONS OF 4IR TECHNOLOGIES

➢ *Cyber Physical Systems (CPSs)*

CPSs enable many contributions to SCs. In virtue of these technologies, SC operations can be traced in real-time. Moreover, they provide significant real-time, resource and cost contributions over conventional manufacturing systems [13]. They contribute to optimizing factories for continuous manufacturing by enabling zero downtime in manufacturing operations [14]. They also enhance SC visibility by raising transparency and traceability [15]. They improve processes by sharing real-time information in the SC [16]. Faults in manufacturing operations can be responded to quickly thanks to them.

CPSs ensure the SC processes are performed more intelligently [17]. They are technologies that enable smart factories to be realised [18]. Customization can be realised in manufacturing with them [19]. Use of CPSs enhances the safety of passengers in transportation activities, inside and outside the vehicle. They increase traffic efficiency by enabling decision-making based on current and historical data with their usage in autonomous vehicles. They make the vehicles safer for people with collision avoidance systems in vehicles [20, 21]. CPSs are technologies utilised not only in road traffic but also in air and sea traffic [22].

CPSs redefines "the nature of business partnerships, customer relationships, products and services, and economic markets". In this direction, they are technologies that offer new business opportunities [13]. These contributions are just

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some of the contributions of CPSs to SCs. The enhanced usage level of these systems has brought some threats to utilisers. The most significant implementation challenges of CPSs are information (data) security and control security issues. When designing these systems, it is also crucial to design a safe system in addition to designing an efficient system. Security problems in its various layers need to be analysed and risks assessed at the stage of implementing it [23]. The fact that they involve both physical and cyber processes increases the implementation challenges that must be considered. Moreover, devices connected to them can dynamically come together in different locations as they scope an ever-changing environment. Since this makes security protection to be conducted more complex, security is an issue that must be handled meticulously in these systems [24].

- *Internet of Things (IoT)*

Utilisation of IoT technology reduces inventory costs by ensuring that inventory counts are conducted efficiently in warehouses. It also reduces the accident risks in warehouses and enhances the efficiency of handling equipment [25]. The integration of IoT and CPS enables the construction of smart factories. These factories assist humans and machines in performing their tasks through information from the physical and virtual world. Smart factories should be built based on the internet of everything to connect things and humans, organize, and manage data and industrial processes [26, 27].

IoT in a SC context is described by Ben-Daya et al. (2019) as "a network of physical objects that are digitally connected to sense, monitor and interact within a company and between the company and its supply chain, enabling agility, visibility, tracking and information sharing to facilitate timely planning, control and coordination of the supply chain processes" (p. 4721) [28]. Therefore, the advantages of IoT to SCs include timely planning of processes in the SC, monitoring and visibility of the SC network, creation of more agile SCs, and enhancing control and coordination in the SC. Moreover, it contributes to lessening energy consumption and ensuring sustainability in the SC [29]. Thanks to the traceability and measurability it enables, it makes significant contributions to the improvement of SCP [30, 31].

- *Artificial intelligence (AI)*

AI has many implementation fields in the SC. It is utilised in activities such as stock control and management, demand planning and forecasting, transportation network design, purchasing, and order picking in SCM [32]. Nowadays, AI has become a significant issue and investments in AI-supported SC systems have continued to enhance. The reason for this is undoubtedly the contributions of this technology to SCs [32, 33]. AI technology enables delivery flexibility, the utilisation of autonomous vehicles, and warehouse automation in logistics and SC operations. It enables more efficient use of assets. In this sense, it has the effect of reducing costs. It can help solve problems in different ways. It also supports the creation of self-correcting SCs that are adaptable and responsive to altering conditions [34].

AI enhances the capabilities and productivity of human capital [35]. It guides the learning process of a product or service, recognizes user preferences, and enables specific recommendations. Moreover, it simplifies the use and purchasing of devices [36]. It facilitates the ability to reduce risk. In addition, it enables SC sustainability. Moreover, it is recognized as a significant analytical tool that enhances SCP [37]. It has the effect of enhancing efficiency in SC processes. The way of doing business has altered drastically with the utilisation of this technology in SCs. Intelligent path planning, distribution with robots, unmanned ground, and aerial vehicles (drones) are thrilling advances of this technology. It also enables superior service and experience to customers. Labor savings also reduce costs. It enhances the satisfaction and loyalty of customers [38]. AI can be used to analyse big data sources to support the decision-making process [39].

- *Autonomous Robots*

Autonomous robots have the potential to make up an unlimited workforce without additional costs in a business [40]. Furthermore, they enhance order accuracy by improving product stock control [41]. In addition, these robots lessen environmental effects. They reduce greenhouse gas emissions, carbon emissions and waste, and raise recycling and recovery rates [42]. However, there are also some negative social effects caused by using them. These are loss of employment at the business level, losses in job quality and polarization of qualification levels. In the context of the external environment of the business, they can cause some ethical problems, loss of socially valuable relationships or services, creation of hostile environments, and lessened accessibility and equality of opportunity [43].

- *Big Data Analytics (BDA)*

Blockchain creates a shared and reliable IS, the data can be used by everyone at every step [53]. In other words, the encryption of all new records added to the database of this technology eliminates the trust problem in commercial relations [54]. It has the potential to lessen corruption in purchasing processes through utilising smart contracts [55]. Blockchain is a technology with a high potential for use not only in financial markets but also in many industries and is expected to be at the centre of the new economic order [56]. The use of smart contracts automates SC processes, which lessens costs and saves time [57,58]. It reduces transaction speed in the SC and boosts collaboration among members [59]. Although blockchain brings many SC risks, it is also a technology that supports identifying and managing SC risks [60]. It enhances the durability and process integrity of SCs compared to traditional systems thanks to the usage of this technology. It enables real-time data monitoring in the SC. Moreover, operations are conducted accurately and on time without the need for human intervention. Blockchain accelerates processes by enabling integration over the internet. Furthermore, it ensures operations are performed at a lower cost [61]. Products can be monitored in the SC at the stages of manufacturing, transportation, and delivery by using a digital asset that can be converted into money, called a digital token. In this way, the value provided at each stage

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of the chain can be determined. Moreover, blockchain is a technology that improves resource utilisation efficiency [62].

➢ *Cloud Computing*

Cloud computing has caused crucial alterations in the fundamental structure of business processes and models [63]. Therefore, it is possible to say that it has caused significant changes in SCM. It also enables real-time access to data from any location and improves collaboration [64]. The utilisation of cloud computing technology provides independence, security, control, and planning contributions to businesses and their SCs [65]. Moreover, it has the effect of reducing costs, enhancing employee productivity, enabling better usage of time, and shortening production cycle time in SCs [66]. Cloud technologies can be dynamically reconfigured. In other words, they can be customized to meet the certain necessities of the company utilising it [67]. Therefore, cloud computing supports meeting future and often unpredictable computing needs over traditional ISs. The ability to deploy quickly is another contribution it offers [68]. Moreover, it can enhance the agility of companies and their SCs [69]. The fact that employees can access information technologies regardless of location brings flexibility. This is very crucial, especially for companies that have offices and employees in various parts of the world [70].

➢ *3D Printers*

Three-dimensional (3D) printer is a technology that makes significant contributions to both 4IR and SCs. High-performance and decentralized additive manufacturing systems shorten shipping distances and lessen on-hand inventory [71]. It enables an enhancement in the integration of design and manufacturing processes [72]. It is a technology that offers unlimited new configuration possibilities at points close to the customer [73]. It has the effect of reducing structural and managerial complexity in SCM [74]. It ensures that existing understandings and methods regarding logistics operations and inventory decisions are questioned, and inefficiencies are eliminated [75,76]. It boosts collaboration with both customers and companies [77]. The main challenges of 3D printing technology are the excessive costs, the need to manage the design and production team, the need to restructure the SC, the availability of printing materials, and the need for continuous customization and design [78].

➢ *Augmented Reality*

Augmented reality is a technology that improves processes in the SC, boosts operational efficiency and competitiveness, and contributes to SCs in many areas, especially in storage, production, sales, distribution, planning and design and human resources management. It reduces delays in receiving products in order-picking activities, increasing the productivity and efficiency of order pickers. Pressures on users are reduced in industrial order picking processes, errors are reduced, and productivity is enhanced with the integration of this technology [79]. It can play a role in manufacturing processes, maintenance activities, assembly processes, and on-the-job training of employees [80,81]. Critical assembly operations can be conducted more effectively with devices equipped with augmented reality technology, which will be made available to operators in factory environments. These assembly operations are performed by displaying virtual instructions in the operator's purview before the product is physically assembled. Unnecessary movements and time loss of employees are reduced, and necessary information is visualized simply by activating smart glasses on workstations. This enables the existing working system to be made faster and more flexible [82].

Augmented reality applications provide faster and easier access to information about freight optimization and delivery for logistics providers. Moreover, its applications support the definition of loads and the creation of delivery routes [83]. Smart glasses support activities along the whole value chain. When the contributions of augmented reality applications are investigated in general terms, the most fundamental contributions to SCs are an enhancement in operational efficiency, occupational safety, quality, fuel efficiency and a decrease in costs and errors [84, 85].

➢ *Virtual Reality*

The applications of virtual reality enable various contributions to the SC. They help customers make their purchasing decisions and provide a better customer experience with high-resolution 3D visuals and enable design and purchasing options by presenting a 3D visual for quotes, pricing, parts list, and components. They offer the opportunity to shorten the fulfilment cycle, increase integration, enhance sales, create additional sales opportunities, and boost revenue in the SC [86].

➢ *Autonomous Vehicles*

Considering that a huge portion of road traffic accidents, approximately 90%, are caused by human errors [87,88], autonomous vehicles will undoubtedly save lives by eliminating these errors [89]. Moreover, autonomous driving will ensure many crucial benefits such as reducing traffic congestion and many externalities, enhancing driving safety, shortening reaction times in traffic, lessening fuel consumption, and increasing efficiency in the transportation industry [90]. In terms of SCM, it has the effect of reducing delivery times, delivery costs, maintenance costs and operating costs, increasing load traceability, and facilitating the transportation of large loads [91]. It is a technology that can advance extant transport and logistics models [92]. Therefore, it has an improving effect on SCP.

➢ *Digital Twins*

Digital twin has many contributions to SCs like other 4IR technologies. Digital twin technology reduces energy costs, maintenance costs and time to market, as well as enhancing visibility and utiliser engagement [93]. It provides optimizing and testing “real-time” operations and locations of fleets, logistics units or inventory [94]. It allows insufficiently utilised or idle assets and bottlenecks to be identified. It also contributes to the reduction of pollution [95]. It helps prevent potential disruptions by predicting future impacts. This technology can be utilised for monitoring, planning, and controlling the SC [96]. The adaptation cost and time required for the high-priced physical

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commissioning step can be significantly reduced with the digital twin-based semi-physical commissioning [97]. It can enhance SC resilience by activating SC control towers [98].

- *Horizontal and Vertical Integrations*

Horizontal and vertical integrations are technologies that enhance integration in the SC and the sustainability of business operations, enable the attendance of employees in processes, make the SC more transparent, lessen uncertainty and reduce risk rates in the SC, enhance product quality, and reduce production, labour, and transaction costs [15, 99]. Moreover, they contribute to the efficient utilisation of resources and have a profitability-enhancing effect [100, 101].

- *Simulation*

Simulation tools are widely utilised in many industries [102]. The most significant contribution of the simulation is that it is a cheap, protected, and fast evaluation tool. Real-time simulation technology is utilised in many different industries today. It is a technology that assists the product design group and enables the progress and review of a variety of digital versions of the product [103].

- *Cybersecurity*

The implementation of cybersecurity technology enables 4IR and its technologies to reach their highest potential and ensures those who utilise this technology deal with data privacy and cybersecurity issues [104]. Undoubtedly, the security challenges faced by every 4IR technology are different. In this context, the security vulnerabilities of the technologies utilised should be investigated separately by the SC managers [105]. It should not be forgotten that the important level of losses encountered in SCs because of cyber-attacks is due to the lack of investment in cybersecurity technology or the insufficient level of these investments [106]. In other words, neglecting what to do about cybersecurity threats is the cause of future damage. Companies must adopt new procedures and policies to deal with these threats, and in doing so, they must consider the attackers' knowledge and skills, market demand, and corporate needs. In this regard, appropriate cybersecurity technologies should be implemented [107] and serious investments should be made in them [108].

- *5G*

5G is a technology that accelerates the pace of development of 4IR [109]. It requires an extremely high total data rate. It consents more information to be delivered more rapidly than 4G, thus impacting many aspects of SC operations. The utilisation of this technology reduces latency in SCs, enhances digital communication, boosts reliability, and enables significant improvements for SCs. Moreover, it enables enhanced effectiveness of IoT when utilised with IoT. In this way, manufacturing activities can be conducted in real-time with high accuracy and remote viewing [110, 111]. 5G can enhance efficiency, lessen costs, improve services, and have responsiveness in SCs, so it contributes to the improvement of core competitiveness [112].

III. METHODOLOGY

The effectiveness of 4IR technologies can be enhanced by benefiting from the combined utilisation of 4IR technologies [113, 114]. To determine intertwined technologies, the correlations of 4IR technologies were examined using the Using Disruptive Technology Scale (UDTS) develop by Özkanlısoy & Bulutlar (2022) [115]. While developing and validating this scale, initially sixteen 4IR technologies utilised in SCs were considered. Afterwards, the eight most used technologies in SCs were designated by considering the factor loading values and various validity types among them. The final form of the scale consists of CPS, IoT, AI, autonomous robots, BDA, blockchain, simulation and 5G technologies.

The sample size of the study consists of 393 companies. Research population of the study consisted of national and international companies operating in Turkey between June 1, 2023, and January 31, 2024. Before the research process began, the necessary permissions were obtained from the relevant institutions and data collection was carried out by the researcher herself. The questionnaires were distributed face-to-face and through e-mail, and it was stated that the study was voluntary. In the study, six industries, namely retail and FMCG, manufacturing, e-trade, transportation, distribution and warehousing, service, and import-export, were discussed and implemented to companies operating in those industries by convenience sampling method. The correlation between technologies was investigated by utilising the SPSS package program. Twenty-eight combinations of 4IR technologies were obtained with the inter-item correlation of eight 4IR technologies, and six intertwined 4IR technologies were determined by considering those with correlation values above 0.50. The 4IR technologies and their interitem correlations are illustrated in Table 1 below:

Table 1 Correlations between 4IR Technologies

4IR Technologies	**r**
AI-BDA	0.601
BDA-Simulation	0.551
CPS-IoT	0.551
IoT-AI	0.529
IoT-BDA	0.524
AI-Autonomous Robots	0.513

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Pearson correlation coefficient was used to determine the correlation levels. As the value of "*correlation coefficient between 0.36 to 0.67 indicates a moderate or modest correlation*" [116], it is possible to say that there is a moderate or modest correlation between all the 4IR technologies mentioned above. The reason why 0.50 is taken as the lower limit of the correlation coefficient was that it can reveal technologies that have more relationships with each other. As seen in the table above, IoT, BDA, and AI are technologies that are used more together with other 4IR technologies.

IoT technology is widely utilised together with CPS, BDA, and AI technologies according to the findings of this study. BDA technology is widely utilised with IoT, AI and simulation technologies. AI technology is widely utilised with IoT, autonomous robots and BDA technologies. The combined utilisation of AI and BDA technologies is higher than the combined utilisation of other 4IR technologies (r=0.601). This combination is followed by the combined usage of BDA and simulation technologies (r=0.551), and the combined utilisation of CPS and IoT technologies (r=0.551).

IV. DISCUSSION

Just as with the utilisation of 4IR technologies together with information technologies, their usage with other 4IR technologies enhances their effectiveness and therefore their contribution to SCs [113, 114]. Therefore, it is necessary to research and implement intertwined 4IR technologies to derive the maximum benefit from them. SC managers and, if applicable, digital transformation leaders working in companies have significant responsibilities at this point. This study is a guide for companies and their supply chains in terms of providing information on the combinations of 4IR technologies.

Due to the increasing growth of information, supply chains have rapidly moved into the era of big data. Its large volume, high variety and fast speed characteristics have caused the traditional data mining method to become inadequate [117]. BDA is a technology that allows different types of data to be distributed and analyzed more quickly [118]. BDA has three main utilisation fields: assessing and managing potential risks, implementing predictive security performance, and enabling information and services to clients. It can be utilised in sales and marketing activities in the SC, product development and optimization of the digital experience [119]. BDA is prevalently used together with other 4IR technologies. This study has revealed that BDA technology is extensively utilised with AI, simulation and IoT technologies.

The combined utilisation of BDA and AI technologies is a hot topic today, frequently discussed by both academic and professional circles [120, 121]. The combination of big data tools and AI techniques is boosting the contributions of these technologies to the SC. While BDA leverages AI for better data analysis, AI technology requires big data to improve decision-making processes., AI technology can help overcome bottlenecks in collecting and storing large amounts of data at the data management stage. It helps address uncertainty and complexity in decision management [117]. BDA takes data inputs, processes them into queries, and sends them to AI-based engines. This improves performance in the process and enables real-time decision making [122]. AI reduces the time required to perform BDA. Repetitive tasks can be done with the help of machine intelligence. Reducing error and increasing the degree of precision is another advantage of AI-powered BDA. Machine learning-based mechanisms focus on improving the accuracy of BDA. Accordingly, AI techniques ensure more precise, quicker and scalable results in big data analysis [123]. Moreover, the use of BDA with AI techniques provides cost reduction, easier development of novel products and services, and a better comprehending of current market conditions [124]. IoT integration with BDA is another example of intertwined 4IR technologies. BDA can use the data produced in IoT technology to make it usable, processable, and interpretable, thus facilitating the operations of the smart warehouse [125]. BDA implementations are influentially interdependent with IoT and CPS implementations [126].

Simulation is a crucial technology for testing and predicting alternative scenarios in SCs, understanding the behavior of complex systems, determining specific performance metrics, or simply discovering new knowledge from raw data by simulating logistics flows. They can serve as proactive decision support systems in SCs [127]. The use of simulation technology with BDA offers it the opportunity to obtain and evaluate data to a degree that it has not been able to achieve until now [128]. Accordingly, this technology integration enables the relevant processes to be covered in detail. Simulations performed with big data are more efficient than others. Furthermore, the combination of these technologies ensures simulations to be performed quicker in SCs [127]. When these they are utilised together, tests can be checked and repeated by more than one person, making it easier to find performance bottlenecks in the SC [129].

IoT system has a connectionless data management that speeds up the supervision of processes. Moreover, it enables the data to be converted into information that will put the CPSs into action [130]. The integration of IoT and CPS enables the construction of smart factories. These factories assist humans and machines in performing their tasks through information from the physical and virtual world. Smart factories should be built based on the internet of everything to connect things and humans, organize, and manage data and industrial processes [26, 27]. With the emergence of AI technology, there has been an intense interest in automatic sensing and cognition, and the decrease in the costs of sensors and processors has accelerated the development of autonomous robots and systems [131].

Other intertwined 4IR technology examples are AI and IoT. AI enables IoT to realize its highest potential. It has transformed IoT into an intelligent entity that can act decisively based on historical data and events [132]. The integration of these technologies enables IoT to achieve more advanced control features and exhibit autonomous behavior. Additionally, it provides new functionality to IoT architecture. To illustrate, it can create cognitive IoT that utilises cognitive

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AI to apply senses and make decisions based on them [133]. The use of AI techniques is one of the popular solutions to prevent IoT from being disrupted and compromised, which is why these technologies are widely utilised together [134].

This study investigated the correlations between 4IR technologies and revealed which technologies are utilised more together, and these technology combinations were named intertwined 4IR technologies. Correlation levels of 0.50 and above among 28 technology combinations were considered to make a clearer distinction, and 6 intertwined technologies were determined accordingly. The 4IR technologies most utilised together are AI and BDA regarding the industries covered in the study (r=0.601). That is followed by the combined utilisation of BDA and simulation technologies (r = 0.551) and the combined utilisation of CPS and IoT technologies (r = 0.551). When intertwined technologies are examined on a technology basis, it is obvious that the 4IR technologies with which IoT technology is most widely used are CPS, AI, and BDA, respectively. BDA technology is mostly utilised together with AI, simulation and IoT, respectively. Furthermore, AI technology is mostly utilised together with BDA, IoT and autonomous robots, respectively. Additionally, the 4IR technology with which CPS is most widely utilised is IoT. Overall, it is obvious that the findings of this study are compatible with the extant literature, when the combinations of the above technologies are examined.

Thanks to this study, companies will be aware of which technologies they will utilise together in their technology investments to achieve higher benefits. While the study has provided that the contributions of 4IR technologies to SCs are enhanced in terms of managerial contributions, it has quantitatively revealed the relationships between them in terms of theoretical contributions.

V. LIMITATIONS AND FUTURE RESEARCH

The limitation of this study is that it included only eight intertwined technologies among the 4IR technologies. These technologies are prevalently utilised within the SC [115]. However, the examples of intertwined 4IR technologies discussed in this study can be enhanced. There are various examples in the prevailing literature.

The autonomous robots take data from IoT technology and convert it into physical movement [135]. Digital twin technology enables data acquisition and real-time viewing when used with IoT and 5G technologies [136,137]. Furthermore, digital twins enable complex tasks to be performed more effectively when used with 4IR technologies such as AI, BDA, IoT and cloud computing [93]. Simulation technology, when used with 3D printers, ensures that the final product has the optimum form and can be produced. Using simulation with digital twins contributes to ensuring optimum efficiency, predicting malfunctions, and providing significant product information [103]. Utilisation of cybersecurity provides those using 4IR technologies to tackle data privacy and cybersecurity issues and allows 4IR technologies to reach their highest potential [104]. 5G technology can communicate with the IoT, cloud computing and autonomous robots; what is more, it is utilised with augmented reality and virtual reality technologies [138]. 5G enables new possibilities for AI technology implementations in SCs [139]. Future research can investigate the intertwined technologies by including 4IR technologies that were not included in the scope of the study.

VI. CONCLUSION

Some approaches and indicators should be pursued today to comprehend the SCs of the future [140]. In other words, keeping up with the technologies enabled by the current era is not a necessity but an obligation for companies and SCs [12]. The utilisation of 4IR technologies and the digital transformation of SCs is a pivotal step today towards being able to follow the SCs of the future. However, another critical issue is not only to put these technologies into practice but also to get the most benefit from them. This study investigated the correlational relationships of the eight most used 4IR technologies in the SC context and designated the technologies with the highest relationship with each other and called them as intertwined 4IR technologies. The study is a guide for companies and SCs that will implement 4IR technologies or invest in a new one.

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