South Asian Journal of Operations and Logistics
Vol. 3, No. 1, pp. 95-111
DOI: 10.57044/SAJOL.2024.3.1.2449
ISSN: 2958-2504

Impact of industry 4.0 on supply chain management

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Article History

Received: 13 March 2023
Revised: 30 January 2024

JEL Classification
N75
L25
R41

ABSTRACT

This study aims to analyze the impact of Industry 4.0 implementation on the supply chain and develop an implementation framework that considers the potential drivers and obstacles of the Industry 4.0 paradigm. A literature search examined the main drivers and barriers to implementing Industry 4.0 in four business areas: strategy, organization, technology, law, and ethics. A system dynamics model will be developed to understand the impact of the implementation of Industry 4.0 on supply chain parameters, and the identified drivers and barriers to technological change will be included. In addition to the empirical basis of this connection, a proposal was a theoretical framework for utilizing Industry 4.0 within the supply chain. The opportunities and new challenges for future supply chains were expected in Industry 4.0. This study analyzed various challenges in implementation and process and proposed a framework for effectively adapting and transferring the model of Industry 4.0 towards supply chains. The research aims to understand the challenges of integrating Industry 4.0 into their networks because it aims to examine the advantages of supply chain management. The implementation impact of Industry 4.0 on the supply chain performance can be analyzed using simulation analysis, and the driving causes and obstacles of this technological transition can be investigated. This connection is provided on an empirical basis. It is proposed that a new industrial conceptual framework be developed. Incorporate Industry 4.0 into your supply chain.

Keywords: *Industry 4.0, Internet of Things, IoT, Big data analysis, Digital supply chain, Digitalization, Performance improvement.*

Citation of this article:

Athar, M. S. (2024). Impact of industry 4.0 on supply chain management. *South Asian Journal of Operations and Logistics, 3*(1), 95-111. https://doi.org/10.57044/SAJOL.2024.3.1.2449

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1. Background of the Study

My research topic is related to my field study, supply chain management. This proposal focuses on the impact of Industry 4.0 on supply chain management. This is an essential issue because Industry 4.0 provides organizations with obvious advantages and benefits, such as minimizing costs and errors and increasing productivity. This study also highlights the challenges and negative impacts of Industry 4.0 on supply chain management. In the 18th-century first business revolution, the arena was treated to manufacturing extra items from constrained and depleting assets to satisfy the developing demand. Therefore, bad environmental influences have been generated (Beier et al., 2018). The phrase "Industry 4.0" was first used in 2011, quickly attracting the attention of corporations and governments worldwide (Ghobakhloo, 2018; Nascimento et al., 2019). To convert whole-generation frameworks and forms through digitization due to the opportunity (Da Costa et al., 2019). Industry 4.0 has produced the ability to usher in a new era of innovation. Organizations ought to base their standards on being maintainable when receiving advances. Organizations that center on feasible improvement look to realize an adjustment between financial, natural, and public columns from the three-legged view area (TBL) (Kiel et al., 2017). Be that as it may, in their operations, it isn't basic for businesses to create supportability (Luthra & Mangla, 2018b). As a result, the analysis should pay more attention to the effects of Industry 4.0 on sustainability and how it might contribute to sustainable development from a financial, natural, and social perspective (Ghobakhloo, 2020; Nara et al., 2021).

Consequently, the evolving mechanization, in addition to the implementation of a mechanized series of facts with the aid of the usage of Internet of Things (IoT) technology, machine learning technology (ML), artificial intelligence (AI), and analytics structures and cloud computing systems used with inside the cutting edge duration, is to this point remodeling the procedure wherein we perform businesses (Rashid et al., 2024a)). Cyber-physical structure and the creation of the Internet of Things are changing the speed of change in supply chain management (SCM) (De Barros et al., 2015). The various visions of the 4.0 revolution related to supply chain management are intended to replace tasks that people often use machines to perform. This is the real problem for Industry 4.0, or the 4th generation of supply chain management, which is breaking out of its comfort zone. The business must be entirely changed by creating things and providing services (Sutawijaya, 2020).

1.1 Research Questions

The following research questions can be determined based on this idea and provide additional guidance throughout the study.

a) To what extent does Industry 4.0 affect organizations' customer relationship and supply chain management?
b) To what extent does Industry 4.0 affect the level of supply chain management information sharing among organizations?
c) To what extent does Industry 4.0 affect the quality of supply chain management information organizations?

1.2 Purpose of the Study

This study will present an empirical study of Industry 4.0's impact on supply chain management. We can show you how Industry 4.0 affects the supply chain in detail here. In recent years, due to various reasons, the introduction of technology in the supply chain has been tested. In this research, we will study these reasons, such as common IT infrastructure standards, implementation complexity, the high cost of implementation and maintenance of SCM systems, and the value of different technologies in SCM.

1.3 Significant of the Study

This research aims to build on previous work demonstrating the development of technology and its positive and negative effects on supply chain management, which will help future researchers and companies prepare for the adoption of modern management. Supply chain management to understand the pros and cons of implementing technology on a multi-channel network. This research can easily predict the future technological trends of supply chain management, allowing the business to retain its leadership position and thus increase efficiency and competitive profitability.

2. Literature Review

This section introduces the investigation of the possible influence of Industry 4.0 on improving supply chain management efficiency, which will lead to the development of investigation and research issues, followed by the system theory analysis, which will form the basis for formulating recommendations for supply chain management based on Industry 4.0.

2.1 Underpinning and Supporting Concepts

2.1.1 Industry 4.0 Concept

This Industry 4.0 effort was started by the federal government and invented with the participation of private companies and universities. Advanced manufacturing systems to boost national industry productivity and efficiency are a strategic development plan. This concept represents a new industrial milestone in the manufacturing system. It integrates many new technologies and fusion innovations that bring value to a product’s full life cycle (Wang et al., 2016; Dalenogare et al., 2018). The social and technological evolution of human beings in the production system is required at this new industry level, in which all work in the price chain is completed smartly (work smartly) (Longo et al., 2017; Stock et al., 2018; Frank et al., 2019).

Based on the overview of Industry 4.0, the vision is to create infrastructure, integrate digital technology, and integrate physical assets into the system (cyber physics). Several trends enable the Industry 4.0 transformation, including the Internet of Things (IoT), which plays a critical role in this transition (Haddud, 2017; Ghobakhloo, 2018). The revolution of Industry 4.0 also brings together automation systems that can accelerate, customize, and accelerate the use of applications required for providing data from various sensors, tools, and devices. Therefore, this has led to the emergence of innovative skills in multiple fields: business development and prototyping, protection and prediction, product design, diagnosis and tracking services, the use and speediness required for remote tracking systems, real-time health monitoring, innovation, and planning (Strange & Zucchella, 2017; Rashid et al., 2024b). During the revolution of Industry 4.0, the success achieved has brought significant benefits to the company in many ways: independent monitoring, actual data analysis, increased transparency, product customization, increased productivity, and dynamic product design (Dalenogare et al., 2018). The most important technologies in Industry 4.0 and their business applications are described as follows:

Big Data Analytics: Improve productivity and efficiency using a large amount of data through big data analysis (Wamba et al., 2017). Companies use big data to increase process efficiency and productivity, flexibility and creativity, and product customization with the help of big data analysis (Wu et al., 2016; Ghobakhloo, 2018). Collecting and analyzing data from multiple methods is becoming the norm and enables fast, real-time decisions (Rashid et al., 2023).

The Industrialized Internet of Things (IoT): This platform will be a data-sharing and central control system interacting with various devices and systems in Industry 4.0. In decision-making, the IIoT provides real-time traceability and monitoring through decentralized analysis (Gunasekaran et al., 2016). The intercompany collaboration will fully automate the value chain, thereby improving the company’s functions and business capabilities (Manavalan & Jayakrishna, 2019).

Business Intelligence: Business intelligence has a technology platform for collecting, sorting, analyzing, and presenting data from different sources and is used in enterprises (Rashid et al., 2024c). Business intelligence supports the decision-making process by obtaining valuable and meaningful information. It is easy to understand from the original data (Ghadge et al., 2020).

Cloud Technology: A cloud system is a distant server storing a huge amount of data acquired from many business systems, sensors, and devices. Cloud technology allows users to access vast amounts of real-time data. It is required to improve organizational departments and value chain data exchange between location and company/organization (Ghadge et al., 2020).

The following is an overview of the main feature of Industry 4.0: vertical and horizontal system integration. According to vertical integration from sub-levels of management to successive phases of processes, production and administration, communication, and information technologies are incorporated according to the organization's variability (Dalenogare et al., 2018). The network and the physical cybernetic system enable this fixed integration to respond to errors, fluctuations, or variable demand in the value chain. Through horizontal integration, ICT can interchange information between different participants (and opponents) within the supply chain network. Integration, including continuous integration, data sharing, and association with all related groups, is complex (Rashid et al., 2024d). This way, Industry 4.0 patch applications can help increase performance, efficiency, and flexibility, improve product customization, and reduce cost.

2.1.2 Industry 4.0's impact on the supply chain

Industry 4.0 uses various cutting-edge tools and technologies to reinvent traditional manufacturing processes, and the supply chain is taking a giant stride towards digitalization, operational flexibility, and automation, as described in the previous section. Digital networks use various technologies to develop transparent, sustainable, efficient, and flexible approaches to various supply chain technologies, including product development, planning, manufacturing, marketing, and asset management. The impact of Industry 4.0 investigations can be divided into countless categories of procurement and supply chain strategies; for example, through integrated processes and better material and product traceability to better predict and schedule, and through collaboration with suppliers, real-time information exchange and synchronization, as well as intelligent vehicle storage and routing systems, enhance the efficiency of suppliers (Hofmann & Rusch, 2017; Ghobakhloo, 2018).

In the digital revolution, companies must now rethink the network structure of their supply chains (Hashmi, 2023). Thanks to the e-commerce platform, transparency, and easy access to multiple choices of when and where to buy, trading platforms are supported by the supply chain. The Internet of Things (IoT) plays a significant role in the supply chain. It may perform a wide range of tasks, including vehicle speed, real-time location, recessed product health, equipment operation, and health, including temperature sensors (Manavalan & Jayakrishna, 2019). The expanding repute of stakeholder participation and the strengthening of interactions between supply chain stakeholders imply that the impact of Industry 4.0 deployment on the supply chain network level has to be assessed (Tjahjono et al., 2017). In the words of Frank et al. (2019), the supply chain is defined as the scope of the Industry 4.0 revolution, which connects digital platforms with customers, distributors, partners, and suppliers. The synergy and information exchange between supply chain partners reduces the overall cost, while the speed and efficiency of the supply chain have been wholly improved (Frank et al., 2019; Ghobakhloo & Fathi, 2019). Improved collaboration and openness in supply chain networks strengthened the relationship between supply chain members and their trust (Ghadge et al., 2020; Rashid et al., 2022a).

Industry 4.0 features include well-organized connectivity and real-time monitoring and control of supply chain materials, parameters, and equipment, reducing risks and helping increase overall supply chain performance (Luthra & Mangla, 2018a). These systems have additionally caused a transformation of business models and management strategies with the Industry 4.0 overview

(Arnold et al., 2016; Ghobakhloo, 2018). In addition to the trends and requirements that promote the supply chain through digital transformation, the risks and new obstacles have also been amplified by trends in the digital revolution and business environments. These interruptions include information security threats, lack of data, lack of trained personnel, etc. (Barreto et al., 2017; Rashid et al., 2024e). Therefore, a theoretical structure and empirical research are needed to support the companies in developing an efficient and reliable supply chain to adapt to Industry 4.0 and rapidly adapt to markets and shifting technologies (Ghadge et al., 2020).

2.1.3 Industry 4.0 key drivers and barriers

Despite the rapid development of Industry 4.0, no research has been conducted to evaluate its possible drivers and impediments to implementation (Lu, 2017). A literature review was undertaken to determine the driving forces and barriers to adopting and applying Industry 4.0 technology. According to the study, Industry 4.0, the main driving factors for its adoption are as follows:

Strengths: The supply chain plays a crucial role in implementing Industry 4. It can achieve real-time planning and control over rapidly changing framework conditions, allowing companies to react flexibly and quickly; for example, responding swiftly to changes in demand and supply reduces cooling time and rotation cycles (Oztemel & Gursev, 2018). You can predict future events and patterns using business intelligence methodologies, such as consumer behavior, delivery time, and output (Barreto et al., 2017).

Customization: The companies deliver multi-choice packages to the customer with the help of mass customization, micro-segmentation, and advanced planning technologies (Hashmi, 2022). Through drone delivery, innovative digital delivery technologies, and sales methods such as exceeding customer expectations (Hofmann & Rush et al., 2017; Ghobakhloo et al., 2018; Ghadge et al., 2020).

Accuracy: Industry 4.0 is a game-changing technology that provides consistent, accurate, and up-to-date information for smart decisions. That is, finally, the performance management systems of the next generation are coming to an end. The correct location of network logistics and customer service and order processing are used to specify the data process; such detailed data comes from important KPIs (Ghadge et al., 2020).

Efficiency: The supply chain efficiency is determined by the visual functions, planning, control, and communication of automation (Pereira & Romero, 2017). Many companies use automation technology, especially in their logistics systems, including robotic manipulators and lifters, freight tracking, fully automated warehouses, unmanned vehicles, automated pallet management systems, etc. (Xu et al., 2018). Companies choose to collaborate and share space because of the flexibility of optimizing transportation. The whole supply chain system configuration is continuously optimized to adapt perfectly to business needs (Baloch & Rashid, 2022).

In addition, there is a force to counter the obstacles, threats, and practices associated with the practical revolution of Industry 4.0; these obstacles are divided into four different business categories: ethics and law, strategic perspective, technical scope, and organizational status (Luthra & Mangla, 2018a). For Industry 4.0 adoption, the most common obstacles are as follows:

Financial limitations: In advanced modern infrastructure development and sustainable technological innovation, financial constraints are a major problem in Industry 4.0 implementation (Nicoletti, 2018). The level of investment is heavily influenced by the technological performance of highly concerned organizations. However, the economic outlook is still in a new stage due to the lack of profitability analysis, and cost is an urgent theme for industrial use within the context of procurement (Arnold et al., 2016; Ghadge et al., 2020).

Lack of Management Support: The changes in the industrial revolution are hasty and require the learning and development of necessary skills. Without strong leadership support, these skills are difficult to achieve (Rasheed et al., 2024). The launch of Industry 4.0 requires cross-functional cooperation through all elements of the value-added network of digitization, which is the most important prerequisite.

Resistant to Change: Industries are uncertain about the economic revolution; thus, they may not recognize the importance of change due to uncertainty in acceptance (Theorin et al., 2017). The expansions of global business networks and markets, operating systems, and management have become more and more difficult. Global data management and the last technological innovations lacking skills in these fields have raised business concerns about implementing Industry 4.0 technology (Ghadge et al., 2020).

Lack of Expertise: The literature requires professionals and scholars to understand and perform organized and targeted research on the impact of Industry 4.0 on logistics and supply chains (Almada-Lobo, 2016; Hofmann & Rusch, 2017). So, to create a structure, it is important for the supply chain driven by the Industry 4.0 revolution and innovative management services to realize benefits, industrial procurement barriers, driving forces, and implementation challenges.

Legal Issues: Big data transactions pose supply chain security risks, so data protection and security should be considered when Industry 4.0 is implemented (Kamble et al., 2018). Every improper execution or Internet connectivity of digital transformation and infrastructure is a major problem in executing the idea (Bedekar, 2017; Ghadge et al., 2020).

A Lack of Government Policies and Support: Governments in most nations supply the necessary infrastructure for the digital world (such as the Internet and communication networks); however, there is no roadmap to change the industrial infrastructure, in particular, due to a lack of understanding of the impact of Industry 4.0 (for example, the 5G introduction and Industry 4.0's ramifications and benefits).

As a result, companies face challenges such as good R&D practices, a lack of trusted partners, poor data, and a lack of digital culture when implementing to take advantage of the revolution. Industry 4.0 is a term that describes a technological revolution (Wang et al., 2016; Luthra & Mangla, 2018b). Based on comprehensive literature research and discussions with two experienced experts on Industry 4.0 implementation at the firm and supply chain levels, the major problems and motivators for implementing Industry 4.0 in the supply chain are listed in Table 1. Industry 4.0 needs to update its understanding and attributes towards supply chain executives to revolutionize the supply chain, considering the driving forces and impediments to Industry 4.0 adoption. Table 1 highlights the drivers and obstacles of Industry 4.0 in the supply chain implementation.

Table 1: Industry 4.0 in the supply chain implementation: Dsrivers and obstacles

Enterprise Scale	Drivers	Driver Barriers
Organization	· Improve Efficiency · Reduce Cost · Improve Quality · Flexibility · Inventory Reduction and Load Balancing	· Monetary Constraints · Support from Management Is Missing. · There Is a Lack of Change-Resistant · There Is a Lack of Strategy And A Digital Vision. · Shortage of Experience · Network Systems Complications
Law And Ethics	· Repetitive Work Reduction · Environmental Impact Reduction	· Lawful Issues · Management and Cooperation Issues · Confidentiality Of Data And Security Focus.
Strategy	· Innovative Commercial Enterprise Models · The Innovative Value Proposition To Improve The Effectiveness	· Overview and Complication Issues · Government and Political Support Are Lacking. · R&D Is Lacking. · Monetary Benefits Uncertain · Digital Culture Lacking

Technology	· Transparency	· Sub-Digital Infrastructure Is Lacking. · Bad Quality and Data Management.

Source: Literature

2.2 Research Framework

Figure 1 below represents the research framework.

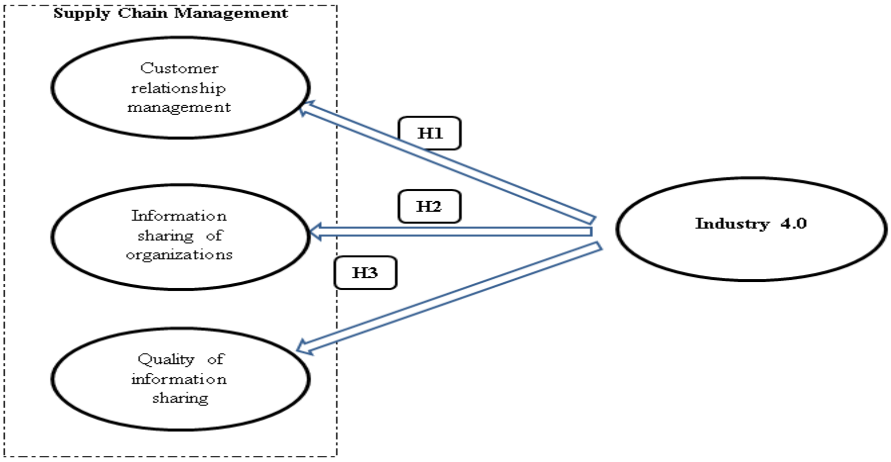

Figure 1: Research Framework
Source: Author's creation

2.3 Hypotheses

H1: Industry 4.0 affects organizations' customer relationships and supply chain management.

H2: The effects of Industry 4.0 on supply chain management information sharing among organizations.

H3: The effects of Industry 4.0 on the quality of supply chain management information organizations.

3. Research Method

3.1 Methodology of Research

A one-stage research approach was used to conduct the exploratory research methodology (Rashid & Rasheed, 2023). An extensive literature search assessed the driving forces and impediments of Industry 4.0 in the supply chain framework (Khan et al., 2023a). Secondary data sources are used in the deployment of Industry 4.0 in supply chain research, such as research articles, scientific articles, technical articles, journals, business reports, consulting company reports, expert blogs, technical videos, and webinars (Khan et al., 2023b; Rasheed & Rashid, 2023). The main drivers and challenges to Industry 4.0 deployment have been identified and classified into four categories: organization, law and ethics, strategy, and technology (Table 1).

3.2 Research Design

This learning process involves seven steps:

1) This study is a descriptive survey.
2) In this study, a quantitative method is used.
3) Based on the quantitative method, the study method is a descriptive survey.
4) Consists of a quantitative tactic, i.e., examining the questionnaire's validity,

reliability, and response rate.

5) The quantitative information series device is a popular questionnaire with a five-factor Likert scale.
6) The information layout is quantitative.
7) The approach to evaluation is primarily based on descriptive and inferential statistics.

3.3 Sampling Design

The questionnaire is an important tool for this research because it collects primary data (Rasheed et al., 2023; Rashid et al., 2022b). The tool was piloted with several patricians at the beginning of data collection. The sample type is probabilistic, and the method is a stratified random sample. However, it should be noted that the sample uses a simple random procedure after inserting a randomized sample (Amriah et al., 2024; Rashid & Rasheed, 2024). This questionnaire was developed for people working in Pakistan and related to the supply chain field to answer questions with knowledge and experience (Rashid & Rasheed, 2022; Rashid et al., 2021). This questionnaire is distributed online, and the responses are recorded using direct electronic data entry.

3.4 Instrument of Data Collection

A supply chain management questionnaire can be developed and used to assess the influence of Industry 4.0 on supply chain management. The questionnaire contains 20 elements of the answer package based on the Likert five-point scale (Hashmi & Mohd, 2020; Rashid et al., 2019). Measure attitudes towards customer relationships, communication level, and communication quality. The table 2 below shows the number of objects associated with the dimension:

Table 2: Questionnaire Indicators

Questions No.	Dimensions
Question 1–5	Customer Relationship
Question 6–10	Level Of Information Sharing
Question 11–15	Quality Of Information Sharing
Question 16–20	Industry 4.0

Source: Literature

Scoring method: As you can see in Table 3, the measurement used within the questionnaire is primarily based on the Likert at the five-desire spectrum, inclusive of strongly disagree, disagree, natural, agree, and strongly agree, as shown in Table 3 (Rashid, 2016).

Table 3: Scale Of Questionnaire Questions

Select	Strongly Agree	Agree	Natural	Disagree	Strongly Disagree
Score	5	4	3	2	1

Source: Literature

3.4.1 Reliability and validity of the instrument:

In this study, the tool of validity and reliability, questionnaire validity, is used to measure all of the characteristics of the questionnaire, from the content validity to the validity of the questions, including the theoretical content of the test questions and two references. Content validity index and content validity content. Further, the SPSS software program was used to investigate the information. Data analysis consists of three parts: descriptive statistics, preprocessing, and logical statistics.

4. Findings and Results

4.1 Introduction

Information obtained from the form is analyzed in 2 levels using SPSS software. Within the 1st level, descriptive statistics methods (frequency, percentage, and frequency chart) are used. Within the 2nd level, inferential statistics methods are used to analyze the data and examine hypotheses.

4.2 Demographic Information

4.2.1 Descriptive results related to demographic variables

In this section, we provide descriptive information from the form that indicates the demographic characteristics of the samples. The results show that descriptive results are related to demographic variables Gender, education, age, and experience-wise statistics data with the number of participants. Descriptive results relate to demographic variables, gender-wise. The number of male participants is 81.9%, and that of female participants is 18.1%. Similarly, descriptive results related to demographic variables—education: 21.9% of participants have a bachelor's and 78.1% have a master's Education. Likewise, descriptive results relate to demographic variables age-wise. 10% of respondents are under 25 years, and 36.9% are between 25-30 years, 39.4% are between 30-35 years, 6.9% are between 35-40 years, and 6.3% are above 40 years. Further, descriptive results are related to demographic variables experience-wise. 33.8% of respondents' experience is less than 5 years, 41.9% of respondents' experience is between 5-10 years and 16.9% of respondents' experience is between 10-15 years, and 6.3% of respondent's experience between 15-20 years and 1.3% of respondent's experience is more than 20 years.

4.3 Reliability

4.3.1 Reliability quality of Information sharing of organizations

Table 4 highlights the case processing summary of information sharing in organizations.

Table 4: Case Processing Summary

		N	%
Cases	Valid	160	100.0
	Excluded	0	.0
	Total	160	100.0

A. List-wise deletion is based on all variables in the procedure.

Source: SPSS output

Table 5: Reliability Statistics

Cronbach's Alpha	N Of Items
.878	5

Source: SPSS output

Cronbach's alpha value is more significant than 0.70 in Table 5, indicating that the scale is dependable (Hashmi et al., 2021a).

4.3.2 Reliability of quality of information sharing

Table 6 below highlights the case processing summary of information sharing by organizations.

Table 6: Case Processing Summary

		N	%
Cases	Valid	160	100.0
	Excludeda	0	.0
	Total	160	100.0

A. Listwise Deletion Based On All Variables In The Procedure.

Source: SPSS output

Cronbach's alpha value is greater than 0.70 in Table 7, indicating that the scale is dependable (Hashmi et al., 2021b).

Table 7: Reliability Statistics

Cronbach's Alpha	N Of Items
.872	5

Source: SPSS output

4.3.3 Reliability of customer relationship management

Table 8 highlights the case processing summary of customer relationship management.

Table 8: Case Processing Summary

		N	%
Cases	Valid	160	100.0
	Excluded	0	.0
	Total	160	100.0
A. Listwise Deletion Based On All Variables In The Procedure.			

Source: SPSS output

Cronbach's alpha value is greater than 0.70 in Table 9, indicating that the scale is dependable (Hashmi et al., 2020a).

Table 9: Reliability Statistics

Cronbach's Alpha	N Of Items
.726	5

Source: SPSS output

4.3.3 Reliability of industry 4.0

Table 10 highlights the case processing summary of Industry 4.0.

Table 10: Case Processing Summary

		N	%
Cases	Valid	160	100.0
	Excluded	0	.0
	Total	160	100.0
A. Listwise Deletion Based On All Variables In The Procedure.			

Source: SPSS output

Cronbach's alpha value is greater than 0.70 in the Table 11, indicating that the scale is dependable (Hashmi et al., 2020b).

Table 11: Reliability Statistics

Cronbach's Alpha	N Of Items
.778	5

Source: SPSS output

4.4 Regression Analysis

Table 12 above shows that Durbin Watson is 2.055. It means no autocorrelation. 563 is the adjusted R square value. This means that this model explains 56% of the variance. This means that the variance is moderate.

Table 12: Model Summary

Model	R	R Square	Adjusted R Square	Standard. Error Of The Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	Df1	Df2	Sig. F. Change	
1	.756a	.571	.563	.43992	.571	69.184	3	156	.000	2.055

A. Predictors: (Constant), Quality.Of.Info, Level.Of.Info, Cus.Rel
B. Dependent Variable: Industry 4.0

Source: SPSS output

The fact that the sig. value is smaller than 5 in Table 13, which indicates that the model is significant. The F value is more than 2. It shows that the model is significant.

Table 13: ANOVA

Model		Sum Of Squares	Df	Mean Square	F	Sig.
1	Regression	40.168	3	13.389	69.184	.000b
	Residual	30.191	156	.194		
	Total	70.359	159			
A. Dependent Variable: Industry 4.0						
B. Predictors: (Constant), Quality.Of.Info, Level.Of.Info, Cus.Rel						

Source: SPSS output

4.5 Coefficient

In Table 14, the VIF value is less than 4, which signifies no multi-co-linearity. The T value is more than 2. It means that all impacts are significant. The P-value is less than 0.05, meaning that the independent variable considerably affects the dependent variable. The above table 14 shows that a 1% increase in customer relationships will increase Industry 4.0 by 17.4%. The impact is significant because the T value is more than 2, and P-value is less than .05, and there is no multi-co-linearity (Rashid et al., 2020). Table 14 shows that a 1% increase in information sharing will increase Industry 4.0 by 24.5%. The impact is significant because the T-value is more than 2, the P-value is less than .05, and there is no multi-co-linearity. Table 14 shows that a 1% increase in the quality of information sharing will increase Industry 4.0 by 40.7%. The impact is significant because the T-value is more than 2, the P-value is less than .05, and there is no multi-co-linearity. Table 15 represents the Collinearity Diagnostics.

Table 14: Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95.0% Confidence Interval For B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-Order	Partial	Part	Tolerance	VIF
1	(Constant)	1.604	.171		9.389	.000	1.267	1.942					
	Cus.Rel	.147	.072	.174	2.046	.042	.005	.289	.654	.162	.107	.382	2.615
	Level.Of.Info	.179	.061	.245	2.922	.004	.058	.299	.672	.228	.153	.391	2.561
	Quality.Of.Info	.313	.068	.407	4.604	.000	.179	.447	.719	.346	.241	.352	2.842
A. Dependent Variable: Industry 4.0													

Source: SPSS output

Table 15: Collinearity Diagnostics'

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	Cus.Rel	Level.Of.Info	Quality.Of.Info
1	1	3.941	1.000	.00	.00	.00	.00
	2	.032	11.019	.93	.02	.12	.03
	3	.015	16.336	.07	.38	.84	.13
	4	.012	18.215	.00	.61	.04	.83
A. Dependent Variable: Industry 4.0							

Source: SPSS output

In Table 16, the minimum and maximum values are, respectively, 2.3 and 4.7. The minimum value of the residual is -1.2, while the maximum value is 1.4. The above Figure 2 shows that this is a normal curve, which means that variables are normally distributed.

Table 16: Residuals Statistics

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	2.3311	4.7968	3.9725	.50262	160
Residual	-1.22797	1.45186	.00000	.43575	160
Std. Predicted Value	-3.266	1.640	.000	1.000	160

Std. Residual	-2.791	3.300	.000	.991	160

A. Dependent Variable: Industry 4.0

Source: SPSS output

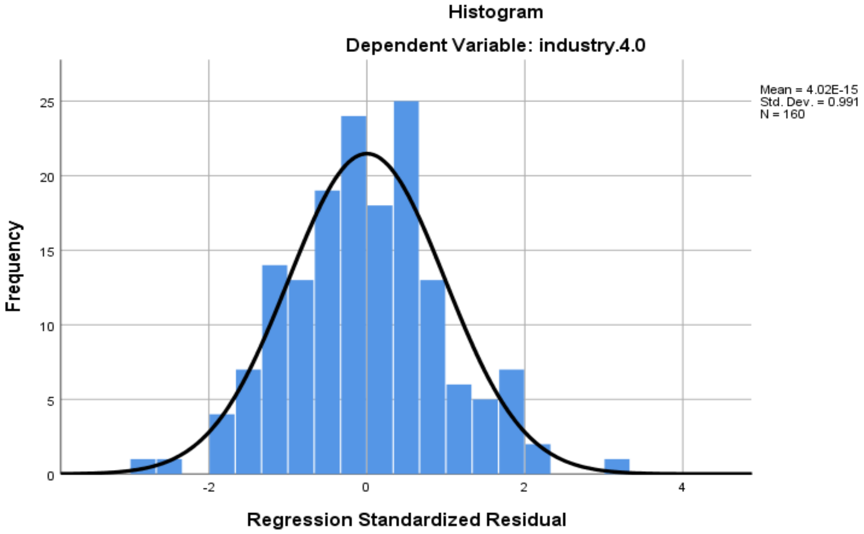

Figure 2: Histogram

Source: SPSS output

5. Conclusion, Discussion, Implications and Recommendations

5.1 Conclusion

The effects of Industry 4.0 on supply chain management have been investigated in this research. First, the important concepts such as supply chain, Industry 4.0, and information technology are defined, and then, through statistical data analysis, the main research questions and the different dimensions of the questionnaires are reviewed. Tests were performed through SPSS software, and based on statistical analysis, it was established that Industry 4.0 is effective in the supply chain and other areas (customer relationship, information sharing level, information sharing quality). Finally, the study's findings suggest that the null hypothesis is rejected and that the study's variable will be useful in the supply chain. The dimensions were selected based on the findings: customer relationship, quality of information sharing, and information sharing with suppliers.

5.2 Discussion

The study's major goal is to determine the impact of Industry 4.0 on supply chain management. The results of the research questions obtained in the previous chapter are mentioned, and the results obtained will be discussed in this chapter. Subsequently, suggestions will be presented in applied and research fields based on their search results. This analysis begins by examining how the Industry 4.0 impacts the supply chains offering aspects. The total number of participants is 160. After gathering data, the data were analyzed through SPSS and research hypothesis results obtained. Since the T value is more than 2, it means that all impacts are significant, and the P-value is less than .05, indicating that the independent variable has a substantial impact on a dependent variable. As a result, it may be concluded that Industry 4.0 is effective in controlling enterprises supply chains. A 1% increase in customer relationships will increase Industry 4.0 by 17.4%. The impact is significant because the T value is more than 2 and P-value is less than .05. A 1% increase in the level of information sharing will increase Industry 4.0 by 24.5%. The impact is significant because the T value is more than 2 and P-value is less than .05 and there is no multi-co-linearity as well. A 1% increase in the quality of information sharing will increase Industry 4.0 by 40.7%. The impact is significant because the T value is more than 2 and P-value is less than .05 and there is no multi-co-linearity as well.

5.3 Implications

Minimizing the costs of supply chain management, increasing efficiency, minimizing inventory, and creating a high turnover in the entire supply chain as long as you don't increase the business cost. Integrated information systems and software are required by e-commerce in the supply chain. Automation is one of the most important elements. Therefore, ensuring customer satisfaction through electronic sales systems and communication with foreign and domestic customers is suggested. The supply chain is the most important factor in supply chain management. As a result, it is suggested that the management of organizations strengthen the interrelationship between customer relationships and supply chain management by developing trust between partners and a trust plan for them. Businesses can improve overall agility and flexibility in operations by quickly adapting to changes in the market, client expectations, and supply chain interruptions.

5.4 Limitations and Recommendations

This research should be considered an addition to existing studies, considering the small amount of work prepared in this area. If the same study were extended to different companies or sectors, completely different results could be obtained. Industry 4.0 technologies being digitalized and implemented have proven to contribute effectively to improving firms' efficiency and productivity. Businesses should spend money on integrated CRM solutions that utilise Industry 4.0 innovations like IOT-enabled consumer interactions and AI-driven analytics. This integration improves customer satisfaction and builds customer loyalty by offering proactive support, personalized experiences, and effective order management. Implementing cooperative platforms that enable smooth information sharing amongst supply chain participants should be an element of embracing Industry 4.0. Real-time data analytics blockchain technology, and cloud-based solutions are essential for increasing transparency, cutting lead times, and facilitating better decision-making throughout the supply chain network.

References

Almada-Lobo, F. (2016). The Industry 4.0 revolution and the future of Manufacturing Execution Systems (MES). *Journal of Innovation Management*, *3*(4), 16–21. https://doi.org/10.24840/2183-0606_003.004_0003

Amirah, N. A., Him, N. K, Rashid, A., Rasheed, R., Zaliha, T. N., & Afthahnoon, A. (2024). Fostering a Safety Culture in Manufacturing Industry through Safety Behavior: A Structural Equation Modelling Approach. *Journal of Safety and Sustainability*, In press. https://doi.org/10.1016/j.jsasus.2024.03.001

Arnold, C., Kiel, D., & Voigt, K.-I. (2016). How the Industrial Internet of Things changes business models in different manufacturing industries. *International Journal of Innovation Management*, *20*(08), 1640015. https://doi.org/10.1142/s1363919616400156

Baloch, N. & Rashid, A. (2022). Supply chain networks, complexity, and optimization in developing economies: a systematic literature review and meta-analysis. *South Asian Journal of Operations and Logistics, 1*(1), 1-13. https://doi.org/10.57044/SAJOL.2022.1.1.2202

Barreto, L., Amaral, A., & Pereira, T. (2017). Industry 4.0 implications in logistics: an overview. *Procedia Manufacturing*, *13*, 1245–1252. https://doi.org/10.1016/j.promfg.2017.09.045

Bedekar, A. (2017). Opportunities & challenges for IoT in India. Retrieved from http://www.startupcity.com/leaders-talk/-opportunities-challengesfor-iot-in-india-nid-3444.html

Beier, G., Niehoff, S., & Xue, B. (2018). More sustainability in industry through industrial internet of things? *Applied Sciences (Basel, Switzerland)*, *8*(2), 219. https://doi.org/10.3390/app8020219

Da Costa, M. B., Dos Santos, L. M. A. L., Schaefer, J. L., Baierle, I. C., & Nara, E. O. B. (2019). Industry 4.0 technologies basic network identification. *Scientometrics*, *121*(2), 977–994. https://doi.org/10.1007/s11192-019-03216-7

Dalenogare, L. S., Benitez, G. B., Ayala, N. F., & Frank, A. G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. *International Journal of Production Economics*, *204*, 383–394. https://doi.org/10.1016/j.ijpe.2018.08.019

De Barros, A. P., Ishikiriyama, C. S., Peres, R. C., & Gomes, C. F. S. (2015). Processes and benefits of the application of information technology in supply chain management: an analysis of the literature. *Procedia Computer Science*, *55*, 698–705. https://doi.org/10.1016/j.procs.2015.07.077

Frank, A. G., Dalenogare, L. S., & Ayala, N. F. (2019). Industry 4.0 technologies: Implementation patterns in manufacturing companies. *International Journal of Production Economics*, *210*, 15–26. https://doi.org/10.1016/j.ijpe.2019.01.004

Ghadge, A., Er Kara, M., Moradlou, H., & Goswami, M. (2020). The impact of Industry 4.0 implementation on supply chains. *Journal of Manufacturing Technology Management*, *31*(4), 669–686. https://doi.org/10.1108/jmtm-10-2019-0368

Ghobakhloo, M. (2018). The future of manufacturing industry: a strategic roadmap toward Industry 4.0. *Journal of Manufacturing Technology Management*, *29*(6), 910–936. https://doi.org/10.1108/jmtm-02-2018-0057

Ghobakhloo, M. (2020). Industry 4.0, digitization, and opportunities for sustainability. *Journal of Cleaner Production*, *252*(119869), 119869. https://doi.org/10.1016/j.jclepro.2019.119869

Ghobakhloo, M., & Fathi, M. (2019). Corporate survival in Industry 4.0 era: the enabling role of lean-digitized manufacturing. *Journal of Manufacturing Technology Management*, *31*(1), 1–30. https://doi.org/10.1108/jmtm-11-2018-0417

Gunasekaran, A., Subramanian, N., & Tiwari, M. K. (2016). Information technology governance in Internet of Things supply chain networks. *Industrial Management & Data Systems*, *116*(7). https://doi.org/10.1108/IMDS-06-2016-0244

Haddud, A., DeSouza, A., Khare, A., & Lee, H. (2017). Examining potential benefits and challenges associated with the Internet of Things integration in supply chains. *Journal of Manufacturing Technology Management*, *28*(8), 1055–1085. https://doi.org/10.1108/jmtm-05-2017-0094

Hashmi, A. (2022). Factors affecting the supply chain resilience and supply chain performance. *South Asian Journal of Operations and Logistics*, *1*(2), 65-85. https://doi.org/10.57044/SAJOL.2022.1.2.2212

Hashmi, A. R., & Mohd, A. T. (2020). The effect of disruptive factors on inventory control as a mediator and organizational performance in health department of Punjab, Pakistan. *International Journal of Sustainable Development & World Policy*, *9*(2), 122-134. https://doi.org/10.18488/journal.26.2020.92.122.134

Hashmi, A. R., Amirah, N. A., & Yusof, Y. (2020a). Mediating effect of integrated systems on the relationship between supply chain management practices and public healthcare performance: Structural Equation Modeling. *International Journal of Management and Sustainability*, *9*(3), 148-160. https://doi.org/10.18488/journal.11.2020.93.148.160

Hashmi, A. R., Amirah, N. A., & Yusof, Y. (2021b). Organizational performance with disruptive factors and inventory control as a mediator in public healthcare of Punjab, Pakistan. *Management Science Letters*, *11*(1), 77-86. https://doi.org/10.5267/j.msl.2020.8.028

Hashmi, A. R., Amirah, N. A., Yusof, Y., & Zaliha, T. N. (2020b). Exploring the dimensions using exploratory factor analysis of disruptive factors and inventory control. *The Economics and*

Finance Letters, *7*(2), 247-254. https://doi.org/10.18488/journal.29.2020.72.247.254

Hashmi, A. R., Amirah, N. A., Yusof, Y., & Zaliha, T. N. (2021a). Mediation of inventory control practices in proficiency and organizational performance: State-funded hospital perspective. *Uncertain Supply Chain Management*, *9*(1), 89-98. https://doi.org/10.5267/j.uscm.2020.11.006

Hashmi, R. (2023). Business Performance Through Government Policies, Green Purchasing, and Reverse Logistics: Business Performance and Green Supply Chain Practices. *South Asian Journal of Operations and Logistics*, *2*(1), 1–10. https://doi.org/10.57044/SAJOL.2023.2.1.2301

Hofmann, E., & Rüsch, M. (2017). Industry 4.0 and the current status as well as future prospects on logistics. *Computers in Industry*, *89*, 23–34. https://doi.org/10.1016/j.compind.2017.04.002

Kamble, S. S., Gunasekaran, A., & Sharma, R. (2018). Analysis of the driving and dependence power of barriers to adopt industry 4.0 in Indian manufacturing industry. *Computers in Industry*, *101*, 107–119. https://doi.org/10.1016/j.compind.2018.06.004

Khan, S. K., Rashid. A., Benhamed, A., Rasheed, R., & Huma, Z. (2023b). Effect of leadership styles on employee performance by considering psychological capital as mediator: evidence from airlines industry in emerging economy. *World Journal of Entrepreneurship, Management and Sustainable Development*, *18*(6), 799-818. https://doi.org/10.47556/J.WJEMSD.18.6.2022.7

Khan, S., Rashid, A., Rasheed, R., & Amirah, N. A. (2023a). Designing a knowledge-based system (KBS) to study consumer purchase intention: the impact of digital influencers in Pakistan. *Kybernetes*, *52*(5), 1720-1744. https://doi.org/10.1108/K-06-2021-0497

Kiel, D., Müller, J. M., Arnold, C., & Voigt, K.-I. (2017). Sustainable industrial value creation: Benefits and challenges of industry 4.0. *International Journal of Innovation Management*, *21*(08), 1740015. https://doi.org/10.1142/s1363919617400151

Longo, F., Nicoletti, L., & Padovano, A. (2017). Smart operators in industry 4.0: A human-centered approach to enhance operators' capabilities and competencies within the new smart factory context. *Computers & Industrial Engineering*, *113*, 144–159. https://doi.org/10.1016/j.cie.2017.09.016

Lu, Y. (2017). Industry 4.0: A survey on technologies, applications and open research issues. *Journal of Industrial Information Integration*, *6*, 1–10. https://doi.org/10.1016/j.jii.2017.04.005

Luthra, S., & Mangla, S. K. (2018a). Evaluating challenges to Industry 4.0 initiatives for supply chain sustainability in emerging economies. *Process Safety and Environmental Protection : Transactions of the Institution of Chemical Engineers, Part B*, *117*, 168–179. https://doi.org/10.1016/j.psep.2018.04.018

Luthra, S., & Mangla, S. K. (2018b). When strategies matter: Adoption of sustainable supply chain management practices in an emerging economy's context. *Resources, Conservation, and Recycling*, *138*, 194–206. https://doi.org/10.1016/j.resconrec.2018.07.005

Manavalan, E., & Jayakrishna, K. (2019). A review of Internet of Things (IoT) embedded sustainable supply chain for industry 4.0 requirements. *Computers & Industrial Engineering*, *127*, 925–953. https://doi.org/10.1016/j.cie.2018.11.030

Nara, E. O. B., da Costa, M. B., Baierle, I. C., Schaefer, J. L., Benitez, G. B., do Santos, L. M. A. L., & Benitez, L. B. (2021). Expected impact of industry 4.0 technologies on sustainable development: A study in the context of Brazil's plastic industry. *Sustainable Production and Consumption*, *25*, 102–122. https://doi.org/10.1016/j.spc.2020.07.018

Nascimento, D. L. M., Alencastro, V., Quelhas, O. L. G., Caiado, R. G. G., Garza-Reyes, J. A., Rocha-Lona, L., & Tortorella, G. (2019). Exploring Industry 4.0 technologies to enable circular economy practices in a manufacturing context: A business model proposal. *Journal of Manufacturing Technology Management*, *30*(3), 607-627. https://doi.org/10.1108/JMTM-03-

2018-0071

Nicoletti, B. (2018). The Future: Procurement 4.0. In *Agile Procurement* (pp. 189–230). Springer International Publishing.

Oztemel, E., & Gursev, S. (2020). Literature review of Industry 4.0 and related technologies. *Journal of Intelligent Manufacturing*, *31*(1), 127–182. https://doi.org/10.1007/s10845-018-1433-8

Pereira, A. C., & Romero, F. (2017). A review of the meanings and the implications of the Industry 4.0 concept. *Procedia Manufacturing*, *13*, 1206–1214. https://doi.org/10.1016/j.promfg.2017.09.032

Rasheed, R., & Rashid, R. (2023). Role of service quality factors in word of mouth through student satisfaction. *Kybernetes*, In press. http://dx.doi.org/10.1108/k-01-2023-0119

Rasheed, R., Rashid, A., & Ngah, A. H. (2024). Role of Leadership Styles to Foster Innovative Capabilities and Green Purchasing. *Journal of Global Operations and Strategic Sourcing*, In press. https://doi.org/10.1108/JGOSS-05-2023-0047

Rasheed, R., Rashid, A., Amirah, N. A., & Afthanorhan, A. (2023). Quantifying the moderating effect of servant leadership between occupational stress and employee in-role and extra-role performance. *Calitatea*, *24*(195), 60-68. https://doi.org/10.47750/QAS/24.195.08

Rashid, A. & Rasheed, R. (2022). A Paradigm for Measuring Sustainable Performance Through Big Data Analytics–Artificial Intelligence in Manufacturing Firms. *Available at SSRN 4087758*. https://doi.org/10.2139/ssrn.4087758

Rashid, A. (2016). Impact of inventory management in downstream chains on customer satisfaction at manufacturing firms. *International Journal of Management*, *IT and Engineering*, *6*(6), 1-19.

Rashid, A., & Rasheed, R. (2023). Mediation of Inventory Management in the Relationship between Knowledge and Firm Performance. *SAGE Open*, *13*(2), 1-11. https://doi.org/10.1177/21582440231164593

Rashid, A., & Rasheed, R. (2024). Logistics Service Quality and Product Satisfaction in E-Commerce. *SAGE Open*, *14*(1), 1-12. https://doi.org/10.1177/21582440231224250

Rashid, A., Ali, S. B., Rasheed, R., Amirah, N. A. & Ngah, A. H. (2022a). A paradigm of blockchain and supply chain performance: a mediated model using structural equation modeling. *Kybernetes*, *52*(12), 6163-6178. https://doi.org/10.1108/K-04-2022-0543

Rashid, A., Amirah, N. A., & Yusof, Y. (2019). Statistical approach in exploring factors of documentation process and hospital performance: a preliminary study. *American Journal of Innovative Research and Applied Sciences*, *9*(4), 306-310.

Rashid, A., Amirah, N. A., Yusof, Y., & Mohd, A. T. (2020). Analysis of demographic factors on perceptions of inventory managers towards healthcare performance. *The Economics and Finance Letters*, *7*(2), 289-294. https://doi.org/10.18488/journal.29.2020.72.289.294

Rashid, A., Baloch, N., Rasheed, R., & Ngah, A. H. (2024a). Big Data Analytics-Artificial Intelligence and Sustainable Performance through Green Supply Chain Practices in Manufacturing Firms of a Developing Country. *Journal of Science and Technology Policy Management*, In press, *https://doi.org/*10.1108/JSTPM-04-2023-0050

Rashid, A., Rasheed, R., & Amirah, N. A. (2023). Information technology and people involvement in organizational performance through supply chain collaboration. *Journal of Science and Technology Policy Management*, In press. https://doi.org/10.1108/JSTPM-12-2022-0217

Rashid, A., Rasheed, R., & Amirah, N. A., & Afthanorhan, A. (2022b). Disruptive factors and customer satisfaction at chain stores in Karachi, Pakistan. *Journal of Distribution Science*, *20*(10), 93-103. https://doi.org/10.15722/jds.20.10.202210.93

Rashid, A., Rasheed, R., & Ngah, A. H. (2024d). Achieving Sustainability through Multifaceted Green Functions in Manufacturing. *Journal of Global Operations and Strategic Sourcing*, *17*(2), 402-428. https://doi.org/10.1108/JGOSS-06-2023-0054

Rashid, A., Rasheed, R., Amirah, N. A., Yusof, Y., Khan, S., & Agha, A., A. (2021). A Quantitative Perspective of Systematic Research: Easy and Step-by-Step Initial Guidelines. *Turkish Online Journal of Qualitative Inquiry*, *12*(9), 2874-2883. https://www.tojqi.net/index.php/journal/article/view/6159/4387

Rashid, A., Rasheed, R., Ngah, A. H., Pradeepa Jayaratne, M. D. R., Rahi, S. & Tunio, M. N. (2024c). Role of Information Processing and Digital Supply Chain in Supply Chain Resilience through Supply Chain Risk Management. *Journal of Global Operations and Strategic Sourcing*, *17*(2), 429-447. https://doi.org/10.1108/JGOSS-12-2023-0106

Rashid, A., Rasheed, R., Rahi, S., & Amirah, N. A. (2024e). Disruptive Factors of Vendor-Managed Inventory in the Manufacturing Industry. *Supply Chain Forum: An International Journal*, In press. https://doi.org/10.1080/16258312.2024.2330913

Rashid, A., Rasheed, R., Tanveer, U., Ishaq, S., & Amirah, N. A. (2024b). Mediation of Integrations in Supply Chain Information Management and Supply Chain Performance: An Empirical Study from a Developing Economy. *Journal of Science and Technology Policy Management*, In press. https://doi.org/10.1108/JSTPM-08-2023-0143

Stock, T., Obenaus, M., Kunz, S., & Kohl, H. (2018). Industry 4.0 as enabler for a sustainable development: A qualitative assessment of its ecological and social potential. *Process Safety and Environmental Protection : Transactions of the Institution of Chemical Engineers, Part B*, *118*, 254–267. https://doi.org/10.1016/j.psep.2018.06.026

Strange, R., & Zucchella, A. (2017). Industry 4.0, global value chains and international business. *Multinational Business Review*, *25*(3), 174–184. https://doi.org/10.1108/mbr-05-2017-0028

Sutawijaya, A. H., & Nawangsari, L. C. (2020). What is the impact of industry 4.0 to green supply chain. *Journal of Environmental Treatment Techniques*, *8*(1), 207–213.

Theorin, A., Bengtsson, K., Provost, J., Lieder, M., Johnsson, C., Lundholm, T., & Lennartson, B. (2017). An event-driven manufacturing information system architecture for Industry 4.0. *International Journal of Production Research*, *55*(5), 1297–1311. https://doi.org/10.1080/00207543.2016.1201604

Tjahjono, B., Esplugues, C., Ares, E., & Pelaez, G. (2017). What does Industry 4.0 mean to Supply Chain? *Procedia Manufacturing*, *13*, 1175–1182. https://doi.org/10.1016/j.promfg.2017.09.191

Wamba, S. F., Gunasekaran, A., Akter, S., Ren, S. J.-F., Dubey, R., & Childe, S. J. (2017). Big data analytics and firm performance: Effects of dynamic capabilities. *Journal of Business Research*, *70*, 356–365. https://doi.org/10.1016/j.jbusres.2016.08.009

Wang, S., Wan, J., Li, D., & Zhang, C. (2016). Implementing smart factory of industrie 4.0: An outlook. *International Journal of Distributed Sensor Networks*, *12*(1), 3159805. https://doi.org/10.1155/2016/3159805

Wu, L., Yue, X., Jin, A., & Yen, D. C. (2016). Smart supply chain management: a review and implications for future research. *International Journal of Logistics Management*, *27*(2), 395–417. https://doi.org/10.1108/ijlm-02-2014-0035

Xu, L. D., Xu, E. L., & Li, L. (2018). Industry 4.0: state of the art and future trends. *International Journal of Production Research*, *56*(8), 2941–2962. https://doi.org/10.1080/00207543.2018.1444806