Industry 4.0 in Supply Chain

Subjects: Transportation Science & Technology | Management | Operations Research & Management Science
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Industry 4.0 is better known as the fourth industrial revolution and describes a future production system's vision. In 2011, the idea of Industry 4.0 was first given and implemented by the German government for supporting automation in manufacturing. The fourth industrial revolution (Industry 4.0) focuses on enabling automation to integrate all manufacturing industries' systems to achieve sustainability. There are many disruptive technologies such as the Internet of things (IoT). This means that all the devices, machines, and processes in supply chains are digitally connected through an internet connection and share the real-time information of all the processes. The Internet of things (IoT) integrates different technologies such as sensors, networks, algorithms, and applications. The IoT enables businesses to improve their supply chain network and gain better productivity. Cyber–physical system (C.P.S.) is another fundamental technology of industry 4.0. C.P.S. can be implemented in many industries such as healthcare, logistics, and automobiles. From an operational view, logistics is the critical function of any business that engages the supply chain movements. A cyber-physical system allows the supply chain network to use networking, computation, and physical processes to add value in the production process to achieve competitiveness. Another concept of Industry 4.0 concerns automatic guided vehicles (A.G.V.), which are widely used by many companies.

supply chain sustainability | supply chain 4.0 | Industry 4.0 | Internet of things | automatic vehicles | drones | cyber–physical system | smart factory

1. Introduction

There are very few research studies available that explain Industry 4.0 technologies' impact on manufacturing companies' supply chain and Industry 4.0 technologies' role in achieving supply chain sustainability. To cover this research gap, the current study is conducted. The main goal of this paper is to review the literature regarding the Industry 4.0 technologies, their roles, and their uses in the supply chain. For this purpose, the literature review was conducted and 55 articles were selected according to the defined criteria and systematic literature review (SLR) methodology adopted. Another goal of this study is to combine and integrate the Industry 4.0 technologies with the supply chain process and develop a framework that shows the role of Industry 4.0 technologies and their impacts on the supply chain process to achieve sustainability. By developing a conceptual framework, this paper helps decision-makers, top-management, policy-makers, and managers to make the right decision for the adoption of the right Industry 4.0 technology for specific supply chain processes. Moreover, this review can be useful for other studies in various areas of the supply chain by defining how Industry 4.0 technologies are evolving in the SC process since the last decade. Furthermore, this paper, to the authors' best knowledge, is the first paper that

highlights these issues and integrates the role of different Industry 4.0 technologies in various steps of the supply chain.

2. Review Discussion and Findings

2.1. Demographics

2.1.1. Contribution by Publishers

In this stage, contributions made by different publishers were identified. It can be seen from **Figure 1** that Elsevier is at the top, with the maximum number of publications of 39 papers. IEEE stands at the second highest with 12 papers and other papers are published by MDPI and InderScience.

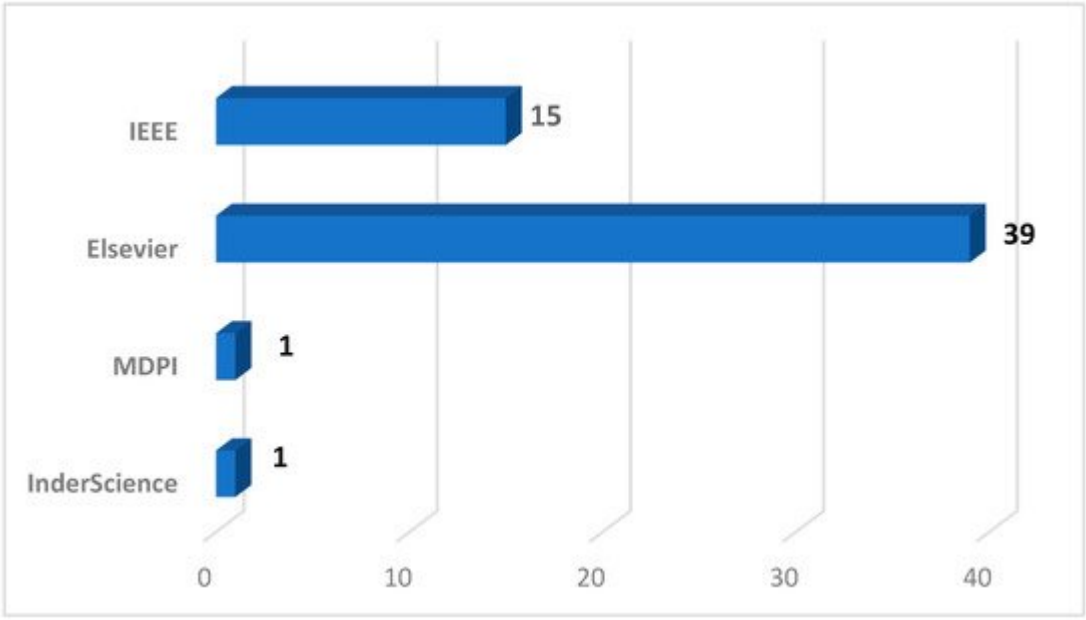

Figure 1. Contributions by publishers (source: author).

2.1.2. Contribution by Journal

There are different sources used for the data collection. **Table 1** explains the sources that were used for finding and selecting papers related to Industry 4.0, its technologies, and supply chain sustainability.

Table 1. Sources of the selected articles.

Journal	Number	Impact Factor
International Journal of Production Economics	13	5.1
IEEE Access	7	3.7
Transportation Research Part E IEEE Access	5	4.6

Journal	Number	Impact Factor
Journal of Industrial Information Integration	5	10.6
Journal of Purchasing and Supply Management	4	3.3
Journal of Business Research	4	4.8
Transportation Research Part D	3	4.0
Journal of Cleaner Production	2	7.2
Technology in Society	2	2.4
Energy and Built Environment	1	2.2
International Journal of Integrated Supply Chain	1	1.7
Sustainability	1	2.5
Technological Forecasting & Social Change	1	5.8
Journal of Building Engineering	1	3.3
Computers and Industrial Engineering	1	4.1
Resources, Conservation & Recycling	1	7.5
International Business Review	1	3.9
IEEE Transactions on Engineering Management	1	2.0
IEEE Transactions on Industrial Informatics	1	8.4
Total	55	

2.1.3. Contribution by Top Author’s

The top ten authors that contributed most to the field of Industry 4.0 and supply chain sustainability are shown in **Table 2**.

Table 2. Top ten authors’ contributions.

Authors (Year)	Author’s Affiliation	Citations
Yang Lu (2017)	University of Kentucky, Lexington, USAUniversity of Manchester, UK	1383
Chen et al. (2017)	School of Mechanical and Automotive Engineering, South China University of Technology, China	439
Frank et al.	Organizational Engineering Group (Núcleo de Engenharia Organizational,	418

Authors (Year)	Author's Affiliation	Citations
(2019)	NEO), Department of Industrial Engineering, Brazil	
Dalenogare et al. (2018)	Organizational Engineering Group (Núcleo de Engenharia Organizacional, NEO), Department of Industrial Engineering, Universidad, Brazil	395
Chen et al. (2017)	China-Europe International Business School (CEIBS), China	208
Manavalan et al. (2019)	School of Mechanical Engineering, VIT University, Vellore, India	162
Mani et al. (2018)	Montpellier Business School, 2300, Avenue des Moulins, France	148
Goodchild et al. (2018)	Department of Civil and Environmental Engineering, University of Washington, Seattle, USA	143
Hansong Xu et al. (2018)	Department of Computer and Information Sciences, Towson University, Towson, USA	142
Bechtsis et al. (2017)	Laboratory of Statistics and Quantitative Analysis Methods, Department of Mechanical Engineering, Aristotle University of Thessaloniki, P.O. Box 461, 54124, Thessaloniki, Greece	110

2.1.4. Contribution by Country

Figure 2 illustrates that China, the UK, and India are the countries that have the highest contribution in this field based on the number of papers.

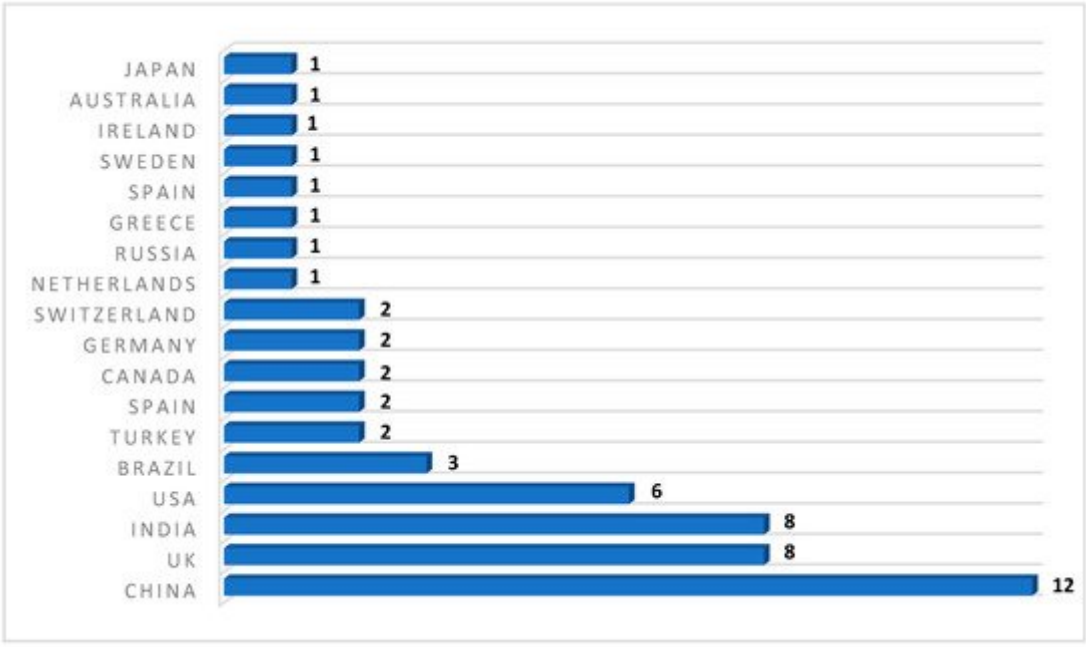

Figure 2. Country-wise publication details (source: author).

2.1.5. Year-Wise Publications

This section provides a review of the selected articles by publication years. It can be seen in **Figure 3** that there is a massive increase in the number of articles in the last few years because Industry 4.0 technologies such as the CPS, the IoT, the sSmart factory, drones, and AGV, as well as supply chain sustainability, have become the key subject areas for both researchers and academicians.

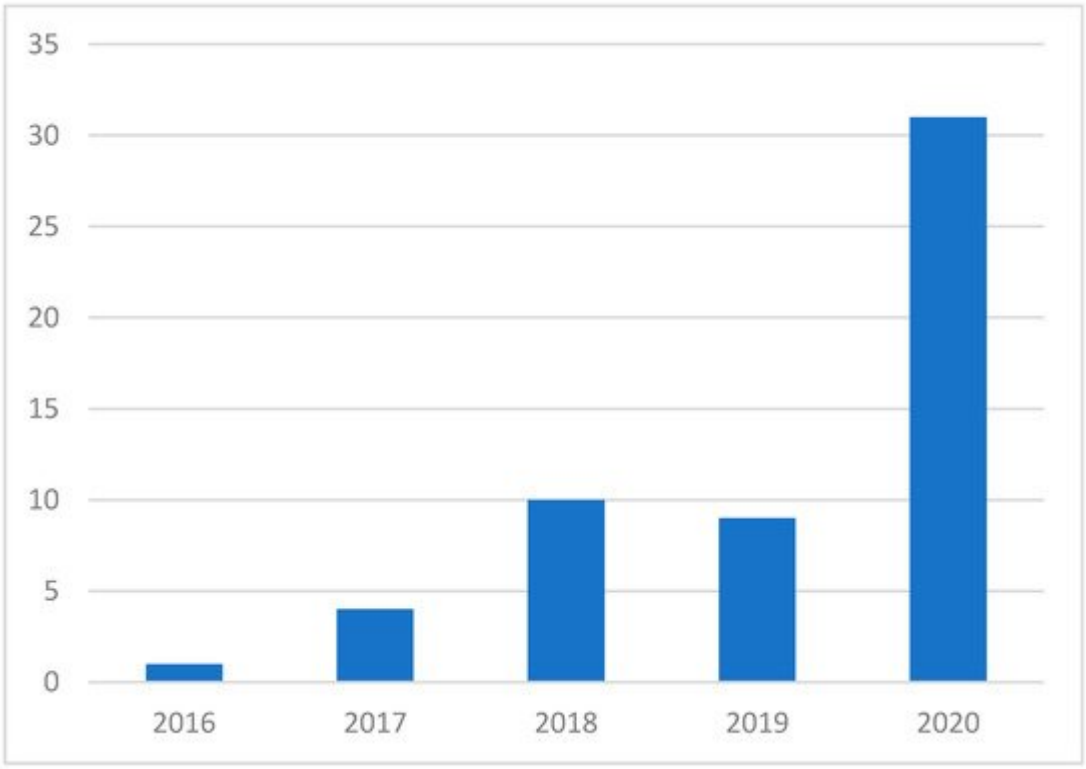

Figure 3. Year-wise publication data (source: author).

2.2. Taxonomy

This work studied two terms, namely Industry 4.0 and SCS. For Industry 4.0, we alienated Industry 4.0 into five technologies that are AGV, the IoT, the CPS, drones, and SF. Moreover, supply chain 4.0 includes SCS. In **Table 3**, the detailed comparison of each research article has been done according to their research focus, research methods, and results.

Table 3. Comparison of classified articles based on their focus, methods, and results.

References	Industry 4.0					SSC	Focus	Research Method	Results
	AGV	IoT	Drone	CPS	SF				
[1]	√	√	√	√	√	√	Study the role of lean and GSCM in the Industry 4.0 paradigm to achieve	Literature review methodology was used to fulfill the aim of the study.	Based on literature, a conceptual model was introduced that links lean and GSCM

References	Industry 4.0				SSC		Focus	Research Method	Results
	AGV	IoT	Drone	CPS	SF				
							competitiveness in SC network.		characteristics with Industry 4.0.
[2]		√			√	√	Address the impact of the IoT on purchasing and supply chain sustainability, and also remove the tensions associated with the IoT.	Used systematic inductive research approach.	Provided a framework that reduces the tensions associated with the IoT emergence in PSM.
[3]	√	√	√	√			Aims to check to what extend internal logistics equipment is capable of working in the Industry 4.0 CPS system.	Design science research (DSR) methodology was used and execution was divided into three steps; relevance, rigor, and design.	Proposed the methods to check the adherence of internal logistics equipment with CPS in Industry 4.0, having a measurement error lower than 1.3%.
[4]	√	√		√			Analyze the risks and security issues associated with the AGV in SC and check how Blockchain overcomes these issue.	A systematic literature review approach was adopted.	Presented a systematic literature review on existing AGV security issues and their countermeasures. In addition, explained how the blockchain linked with AGV in SC to minimize these security issues.
[5]	√	√	√		√	√	The focus was integrating the automatic guided vehicle (AGV) with supply chain sustainability by following the systematic way adopted from the literature review.	A taxonomy approach was adopted for the literature review. The methodological approach is divided into two steps; literature identification and decision-making framework development.	Based on the literature, presented sustainable supply chain cube (SSC2) which helps to integrate the SSC with AGV, and also discussed how AGV contributes to achieving economic,

References	Industry 4.0					SSC	Focus	Research Method	Results
	AGV	IoT	Drone	CPS	SF				
									environmental, and social sustainability.
[6]		√	√	√	√	√		The study aimed to combine the diverse perspectives and findings of the smart factory in Industry 4.0 based on a literature review to develop a research model for SF.	This study adopted a systematic literature review and applied research methodology.	Based on the literature review, qualitative content analysis and qualitative coding approach; a research model for the smart factory was introduced with eight key technologies as a factor.
[7]		√	√	√	√	√	√	Aimed to find the key enablers of industry 4.0 that drives the supply chain sustainability.	Systematic literature review methodology was used in the field of Industry 4.0 and SSC.	Through the literature review, this study finds 13 enablers of Industry 4.0 that impact the sustainability of the supply chain.
[8]		√	√	√	√	√	√	Examined and reviewed the literature based on Industry 4.0, sustainability in the supply chain, and big data.	This study used bibliometric and used network analysis techniques within the literature review approach	Reviewed the literature since 2009, including their similarities and differences, and six research categories were proposed.
[9]		√	√				√	The target was to give an overview of barriers and issues associated with AGV adoption.	Employed a mixed research methodology to fulfill the objectives of this study.	A framework was proposed that explains the issues and barriers for AGV in the company and helps future researchers to find the best suitable solution to overcome these barriers.
[10]		√		√		√		The focus was on highlighting the factors that resist the adoption of automatic guided	Used mixed research methods that includes a literature review	Findings include four main factors that include contractor side, client-side,

References	Industry 4.0					SSC	Focus	Research Method	Results
	AGV	IoT	Drone	CPS	SF				
							vehicles and robotics in the construction industry.	and qualitative and quantitative data analysis.	technical, and work-culture economic factors.
[11]	√	√	√	√	√	√	The purpose was to give an overview of the role of logistics management practices in Industry 4.0.	A qualitative research methodology was adopted for this study.	This study proposed research questions for further studies. It also discussed the technologies of Industry 4.0 and their impacts on logistics effectiveness.
[12]	√	√	√	√	√	√	Aimed to check the effect of new industrial technologies in Industry 4.0 on logistics centers.	The literature review and fuzzy multi-criteria decision-making methodology were used.	Proposed the research model for new logistics centers and gave the strategy map which is helpful for other industries and researchers.
[13]	√	√	√	√	√	√	The purpose of this study was to link the technologies of Industry 4.0 with the industries to explain their side effects.	Secondary data analysis was done on data collected from questionnaires.	This study explained the expected benefits of the adoption of Industry 4.0 technologies by proposing a framework.
[14]			√		√	√	Aimed to check whether drone delivery in the industry will contribute to achieving sustainability by reducing CO2 emission.	Comparative analysis was used and models were developed for each scenario.	Results show that drone delivery plays a positive role in overcome carbon emissions.
[15]							The purpose was to establish an IoT-based logistics dispatching system to	IoT technology, a dynamic multi-objective method, and control theory	Developed an intelligent dispatching system that will further help researchers and industries to

References	Industry 4.0				SSC	Focus	Research Method	Results
	AGV	IoT	Drone	CPS	SF			
						integrate robotics and customers.	were adopted in this study.	understand the need for this system.
[16]	√		√		√	The purpose of this study was to examine the benefits and challenges associated with the HFW logistics system.	This study used a multi-objective mathematical model and a comparative analysis was used to justify the validity of the system.	The results of this paper explained the risks and benefits of a humanitarian flying warehouse system by analyzing the case studies. Helps researchers to further investigate the efficacy of this system.
[17]	√		√			Aimed to check the adoption of UAVs in sub-Saharan Africa by reviewing existing literature	A systematic literature review approach was adopted to perform this study.	The result shows that UAV adoption in the sub-region is still in the early-stage and the industry is more concerned from social and technical perspectives.
[18]	√		√		√	The purpose of this study was to examine the pros and cons of automatic guided vehicles, both on the ground and in the air, used for delivery services to reduce carbon emissions.	Modeling techniques were adopted to measure the defined variables.	Results show that these technologies have more benefits than risks in reducing the CO_2 emissions in the industry.
[19]			√	√	√	The purpose of this study was to do a comparison between truck-based and drone-based delivery systems.	The modeling technique was used to develop an energy consumption model for the drone.	Results show that the use of only a drone-based parcel system is not acceptable at all and companies must move to mix modes of transport.
[20]		√			√	The concept of this paper was to	Research review methodology	This paper contributes by

References	Industry 4.0				SSC		Focus	Research Method	Results
	AGV	IoT	Drone	CPS	SF				
							give a detailed review of the IoT in Industry 4.0 and discuss its impact on SSC.	was used in this paper.	combining their findings in developing a framework for the IoT that drives a company to achieve SSC.
[21]		√	√		√	√	The purpose of the study was to provide knowledge about blockchains in Industry 4.0 and discuss its importance in supply chain sustainability.	A four-step literature review method was used in this study.	This study reveals the research gaps based on literature and gave five research directions for further research.
[22]		√	√	√	√	√	The aim was to find the solution to the challenges related to SSC adoption in the industry in the context of Industry 4.0 and the circular economy.	The literature review approach and hybrid BWM-ELECTRE approach were used to test the case.	Key findings of this study include a framework that helps to resolve 28 SSCM challenges by defining 22 solutions based on the literature review.
[23]		√	√	√	√	√	The goal of the study was to connect Industry 4.0 with a sustainable supply chain in sustainable food manufacturing.	A qualitative research methodology along with a literature review approach was used.	Proposed the framework that would be helpful to achieve sustainability in the food manufacturing industry.
[24]		√	√	√	√	√	The idea of this study was to examine digital technologies (Industry 4.0) and their effects on the construction industry	A systematic literature review approach was adopted in this study.	Developed the framework on the CPS system that integrates the Industry 4.0 technologies and helps to boost the construction industry.

References	Industry 4.0					SSC	Focus	Research Method	Results
	AGV	IoT	Drone	CPS	SF				
[25]	√	√	√	√	√	√	This study was conducted to check the challenges, benefits, and issues related to Industry 4.0 and sustainability in SCM.	The bibliometric performance and network analysis (BPNA) were used to perform this study.	Key findings of this research were involved in defining 12 research clusters and the network structure of each cluster was tested. It also explained the challenges and issues that occur during the integration process of Industry 4.0 and sustainability.
[26]		√		√	√	√	The aim was to integrate the physical factory with the digital factory to build a smart factory in-ear of digitalization.	Qualitative research methods and case applications were used to complete the purpose of the study.	This study proposed the hierarchal structure of a smart factory and gave details of each layer that exists in a smart factory.
[27]		√		√			The purpose of the study includes the IoT-related threats and security issues in both the public and private sector.	Literature review methodology was adopted in this study.	Results explained the threats associated with the IoT and gave the countermeasures to overcome these threats.
[28]		√		√			The aim was to outline the properties of the industrial IoT system and its applications in the context of CPS.	Literature review methodology was used to conduct this study.	Proposed the three-dimensional framework to fix the problems associated with the industrial IoT and explained issues and challenges for future research.
[29]	√	√	√	√	√	√	The goal was to redesign the business model in the context of Industry 4.0.	A review of 32 case studies collected from literature was	This paper created an integrated BM design for Industry 4.0 that will be useful for

References	Industry 4.0					SSC	Focus	Research Method	Results
	AGV	IoT	Drone	CPS	SF				
								used as a methodology.	businesses and future studies.
[30]	√	√	√	√	√	√	The purpose of this study was to involve a knowledge management approach in Industry 4.0 to achieve digitization in the supply chain.	Content analysis and statistical analysis were adopted in this study.	The framework was developed to show how supply chain management and knowledge management integration achieves digitization.
[31]		√				√	This paper emphasized the role of the IoT and business models by assessing the literature review.	Systematic literature review methodology was used.	Developed the systematic connection between the IoT and business model by proposing a framework extracted from literature.
[32]	√	√	√	√	√	√	The purpose of this study was to extend the understanding and the current knowledge on Industry 4.0 specifically in the plastic industry.	This study adopted bibliometric analysis in the context of the literature review.	This paper provided integrated knowledge of Industry 4.0 resulting from the bibliometric analysis.
[33]	√	√	√	√	√	√	The idea of this study was to check the impact of digital technologies on economic and environmental performance in the context of supply chain	The qualitative research methodology was used in this study.	The study finds that these digital technologies have a positive impact on economic and environmental performance based on data collected from Chinese enterprises.
[34]	√	√	√	√	√	√	The goal of the study was to check the influence of Industry 4.0 on	Bibliometric analysis was used in this study.	Results show that each technology has its benefits and issues after implementing these

References	Industry 4.0					SSC	Focus	Research Method	Results
	AGV	IoT	Drone	CPS	SF				
							the maritime industry.		digital technologies in the maritime industry.
[35]				√		√	The purpose of the study was to enhance the efficiency of the scheduling process in smart manufacturing.		Proposed the scheduling system based on real-time data available in CPS; this system is better used for the decision-making process.
[36]	√	√	√	√	√		The study aimed to check how fast companies adopt Industry 4.0 technology and under what conditions.	A cross-sectional survey was done to perform this study.	Proposed the framework explaining the layers of Industry 4.0 technologies and conditions for the adoption of these technologies.
[37]	√	√	√	√	√		The purpose was to integrate the concepts of Industry 4.0 to make a single presentable definition and scope of Industry 4.0.	This study adopted a systematic literature review approach.	Explained the series of definitions related to Industry 4.0 and created a more scientific definition of Industry 4.0.
[38]	√	√	√	√	√		The goal was to check the knowledge of Industry 4.0 based on experience and seniority levels in the pharmaceutical industry.	The qualitative research methodology was adopted by this study.	This study concludes that having more experience in the industry led to more knowledge of Industry 4.0. to implement Industry 4.0 in the industry. They also state that it is better to have a clear understanding of Industry 4.0 with peers of organization.
[39]				√		√	The purpose of this paper was to	The qualitative research	Proposed a model that explains the

References	Industry 4.0					SSC	Focus	Research Method	Results
	AGV	IoT	Drone	CPS	SF				
							check how addictive manufacturing modifies the industrial production system in the context of globalization.	methodology was adopted in this study	effect of additive manufacturing on different industry sectors. These findings can also be helpful for future studies.
[40]	√	√	√	√	√	√	The goal of the study was to check the issues and barriers related to implementing Industry 4.0 technologies in the manufacturing sector	The Grey Decision-Making Trial and Evaluation Laboratory (DEMATEL) approach was adopted to analyze results.	The results of this study are helpful for decision-makers and policymakers to educate the industrial sector so that they may adopt these technologies to enhance their productivity.
[41]	√	√	√	√	√	√	The goal was to examine the role of Industry 4.0 in small and medium enterprises to add value creation.	This study adopted case study analysis and a qualitative research methodology.	Results explained that the adoption of 4.0 technologies in SMEs requires more resources and each technology has its conditions for adoption. It is a necessity to adopt the right technology at the right time.
[42]	√	√	√	√	√		The study aimed to check the socio-technical role of Industry 4.0 in the industrial sector.	A systematic literature review was used for this study.	Proposed an integrated framework that includes both human and non-human involvement in Industry 4.0 technologies.
[43]		√		√			The focus of the study was to give brief insights into Industry 4.0 technologies and their scope based	The two-state approach for literature review was used in this study.	A framework was proposed that explains the four major key technologies of Industry 4.0 and

References	Industry 4.0					SSC	Focus	Research Method	Results
	AGV	IoT	Drone	CPS	SF				
							on previous studies.		their applications in the industrial sector.
[44]						√	The purpose was to investigate how sustainability can be achieved in the fashion industry by applying the system of system theory.	The multi-methodological research approach was adopted by this study.	A framework and action matrix were developed to achieve sustainability in the fashion industry and check its applications in real cases.
[45]						√	The focus was to integrate the production and transport system of the supply chain to achieve sustainability in the environment and production system	The multi-stage optimization and simulation methodology was used to develop the methodological model.	Proposed the methodological framework related to the optimization of production and transport systems based on computer simulations.
[46]	√	√	√	√	√	√	The paper emphasizes enabling sustainability into the industry in the new technological world (Industry 4.0).	AI, machine learning, and the expert system were used in this study.	An integrated framework was proposed by combining sustainability and Industry 4.0. Practical implications were shown through an example.
[47]	√	√	√	√	√	√	The concept of this study was to check how the adoption of Industry 4.0 technologies leads to achieving society's sustainability.	Multiple methodologies such as HFS, CPT, and VIKOR were used.	The key finding of this paper was to develop a framework that explains the Industry 4.0 key technologies with respect to sustainability.
[48]						√	The purpose of the study was to analyze the role	Integrated ISM and the fuzzy DEMATEL	The ten key enablers were defined, which can

References	Industry 4.0				SSC		Focus	Research Method	Results
	AGV	IoT	Drone	CPS	SF				
							of the key enablers of sustainability in the agriculture and food sector.	research methodology were used.	be used to achieve supply chain sustainability in A-FSCs.
[49]					√	√	This study's focus was to check which type of sustainability (social, environmental, and economic) approach has a greater impact on firm performance.	Literature review methodology and Psychometric meta-analysis were adopted.	The results of the study revealed that adopting social and environmental sustainability practices in any type of the industry, it will led to an increase in firm financial and operational performance.
[50]					√	√	The goal of the study was to check how intermediates in the supply chain system resolve the buyer and suppliers' problems when there is a lack of sustainability.	The qualitative research methodology was used and IRR was adopted to perform the reliability analysis.	Results explained that intermediates play a positive role in the built connection between buyer and supplier and help both parties to achieve sustainability.
[51]						√	The goal was to find the social issues regarding suppliers and find the enablers that can resolve these issues by achieving social sustainability in SC.	Qualitative research methods and structural equation modeling were used.	The results revealed 18 different supplier social sustainability measures that underline five dimensions.
[52]	√	√	√	√	√	√	The aim was to check how computers technologies (AI) influence the production and resources of a	This paper adopted a systematic literature review approach.	Proposed a framework of AI-based on literature and explained the factor that led the company to achieve sustainability in the

References	Industry 4.0				SSC	Focus	Research Method	Results
	AGV	IoT	Drone	CPS	SF			
						company to achieve SCS.		supply chain system.
[53]					√	The purpose of this study was to check the effect of supply chain collaboration on supply chain performance to achieve sustainability.	This study was performed by using a literature review methodology.	This study reveals that supply chain collaboration has a positive effect on supply chain performance by proposing a framework based on literature.

Duarte et al. [1] explained the relationship between lean and GSCM to smoothen the physical production process. For the virtual flow of information and data, they linked lean and GSCM with Industry 4.0, and companies can achieve a competitive advantage if they understand their characteristics. Further research can also be done to check which characteristics have more influence to achieve sustainability in the supply chain. Legenvre et al. [2] proposed a framework by using a systematic inductive research approach to remove the issues that are associated with purchasing and the supply chain management function while installing IoT systems. They concluded that the adoption of IoT facilities in the company is the more productive approach. Matana et al. [3] presented the model that helps to explain the association of internal logistics activities with the CPS system. Gupta et al. [4] introduced the countermeasures and blockchain-based integrated AV architecture that helps to prevent cyberattacks and threats associated with AGV in Industry 4.0. Osterrieder et al. [6] found eight distinct viewpoints within the concept of the smart factory based on currently available literature. Bag et al. [7] identified 13 key enablers of Industry 4.0 that can be used to achieve sustainability in the supply chain system. Chalmeta et al. [8] expanded the understanding of Industry 4.0 and big data in the development of a sustainable supply chain based on a literature review. They also defined six research directions for future studies. Bezai et al. [9] presented a detailed review of automatic guided vehicles and combined the obstacles related to AV in one framework. Tang et al. [11] examined the uses and applications of Industry 4.0 technologies. They also examined the role of logistics functions to achieve sustainability in the presence of these technologies. Yavas et al. [12] conducted a comparison of traditional logistics centers with transformed logistics centers in Industry 4.0. Furthermore, they defined the criteria for the successful installation of smart logistics centers. Dalenogare et al proved that not all the Industry 4.0 technologies are beneficial for industrial performance and that some of the technologies can meet the expectations of industries while others are still in the adoption stage. Goodchild and Toy [14] explained that drone delivery service is the more profitable approach for companies in the future. It also protects the environment from carbon emissions (CO_2). Moreover, they compared and explained the pons and cons of both traditional truck and drone delivery options. Wang et al. [15] introduced an integrated IoT-based logistics system (combining the robotics and human coordination) to optimize the dispatching operations. Jeong et al. [16] presented the idea of a humanitarian flying warehouse (HFW) that can be used for parcel delivery. Their goal was to overcome the risks and issues of ground vehicle delivery. Figliozzi [18] compared the efficiency of both AV and ground vehicles used for last-mile delivery.

Efficiency was measured in terms of vehicle capacity, range, and CO_2 emission. They found that sustainability in the supply chain can only be achieved if they adopt AV for last-mile delivery; however, this delivery system also has some disadvantages. Kirschstein [19] summarized that drone delivery utilizes more energy than the normal conventional electric or diesel ground vehicles.

Manavalan et al. [20] from the literature review proposed a framework that explains the adoption process and benefits of IoT-based systems in the company that led to achieving supply chain sustainability. Yadav et al. [22] developed a framework that provides 22 ways to resolve different challenges SSC faced during the adoption of Industry 4.0. Ojo et al. [23] emphasized that optimization of all the operations in the supply chain is essential to achieve sustainability. For this reason, they bring Industry 4.0 to the food industry. Moreover, You and Feng [24] developed the CPS system to integrate Industry 4.0 technologies with the construction industry to flatter all the processes and pave the path for intelligent construction.

For challenges related to Industry 4.0 and supply chain sustainability, Furstenau et al. [25] provided a literature review about Industry 4.0 and sustainability. They also point out the challenges and issues related to Industry 4.0 implementation in the industry. Chen et al. [26] created the idea of a smart factory in the digital business era. They found core technologies that are required to build the structure of a smart factory for the purpose of increasing efficiency. Meneghello et al. [27] examined the threats associated with IoT-based products and provided their countermeasures to overcome security risks. Xu et al. [28] provided the gathered understanding of current IoT-based systems based on three system aspects which are control, networking, and computing. Weking et al. [29] developed an innovative business model with the integration of Industry 4.0 technologies. They proved that this integrated BM enhances the coordination of all members in the supply chain and led the business to achieve sustainability. Palmaccio et al. [31] found changes in the business process due to the adoption of IoT-based systems. Echchakoui and Barka [32] found that the implementation and installation of Industry 4.0 in the plastic industry is still at the early adoption stage. They also highlighted the issues and obstacles that occur during the adoption of Industry 4.0. Zarzuelo et al. [34] studied the effects of Industry 4.0 technologies on the maritime industry. They concluded that each technology in Industry 4.0 has its benefits and drawbacks; companies should adopt these technologies after analyzing their aftereffects. Li et al. [33] explained the benefits of the digital supply chain on economic and environmental performance to accomplish sustainability in SC. Rosit et al. [35] introduced the CPS-based integrated scheduling system in the company that uses real-time information to enhance the decision-making process and schedule the tasks effectively. Culot et al. [37] through a systematic literature review, compared the different fragmented definitions of Industry 4.0 and creates a more specific definition of Industry 4.0. Reinhardt et al. [38] identified the knowledge of Industry 4.0 in pharmaceutical companies and found that more experienced employees have more knowledge about Industry 4.0; thus, for a better understanding of Industry 4.0, there is a need for training required of all workers and employees in pharmaceutical companies in Ireland. Raj et al. [40] identified 15 barriers in implementing Industry 4.0 in the manufacturing sector. They found that through involvement of company's peers government bodies, and proper education of these technologies, these barriers can removed.

Lu [43] provided detailed insights of Industry 4.0 applications on industrial sectors to achieve sustainability and achieve a competitive advantage. Choi et al. [44] explained the involvement of Industry 4.0 technologies in the

fashion industry that converts it into a sustainable fashion industry. For this, they proposed a framework that explains how sustainability can be achieved in the fashion supply chain. Liotta et al. [45] established the framework that integrates the production and transportation process, which led the company to achieve sustainability in the supply chain. Dossou [46] proposed a new framework that considers sustainability as a key benefit for future factories and integrates sustainability with Industry 4.0. Bai et al. [47] explained that Industry 4.0 technologies have a positive impact on social sustainability. However, each technology should be examined carefully before implementation. Govindan et al. [49] studied sustainability in terms of social, economic, and environmental sustainability. They found that social and environmental sustainability practices have positive impacts on firm operational and financial performance in all industrial sectors. Cole and Aitken [50] identified that intermediates play an important role in building a strong relationship between suppliers and buyers, and led them to attain sustainability in which there is weak sustainability knowledge. Vaio et al. [52] through a literature review, proposed a framework that explains how computer-based technologies (AI) help to achieve SCS.

3. Research Framework

The above section provides detailed insight on the literature through a comparison of the focus, methods, and results of different studies. After a thorough review, we have developed a framework that explains the role of Industry 4.0 technologies in the supply chain process which led companies to achieve supply chain sustainability. This study includes five Industry 4.0 technologies including the smart factory, the Internet of things (IoT), the cyber–physical system, automatic guided vehicle (AGV), and drones.

Figure 4 depicts a clear picture of Industry 4.0 technologies and their inter-connections with the supply chain process. Smart factories and the Internet of things are involved in the order placement and purchasing or sourcing process of the supply chain through the internet connectivity of all the devices and machines. The cyber–physical system (CPS) plays a vital role in smoothening the product planning and scheduling process. Automatic guided vehicles (AGVs) play an important role in the storage and distribution process of the supply chain, and AGVs are responsible for moving the goods from one place to another in the supply chain, especially during production, storage, and distribution processes. Drone delivery is evolving in the product delivery process, which is also called the last-mile delivery process of the supply chain process, to provide better services to customers. Penetration of these Industry 4.0 technologies and the correct use of Industry 4.0 technologies at right time in the supply chain process will lead companies to achieve supply chain sustainability (economic, environmental, and social sustainability). For manufacturing companies, especially for SMEs, it is difficult to accept a technological change, move towards digitalization, and mold their whole value chain. SMEs have limited resources in terms of investment and workforce.

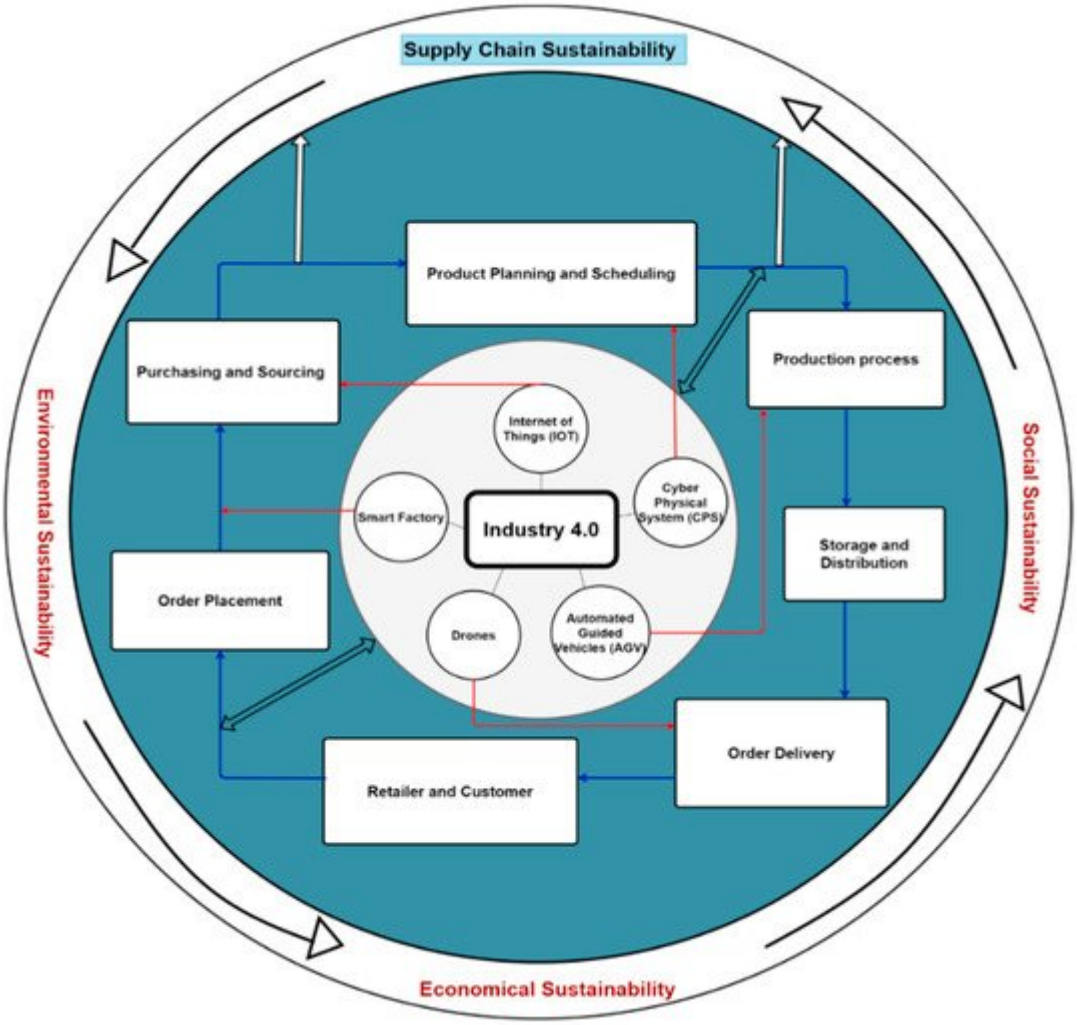

Figure 4. Research framework (author's compilation).

4. Current Insights

In the digital world in which global companies strive to attain competitive advantage, companies need to consider Industry 4.0 in their supply chain network. Technological advancement brings many changes in all industrial sectors and it is the right time for manufacturing companies to alter their supply chain network. Industry 4.0 has the power to disturb the current structure of companies due to its disruptive technologies. In this paper, we highlight the five Industry 4.0 technologies that are more closely related to the supply chain network of the company. Many large companies such as Amazon, Alibaba, and Google are moving towards drone delivery. In China, companies are following the concept of "Made-In-China 2025".

We found that the adoption of sustainable practices is the point of focus for companies. It shows the good repute of the company because of its sustainability concern. The 22 (40%) out of 55 papers specifically discussed the challenges, benefits, and issues related to SCS. Sustainability can be measured as companies' efforts towards environmental, social, and economical concerns. Through the literature review, we conclude that environmental and social sustainability can lead a company to enhance its operational performance of the supply chain and

ultimately increase profits. However, many factors affect the implementation of Industry 4.0 technologies in companies. It requires a large investment to modify the current production process of the company. Secondly, we found that there is a lack of knowledge, especially in SME's, concerning Industry 4.0 benefits. Thus, it is necessary to educate employees regarding Industry 4.0 technologies, their installation, and the adoption process.

We have identified that each technology of Industry 4.0 is linked to different stages in the supply chain network. Drone delivery service is linked to the distribution and parcel delivery process of the supply chain. Automatic guided vehicles are used in the production and transportation process of SC. Smart factories enable the company to perform all the tasks with the use of the internet and robotics are used to perform tasks. The CPS system helps in scheduling and decision-making processes due to its use of real-time information of all the processes. Moreover, Industry 4.0 technologies have many benefits such as low labor cost, reduced lead time, increased efficiency, lowered operational cost, and quality of achieving greater sustainability.

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