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The Role of Data Management and Automation in the Impact of Industry 4.0 On Supply Chain Performance: Empirical Analysis

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Abstract: This research aims to assess the degree to which the Pakistani textile sector is ready for industry 4.0 (I4.0) and how this readiness affects Supply Chain (SC) performance. The paper seeks to provide concrete evidence of the potential benefits of implementing Industry 4.0 by the Data Management (DM) and Automation Level (AL) and how doing so can affect SC efficiency. An empirical study is conducted to evaluate the capability of the industry to implement industry 4.0 and its effects on SC efficiency. Three hundred and fifty-one workers in Pakistan's textile sector provided the data. The research has two main categories. After determining the state of DM and AL in the business world and the sector's overall level of preparedness, the author used a Structural Equation Model (SEM) strategy to find the impact on SC performance. The author evaluated a research framework in Spss and AMOS. By employing a CFA and SEM strategy, we learned that DM and AL significantly influence the feasibility of implementing industry 4.0. It demonstrates a significant negative relationship between the possible application of industry 4.0 and SC efficiency. The study only looked at the Pakistani textile industry, limiting its applicability to other emerging countries and manufacturing sectors like automobiles and electronics. As a result of this study, businesses will have a better idea of where they need to focus their efforts to improve. Managers and researchers can determine the readiness level of any organization or sector by assessing how well they fit the study's components and framework. This research contributes to the literature by expanding our understanding of the interplay between DM, AL, the application of industry 4.0, and the performance of SC through the presentation of new data and empirical findings. Researchers and businesses can then coordinate their efforts to advance toward Industry 4.0 and identify the roadblocks to improved SC efficiencies.

Keywords: Data management, Automation level, Supply chain performance, Potential use of industry 4.0

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INTRODUCTION

Humans have been searching for methods to enhance the SC since trading began, whether to fix an issue with operations or make the system more streamlined and reliable. Robotics (including automation) and new ideas are two forms of technology that have significantly contributed to these advancements.

In the 1950s and 1960s, most enterprises relied on mass production to reduce unit costs, with little product or process flexibility. Product innovation was slow due to internal isolation. Extra supplies were kept on hand and used as a buffer to minimize bottlenecks, resulting in a considerable WIP expense. Researchers viewed cooperation and buyer-supplier cooperation as too risky and undesirable. In the 1970s, managers realized the detrimental consequences of huge WIP inventories on manufacturing costs, quality, product development, and delivery lead time, which led to the Material Needs Planning (MRP). Manufacturers use new materials management technologies to enhance production. Due to the complexity of today's economic climate, the unpredictable consumer demand, and the need for a company's adaptability, cutting-edge technology is gaining relevance (Öberg & Graham, 2016; Chung & Swink, 2009). Companies now consider technical development a formidable strategic weapon for long-term success and sustainable performance (Shrivastava, Ivanaj, & Ivanaj, 2016; Villagomez et al., 2019). In the 1980s, when the competition was intense worldwide, even famous corporations lowered costs without losing quality or dependability. Just in Time (JIT) and other management technologies improved manufacturing efficiency and cycle time. Manufacturers have come to appreciate strategic buyer-supplier collaborations in JIT manufacturing, where stockpiles are tiny and production issues are infrequent. SCM originated when firms formed agreements with their closest suppliers. Logistics professionals added shipping, storage, and inventory management to the idea (Tan, 2001).

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The fast pace of information and communication technologies and their inclusion into SC's over the past few years have steered the fourth industrial revolution, termed "Industry 4.0." (Alejandro Frank, Mendes, Ayala, & Ghezzi, 2019). As a result of technological advancements and shifting consumer preferences, commercial competitiveness has intensified. As business ecosystems undergo radical change, operational frameworks and management strategies are highly influenced to adapt and integrate with new issues in an ever-changing environment (Barreto, Amaral, & Pereira, 2017).

Industry 4.0 is anticipated to significantly affect industrial production, management, logistics, and BPM (Strange & Zucchella, 2017). Digitalization has become an absolute must for SC to succeed in the current fast-paced, aggressive marketplace (Pereira & Romero, 2017). To effectively manage the next generation of digital SCs, businesses must integrate new technology into their operational procedures and deal with the ever-increasing volume of data flowing through their value chain Despite being among the world's top 10 textile exporters, Pakistan is a developing nation.

The country accounts for 2.2% of global textile and garment exports. In contrast, the textile industry is critically important to the home economy. More than 80% of Pakistan's textile output is thought to be exported as raw materials (yarn and textiles) or as finished items (clothing, housewares, towels). Several reports have focused attention on the global problems within the textile industry. Mehar (2002); Pandey and Savita (2017) have highlighted critical concerns about the trade in textiles and clothing in the Indian and Pakistani settings. One of Pakistan's primary sources of export revenue is its textile industry. Pakistan's textile industry may improve its output and exports by capitalizing on the country's innate knowledge of the global market for its traditional goods. Investment in machinery, equipment, and new technology is crucial if the company keeps its current market share and expands into higher-margin high-value items. Training employees, increasing labor productivity, conducting research and development, developing product lines, and building a name for one's brand are all pressing concerns for every business. It has, however, been experiencing several technological difficulties. Slow technical progress is detrimental to production, which in turn has affected overall performance. Over 60% of Pakistan's total exports come from the textile sector (Pakistan Bureau of Statistics- 2022). Figure 1 shows the exports of Pakistan's textile industry in the last five years, which offers an overall increase over the previous two years.

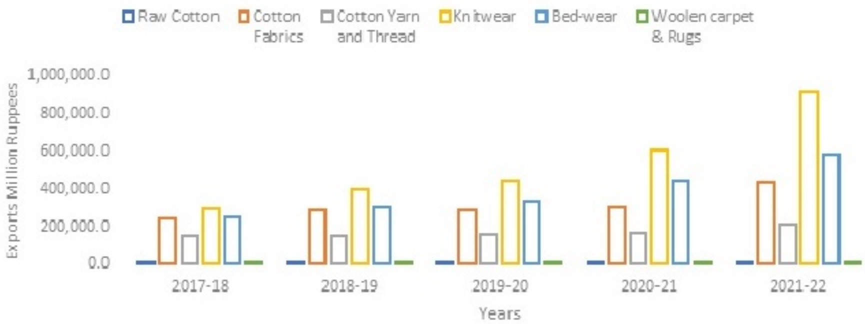

Figure 1: Export by commodity/ group

There is now an urgent need to investigate SC management beyond only logistics to reclaim worldwide competitiveness. Many sectors are hesitant to adopt technological advancements because of unstable market conditions (Gloy, Greb, & Gries, 2013; Simonis, Gloy, & Gries, 2016). The world is changing so quickly that waiting to act is no longer an option (Gloy et al., 2013). Industry hurdles include:

- Uncertain monetary advantages (Küsters, Praß, & Gloy, 2017).
- Cybersecurity concerns
- A need for more expertise
- A reluctance to accept dramatic change
- A failure to effectively cooperate within departments

SC, business models, and processes will undergo substantial shifts because of Industry 4.0 (Blanchet, Rinn, Von Thaden, & De Thieulloy, 2014). Therefore, many industries need help assessing the diversity of advances and concepts represented under industry 4.0 and developing their development plans (Beckert, 2015).

Hype and over enthusiasm accompany industry 4.0 much as they have preceded other disruptive innovations. As a result, many sectors and organizations need help implementing industry 4.0 or start too early and make irreparable mistakes. Studies have been conducted to investigate the usefulness of Industry 4.0. However, it is still being determined what critical aspects determine the future usage of Industry 4.0. Furthermore, how they will affect SC performance.

As a result, this article provides information on the potential of implementing Industry 4.0. More importantly, how it impacts efficiency in the SC. Studies have either measured the readiness for industry 4.0 or its impact on many facets of business, but they have yet to do both analyses simultaneously. We did some investigation into how a company's level of maturity impacts SC performance. This method will allow researchers and businesses to focus on achieving Industry 4.0 and removing the roadblocks preventing greater SC efficiencies.

LITERATURE REVIEW

Industry 4.0

The phrase "industry 4.0" is considered an umbrella, covering not just a wide range of cutting-edge ideas but also a wide range of related fields of study (Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014). Internet of things (IoT), cyber-physical systems (CPS), smart factories, big data, and interoperability all come together to form an example characterized by rapid technological development. It is possible that introducing such technologies would lead to a change in the manufacturing process, a phenomenon known as the "technology push" (Lasi et al., 2014). Factories, especially those in high-cost countries, need to be able to compete globally despite differences in labor costs by making use of the innovations made possible by Industry 4.0. (Buer, Strandhagen, & Chan, 2018). The potential of I4.0 is enormous, especially by utilizing the fundamental shifts in market structures, production practices, and organizational norms innovations in science and technology; it will create numerous business and societal prospects (Brixner et al., 2020). The industrial internet of things (IIoT), a subset of IoT (Ghobakhloo, 2018; Haddud, DeSouza, Khare, & Lee, 2017), is an essential component of the Fourth Industrial Revolution. In addition to the Internet of Things (IoT), other significant technologies such as cloud computing, artificial intelligence, intelligent enterprise resource planning, programmable logic controllers, automation/industrial robots, sensors/actuators, additive manufacturing, simulation, and other innovative models of data exchange play a crucial role in digitalizing SC (Dalenogare, Benitez, Ayala, & Frank, 2018; Alejandro Germán Frank, Dalenogare, & Ayala, 2019; Ghobakhloo, 2018). Through the collection and analysis of data from a wide range of devices, sensors, and tools, the automated systems that makeup "Industry 4.0" make it possible to increase the speed, flexibility, and adaptability of production and service delivery (Ghadge, Kara, Moradlou, & Goswami, 2020).

The Internet of Things is primarily utilized for data collection from textile machinery, but it is also employed as a component in more advanced Industry 4.0 setups. Cloud computing has facilitated improved collaboration across businesses in the textile industry (Kemper, Gloy, & Gries, 2017; Damodaram & Ravindra Nath, 2010). It has been observed that Virtual Reality (VR) or Augmented Reality (AR) is being used in the retail sector to improve the consumer experience and is also used to address a significant issue in the textile industry—the need to upskill the workforce. The impact on social and economic sustainability could be substantial. Using Internet of Things (IoT) sensors, Radio Frequency Identification (RFID) readers, and a bespoke piece of software was able to create a Central Processing System (CPS) that ties together various stages of the textile production chain, allowing for the collection of new data and the exercise of greater control (Stulga, Whitfield, Love, & Evans, 2022).

The full potential of Industry 4.0 may be achieved if the ideas and technologies shown in Table 1 are implemented (Akdil, Ustundag, & Cevikcan, 2018).

Table 1: Principles and technologies concerning industry 4.0

Principles	Technologies
Real-time DM	Internet of things (IoT)
Interoperability	Cyber-physical system
Virtualization	Cloud computing
Agility	Additive manufacturing
Decentralization	Augmented reality
Integrated business	Block chain
processes	Big data analytics

Data management

Data is the "oil" of the modern day. This analogy adequately captures the significance of this concept in the present day. The information age is often compared to a car: the combustion engine is information. More is needed to collect data; it also needs to know how to organize it, retrieve relevant information, and apply it in meaningful ways. Plug-and-produce strategies based on autonomous assembly stations are replacing the more rigid mass manufacturing methods of the past (Lucas-Estañ & Gozalvez, 2019).

Data is the way to make smarter choices. It shows that when comparing firms based on financial and operational performance, the ones that are more data-driven fare better (McAfee, Brynjolfsson, Davenport, Patil, & Barton, 2012). Management of data is becoming increasingly complex in the digital age. It is no exaggeration to say that access to reliable information is crucial to a company's success in today's economy, where data has become the most valuable resource (Axmann & Harmoko, 2020; Emami-Naeini, Dixon, Agarwal, & Cranor, 2019). Correctness, veracity, accessibility, objectivity, timeliness, relevance, and usefulness are the pillars of data quality (Axmann, Hamberger, & Liegl, 2019). Data exchange and storage are more common among SMEs than large enterprises (Axmann & Harmoko, 2020).

Everything from data collection and processing to dissemination and decision-making is automated. Through this method, the company can make better use of its resources. Consequently, enhanced automation may be attributed to the rising 4.0 industrial potential (Storey & Song, 2017).

Automation level

The idea of a "digital factory" may be summed up as "Industry 4.0." (Hofmann & Rüsch, 2017). Fully automated processes and procedures with less human contact characterize a digital factory.

Strategic benefits and customer-focused services are possible with enhanced SC automation (He, Aggarwal, & Nof, 2018). "To ensure that supplies are not running low, a sensor-based automated inventory management system can now assess stock levels and place orders as needed. Consequently, the amount of trash created may be drastically reduced, and workers can shift their attention to other tasks " (Chowdhury & Raut, 2019). Research shows that SC quality, traceability, and efficiency may all improve with automation (Da Xu, He, & Li, 2014). Organizations need help when new technologies are introduced. If the SC is to maintain its competitive advantage, it must adopt the most cutting-edge innovations (Büyüközkan & Göçer, 2018). Robots should not be dreaded; they should be incorporated in systems. Automation spreads to encompass robots, AI, and automated procedures. SC procedures are simplified and streamlined by automation as reported by (Büyüközkan & Göçer, 2018).

Spreadsheets are used for reporting in conventional SC, although this method needs to be revised and reliable. A significant weakness is their virility to provide a competitive edge to any sector. Real-time execution choices, process optimization, and big data analytics make efficiency possible.

Production lines can be completely mechanized once Industry 4.0 technologies are implemented. The manufacturing operations will be fully automated. Intelligent parts will eventually be able to direct and regulate themselves by AI to reach the pinnacle (Büyüközkan & Göçer, 2018; Waheed, Kaur, Ain, & Sanni, 2015). Without human assistance, these production systems can share information (Weyer, Schmitt, Ohmer, & Gorecky, 2015).

Potential use of industry 4.0

"Readiness" and "maturity" are similar concepts (Carolis, Macchi, Negri, & Terzi, 2017). By indicating a person's or company's current maturity level, MMs may help them through a steady growth process (Mittal, Khan, Romero, & Wuest, 2018). Preparedness evaluations evaluate the level of preparedness, attitude, and resources at all system levels. Many companies declare I4.0 as a development target and need to understand how to get there (Ghobakhloo, 2018). Actively developing I4.0 companies must know their resources and technologies (Carolis et al., 2017).

Simpson, Weiner, and Oxford University Press (1989) define maturity as "completeness, perfection, or readiness." To progress means a system has evolved. Developing a system (biological, organizational, or technological) increases its capabilities. According to Kohlegger, Maier, and Thalmann (2009), qualitative and quantitative techniques are beneficial for measuring maturity. Mature models are often used to conceptualize and assess company or process maturity. Using models that record beginning circumstances and start development simplifies project planning. Before starting the maturing process, we analyze preparedness to capture the current scenario.

"IT readiness" describes a business's preparedness to implement and profit from IT (Dyerson, Spinelli, & Harindranath, 2016; Kwahk & Lee, 2008). Readiness requires maturity. Maturity is judged after a project is implemented, whereas preparation is examined before(Schumacher, Erol, & Sihn, 2016).

With Industry 4.0, materials, equipment, and SC characteristics can be monitored and controlled in real-time, improving value chain efficiency and lessening risk (Caiado, Scavarda, Azevedo, de Mattos Nascimento, & Quelhas, 2022; Luthra & Mangla, 2018). Industry 4.0 applications transform business paradigms and network management (Ghobakhloo, 2018; Jamwal, Agrawal, Sharma, & Giallanza, 2021).

Impact of industry 4.0 on supply chain

The SC sector is rapidly digitizing, automating, and evolving. From product creation to manufacturing to distribution, today's digital SC networks employ various technologies to deliver a flexible, scalable, and reliable backbone for the whole SC. Industry 4.0 is having an impact on SC and Supply Chain Management (SCM) strategies in a variety of ways, including more accurate forecasting and planning thanks to integrated flow and increased traceability of materials and products, improved supplier performance thanks to real-time information sharing and synchronization with suppliers, and intelligent warehousing and vehicle routing systems (Ghobakhloo, 2018; Hofmann & Rüsch, 2017; Ivanov, Dolgui, & Sokolov, 2022).

Companies need to reevaluate the structure of their SC networks, considering the challenges of digitization. Due to the transparency that e-commerce sites provide regarding product pricing, stock levels, and expected shipping timeframes, the SC now features more intense levels of competition. The Internet of Things (IoT) is crucial to developing SCs because it allows for numerous new applications, including remote and real-time vehicle tracking, freshness tracking of perishable commodities using temperature sensors, machine health and efficiency updates (Kumaresh, Gupta, Jawaha, Pareek, & Kumar; Manavalan & Jayakrishna, 2019). Increasing data sharing and coordination levels among SC partners facilitate lower operating expenses and more excellent responsiveness and flexibility across the SC (Frank et al., 2019; Ghobakhloo, Fathi, Iranmanesh, Maroufkhani, & Morales, 2021).

Enhanced trust and closer bonds amongst SC members are other benefits of the network's greater openness and cooperation. Industry 4.0 improves value chain performance and reduces risks with capabilities such as highly structured interconnection and real-time monitoring and control of materials, equipment, and SC parameters(Sharma et al., 2021). Business models and management techniques in these networks are changing due to Industry 4.0.(Ghobakhloo et al., 2021; Montasser, & El-Nakeeb, 2017).

Modern digital SC networks are used across the board in the product life cycle to construct effective, open, adaptable, and resilient structures. These phases include conceptualization, design, fabrication, Supply Chain Management (SCM), and promotion. Improved supplier performance through real-time information interchange and synchronization, more accurate forecasting and planning through integrated flow, and improved commodity traceability are just a few ways SCM strategies may be influenced by Industry 4.0. (Ghobakhloo, 2018; Hofmann & Rüsch, 2017).

Obtaining exact data is simple when employing Industry 4.0 practices. Future performance management systems will improve SC transparency (Miragliotta, Sianesi, Convertini, & Distante, 2018). Everything from the broad picture, like customer service and order fulfilment, down to the little, like the precise position of vehicles, is tracked and recorded by the logistics system. Improvements in physical job automation, planning, control, and data transfer are primarily responsible for SC's recent surge in output (Barreto et al., 2017). Because of IT development, many businesses today use software to automate their SCM (Xu, Xu, & Li, 2018). Through collaborative business activities, transport efficiency may be improved across organizations. Continued work is being put towards optimizing the SC network for the business. The main benefits of digital technology to SCM are shown in Table 2 (Ardito, Petruzzelli, Panniello, & Garavelli, 2018; Tran et al., 2021)

Table 2: Industry 4.0 technology and their benefits to SCM

Technology	Benefits to SCM
Industrial IoT	Collection of operational data (such as product life cycle and supply chain information) in real-time
Cloud computing	Using IoT technology to collect operational data and store it in a structured fashion
	Distributing marketing-related data in real-time from operations
	Supply chain-wide real-time access to operational data
	faster communication along the entire supply chain
Data analytics and customer profiling	Estimating Future Needs and Requirements
	Improved quality of service
	Minimized Purchasing Expenses
	Decreasing stock
	Stock-outs are less frequent
Cyber security	Protecting information about products and suppliers

Framework and hypothesis

Theories on the factors that affect the adoption and use of new technologies in the industry are examined. The TOE framework describes the interplay between the technological, organizational, and societal factors influencing a company's decision to embrace and use new technologies. It makes more sense to use the TOE framework to investigate Industry 4.0. With TOE, we explore the variables that affect the likelihood of technological adoption (Abed, 2020) Researchers employ the TOE strategy to enquire into the practical applications of technology, including Electronic Data Interchange (EDI), Web 2.0, mobile reservation systems, and Enterprise Resource Planning (ERP) things like systems, e-SCM, e-commerce, Information and Communication Technology (Lin, Schulz, & Straube, 2017). Organizational and technological contexts are discussed, as is the role each plays in adopting and implementing new technologies inside an organization (Abed, 2020). We reviewed the literature and devised a framework to examine how different DM and ALs affect the viability of implementing industry 4.0. After that, we discussed how PUI affects SC performance.

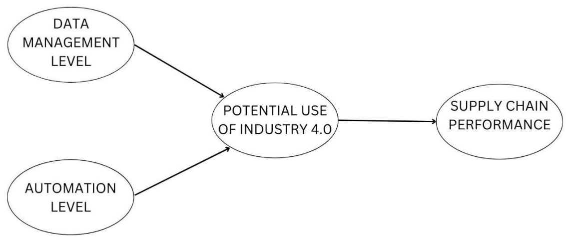

Figure 2: Conceptual framework

Based on the above framework, we proposed three hypotheses;

Since the beginning of the Fourth Industrial Revolution, the rate at which new information is generated has increased dramatically in quality, volume, and velocity (Lee, Kao, & Yang, 2014). The type and volume of collected data have significantly increased as sensor technology and the computer capability of the devices themselves have advanced. When taking measurements, only the most important ones were considered in the past. A constant flow of data is generated today (Schmidt et al., 2015). A continual data stream is available instead of isolated instances or brief periods. Previously impossible levels of analysis and optimization of manufacturing are now possible because of the vast volumes of data accessible. Improved predictive analytics is a result. So, we proposed our first hypothesis.

H1: DM has a significant impact on Industry 4.0's potential.

According to Groover (2001), automation is "any technology that allows a process or operation to be carried out without the intervention of human beings." Industrial Revolution 4.0 (I4.0) refers to the current movement toward more digitization and automation in the factory (Ashima, Haleem, Bahl, Nandan, & Javaid, 2023; Oesterreich & Teuteberg, 2016). To achieve optimal workflow, assembly systems must deliver the right items to the right place at the right time in the correct quantity, all while reducing waste, being adaptable, and being able to adjust (Liker, 2004). Based on the literature second hypothesis is proposed.

H2: AL has a substantial effect on the possible use of industry 4.0.

SC performance parameters are indicators used to evaluate a specific SC system's efficiency and effectiveness. Quantitative indicators of SC effectiveness include revenue growth, expense cuts, ROI improvements, fill rates, reduced lead times, faster product deliveries, and quicker responses to customer requests (Lima-Junior & Carpinetti, 2017). I4.0 can significantly alter SC systems, policies, and models (Duarte & Machado, 2017; Fatorachian & Kazemi, 2021). I4.0 promotes horizontal, vertical, and end-to-end digital integration in industrial supply chains SC to increase social, economic, and environmental benefits that contribute to a sustainable culture (Bag, Gupta, & Kumar, 2021). As a result, total system integration and automation are affected across the SC (Luthra, Kumar, Zavadskas, Mangla, & Garza-Reyes, 2020).

H3: Potential use of industry 4.0 affect significantly SC performance.

RESEARCH METHODOLOGY

The textile industry is primarily targeted because of the difficulties it faces, including the need to select the appropriate distribution channel (Khan & Khan, 2010), a lack of government support in the form of tax incentives for exports, imports, infrastructure development (Afzal, Rasool, Waseem, & Aslam, 2017) and a lack of technological improvements.

We divided our model into two parts.

In the first section, we evaluated the DM and automation capabilities of industry 4.0. We used six groups of sequential and cumulative metrics (Pacchini, Lucato, Facchini, & Mummolo, 2019) based on the International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC) 15504-5 standard elaborated in Table 3 to assess an enterprise's readiness to implement industry 4.0.

Table 3: Status of readiness

Degree of Readiness %	Status	Description
0-10	Embryonic	Industry professionals have only a cursory understanding of a handful of critical enablers.
10-25	Initial	The industry may be familiar with some but not all emerging technologies.
25-50	Primary	The industry understands all technologies, but not all have been adopted.
50-75	Intermediate	The industry is fully aware of all available technologies and has begun implementing some of them.
75-90	Advance	To a large extent, all technologies are widely adopted and are well-known throughout the industry.
90-100	Ready	All necessary technologies for this sector's most incredible acceptance rate have already been implemented.

In the second part, we used the Analysis of Moment Structure (AMOS) tool, which allows us to use statistical methods like SEMing (SEM) and Confirmatory Factor Analysis (CFA). Structural modelling employs (SEM), while CFA serves as the measurement model. Hypothesized causal relationships between several constructs with statistical dependencies are modelled using a SEM (Shipley, 2016). SEMling is carried out utilizing AMOS 24. In the current study, we chose to utilize AMOS for SEM because its graphical representation of the path diagram is intuitive. Since any model can be built with a few sketching tools and drag-and-drop capabilities without the need for command-line input, AMOS may be used to analyze the data after it is imported.

Validation of the data's compatibility with the suggested model has been accomplished using SEMing (SEM). For this study, we analyzed data from a total of 370 replies. Literature states that the minimum sample size necessary to utilize SEM depends on the number of indicators, parameters, cases, and multivariate normality of the data; moreover, there has yet to be a general agreement. A sample size of 200 to 400 numbers is suggested by Jackson (2001).

Information is gathered from operational managers, SCM, and front-line managers of the textile industry who are directly involved in Industry 4.0 operations through a survey questionnaire.

Summary of research design

In this study, we gathered information from Pakistan's textile industry to assess the sector's preparation for Industry 4.0 and its effect on SC performance. We have chosen to focus on Pakistan's textile business. We targeted the companies that are listed on the SECP of Pakistan. We selected staff line, middle, and top managers as respondents because of the breadth and depth of their knowledge and experience inside the firm. We sent out our questionnaire through emails and filled out some on the telephone. A summary of sample details is shown in Table 4.

Table 4: Research design

Targeted Audience	Details
Target	Textile Industry of Pakistan
Sample source	SECP-listed textile companies
Sample size	351
Method of survey	Email, Online, telephonic
Statistical tools	MS Excel, Spss 21, Amos 24
Statistical technique	CFA, SEM, Cronbach's alpha

Four hundred twenty-three textile industries are working in the country. We included SECP-registered companies in our analysis. Pakistani textile industry has three major sections that are shown in Table 5.

Table 5: Textile companies listed in SECP

Textile Companies SECP	123
Composite	51
Spinning	63
Weaving	9

Composite mills are vertically integrated facilities that perform all stages of textile production in-house, including dying, printing, spinning, weaving, and finishing.

Spinning is creating yarns or threads for textile crafts like weaving and knitting. Spinning mills are essential to the textile industry since they produce wool by twisting together several drawn-out fiber strands.

Fabrics, such as plain or patterned weaves and ribbons, are woven by piling yarns or threads across to form long strips. The creation of cloth from lines is known as weaving.

These companies reside in Faisalabad, Haripur, Hyderabad, Islamabad, Karachi, Kasur, Khyber, Pakhtunkhwa, Kohat, Lahore, Multan, and Rawalpindi as shown in numbers in Table 6 and Figure 3.

Table 6: Number of textile companies in different cities

Cities	Number of Companies
Faisalabad	11
Haripur	1
Hyderabad	2
Islamabad	2
Karachi	50
Kasur	3
Khyber Pakhtoonkhwa	1
Kohat	1
Lahore	42
Multan	7
Rawalpindi	3

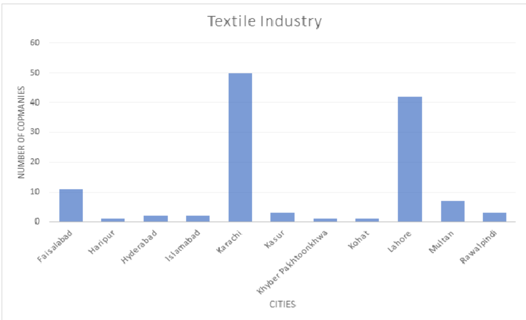

Figure 3: Textile industries in different cities in Pakistan

Data collection

We collected the data by sending questionnaires through email, google forms and some through telephone. About two-thirds (400) of the 450 questionnaires we sent out were returned for analysis, and 49 were deemed ineligible for further review because of incomplete information. Thus, data from 351 completed questionnaires are analyzed using the Amos-SEM.

We used a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) to collect our data. A Likert scale is recommended to analyze better respondents' thoughts and feelings (Sekaran & Bougie, 2016). In addition, a 5-point Likert scale is favored since it decreases responder irritation while boosting data novelty. Eight items adopted from Terry Anthony Byrd (2000) measure the DM level. Eight items for the AL are adopted from Barua, Konana, Whinston, and Yin (2004). We adopted ten items from Singhry (2015) to assess SC performance.

To ensure validity and dependability, we employed a dual method. Two of the responsibilities are to guarantee the accuracy of the measuring tools, the models' reliability, and the responses' accuracy. Statistical tests are employed to ensure the instruments and models are valid, while a demographic check is used to ensure respondents are who they said they were. The questionnaires used in this study are split up into two distinct sections. Part one of the survey inquired about demographic information such as respondents' gender, age, working experience, and management level. Reaching our target population and ensuring that our respondents are credible and genuine required the usage of socio-demographic questions. We used these questions about demographics to double-check the data with the HR department of the sample population. The author contacted HR divisions to verify how many managers are present in the various age ranges, levels of experience, and gender of the divisions we are interested in. We compared the HR department's answer sheet with the responses once we received it. The goal is to eliminate any subjects whose HR and self-reported demographic information did not match. To protect the privacy of those that responded, we did not give out any names to HR when we asked them for information. As a result, demographic verification aided in determining the credibility and authenticity of the respondents.

Questions about DM, automation, and SC performance made up the second section of the questionnaire.

ANALYSIS AND RESULTS

Demographics analysis

We compile data tables from the SPSS database to analyze the demographic proportions in a single pass. Table 7 reveals that most respondents (out of 351) had between 11 and 15 years of work experience, while Table 9 demonstrates that men make up most of the workforce. According to Table 8, the percentage of staff line managers ranges from 66.3% to 27.9%, with 8.8% being upper-level management. Table 9 shows that 77.8% of our sample are male respondents. Table 10 shows that the average age of a company's employees is over 40.

Table 7: Work experience of participants

		Frequency	Percent
Work experience	less than 5	37	10.5
	10-Jun	123	35
	15-Nov	137	39
	16-20	54	15.4
	Total	351	100

Table 8: Management level of participants

		Frequency	Percent
Management level	Staff line supervisor	222	63.2
	Middle management	98	27.9
	Top Management	31	8.8
	Total	351	100

Table 9: Gender of participants

		Frequency	Percent
Gender	Male	273	77.8
	Female	78	22.2
	Total	351	100

Table 10: Age of participants

		Frequency	Percent
Age	less than 25	13	3.7
	26-30	24	6.8
	31-35	115	32.8
	36-40	80	22.8
	above 40	119	33.9
	Total	351	100

Next, we utilize cross tabs (Figure 4) to compare the two demographic variables. According to that, more men aged 40 and up are employed in the industry. The actual population of women is lower than men.

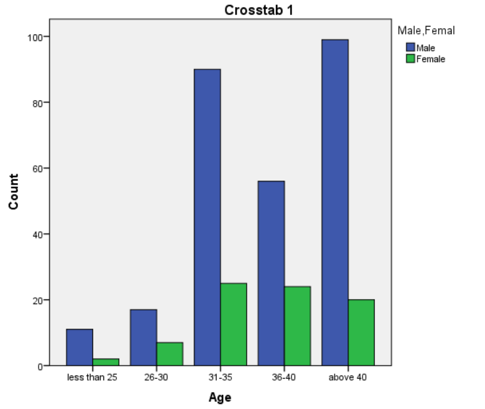

Figure 4: Cross comparison of age and gender

The count is the number of responses in above figure.

Figure 5 reveals an intriguing fact: A more significant fraction of staff line managers had birthdays in the 1980s and 1990s. An overwhelming majority of middle managers are between 36 and 40. There appears to be a maximum of 30 working in upper management.

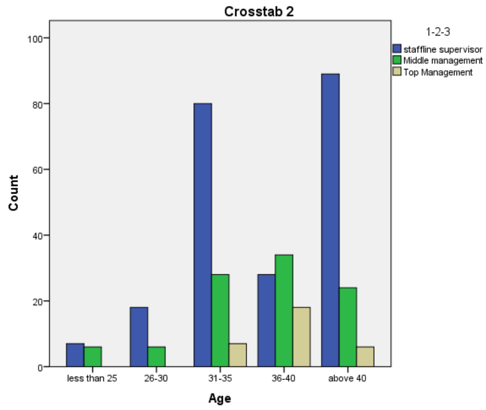

Figure 5: Cross comparison of age and management level

Potential use of industry 4.0

We suggest measuring the amount of adoption utilizing a development presented to gauge a company's preparedness concerning an enabling technology (Lucato, Pacchini, Facchini, & Mummolo, 2019). According to (Günther, Mehrizi, Huysman, & Feldberg, 2017), we may determine an element's readiness level, denoted as 'n,' by dividing the number of points we got from our evaluation by the sum of the points we might have earned.

$$gn = \sum \text{points obtained as a result of an evaluation of components of element/Maximum points possible} \quad (1)$$

$$DR =| g1 + g2 + g3 + \cdots + gn/n = \sum n1gm/n \quad (2)$$

Here DR = degree of readiness of a given company. g1 = degree of adoption concerning component 1 (Score of the first indicator). g2 = degree of adoption concerning component 2 (score of the second indicator). and gn = degree of adoption concerning component n (score of n indicator) Following the rules mentioned above, we calculated the readiness level of organizations in the context of DM and AL.

Table 11: Potential and status of DM and AL

Status	Dimension	Potential
Intermediate	DM Level DM	52.10826
Intermediate	AL	64.60826

Regarding the technological landscape, the term "status" indicates the current industry climate. The industry is said to be at an "intermediate" level if its preparedness falls between 50% and 75%. The results in Table 11 suggest that DM is at a 52% readiness level and that the AL has a 64.6%. It signifies that the Pakistani textile sector has begun adopting new technology and reached the intermediate development stage.

Model analysis

Reliability statistics The reliability of a test is how consistent or steady the results are. We utilized SPSS's Cronbach's alpha for multiple-choice assessments to determine internal consistency. When Cronbach's alpha is more than 0.7, it shows that the data is highly reliable among themselves. Our model's Cronbach's alpha is 0.767 (Table 12) based on all the factors we examined.

Table 12: Reliability statistics

Cronbach's Alpha	N of Items
.767	27

To check if the present model is a good match for the data at hand, a CFA is carried out in AMOS 24. To determine whether the current model, which contains DM, AL, PUI, and SCP, is a good match, the calculation of the essential indices of model fitness shows a perfect fit, as shown in Table 13.

Table 13: Model fit indices for CFA

Indicator	Threshold	Findings
CMIN/DF	3	2.549
GFI	0.8	0.851
CFI	0.9	0.93
IFI	0.9	0.935
RMSEA	0.08	0.067

CMIN/df

The Chi-square value, abbreviated as CMIN, is used to evaluate the statistical significance of the differences between the observed and predicted values. The model's flexibility is quantified by a parameter called Degree of Freedom (DF). The data matches the model perfectly if the chi-square value is 0. A high chi-square value indicates a low degree of fitness. Therefore, chi-square fit measures how well a given model fits the data. To ensure a satisfactory fit, a CMIN value below 3 is advised (Byrne, 2012). The resulting CMIN value is 2.54. As a result, we know that the model is satisfactory.

GFI

The Goodness of Fit Index (GFI) measures how well two data sets fit together under maximum likelihood assumptions (Tanaka & Huba, 1985). It was in 1981 that the first standardized fit index, the Good of Fit Index (GFI), was conceived. It is nearly close to R^2 in nature. It can take on values between 0 and 1, where 1 denotes an excellent fit and 0 is an imperfect one. For CFA, we found a GFI of 0.851 using AMOS, which falls within the range of values considered "good" (Shevlin & Miles, 1998).

CFI

Comparative Fit Index finds a gap between the theoretical model and market data samples. It is a normed number. Thus, it can be anywhere from 0 to 1. For a perfect match, set the value to 1. It is considered a good match if the value exceeds 0.90 (Hu & Bentler, 1999). The CFI for CFA is 0.93, which is within the allowable range, as shown by the AMOS output result.

RMSEA

Root Mean Square Error of Approximation (RMSEA) compares the observed and predicted covariance matrices for each degree of freedom (Chen, 2007). It is possible to have an RMSEA score between 0 and 1. The lower the value, the better the fit, in contrast to most other indices. Its value of 0 shows a perfect fit with the model, while a value of 1 indicates a total departure from The model. There is no unacceptable range unless the value exceeds 0.08 (MacCallum, Browne, & Sugawara, 1996). RMSEA of 0.067 is less than the threshold of 0.08 required for the broad applicability of the hypothesized model.

Table 14: AMOS SEM output

	ESTIMATES	*p*-value
PUIa <— DMa	.485	0.001
PUIa <— ALa	.755	0.001
SPa <— PUIa	-.236	0.001

All the model's fit metrics—CMIN/DF, GFI, IFI, CFI, and RMSEA—are within their respective acceptable limits, demonstrating that the present model is solid.

Structural equation model

SEM estimates how well the model fits the data after it passes reliability and validity tests. We will need to develop the SEM path diagram from the theoretical framework. Figure 4 is a representation of the structural model's causal diagram. The mathematical equation is graphically represented in Figure 3 (Byrne, 2012). It provides a formal mathematical illustration of the interdependencies between the various components. The magnitude of an exogenous variable's effect on an endogenous variable can be determined by comparing the two variables' unstandardized and standardized regression coefficients.

The sample data can be imported from SPSS into AMOS after the SEM is drawn, and then the model is run. Table 14 and Figure 6 shows the output of AMOS.

P-value less than 0.5 allows us to accept the hypothesis, and estimates show the relationship's nature. In the above table, we can understand that all hypotheses are accepted. A value of 0.001 indicates a significant relationship between our DM and potential use of industry 4.0, AL and potential use of industry 4.0, the potential use of industry 4.0 and SC performance. DM to PUI and AL to PUI show significant positive relation, while PUI and SP show a significant negative relationship.

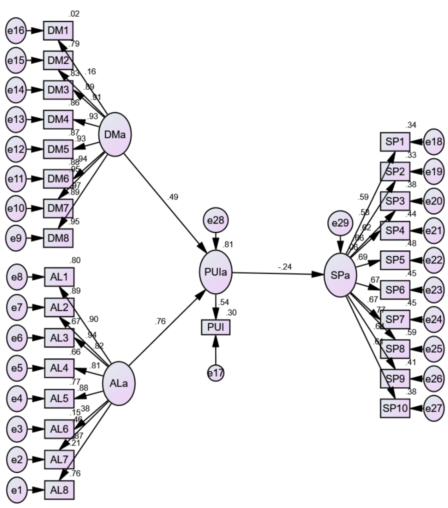

Figure 6: SEM

DISCUSSION

This study is the first to employ SEM. The data's compatibility with the suggested model is tested using SEM. It helped us to investigate the status of the potential application of Industry 4.0 in the DM and AL and the overall influence on SC performance in the Pakistani environment. Since the sample data agrees with the hypothesized model, we have extrapolated the result using SEM. There is no problem with the data quality for analysis because the reliability and validity of the data are already tested before executing any statistical test. Here are some of the most important results from the study.

The potential adoption of industry 4.0 is greatly aided by effective DM, as shown by Table 14, where the b-value is 0.485 and the p-value less than 0.001 shows its significance. It shows how more sophisticated DM systems allow for more bold use of industry 4.0 technologies.

Furthermore, the degree of automation has a positive and substantial effect on the application of industry 4.0 because its b-value is 0.755.

The potential implementation of industry 4.0 is having a negative effect due to a negative b-value of 0.236 on the performance of the SC in Pakistan. Considering the significance, the hypothesis is accepted.

CONCLUSION

Today, SC are one of the most critical competitive arenas for organizations of all kinds and sizes. The goal is to provide clients with the most effective solutions possible in a timely way. Industry 4.0 has captured the attention of the whole globe, and companies that wish to remain competitive will have no choice but to conform to the emerging norm. It is no longer a viable choice to refrain from investing in the technologies that will allow Industry 4.0. The advent of the Covid-19 era, a dynamic global economy, fast-altering consumer tastes, an uncertain environment, and a growth in the number of accessible options have contributed to an increase in the utilization of cutting-edge technology.

It is critical to handle enormous volumes of data in real time effectively. With automation in information flows, order processing, delivery operations, and manufacturing processes, considerable time savings have been made possible. When supply networks reduce their customers' wait time, they become more efficient. Companies operating in every industry need to explore the challenges that stand in the way of them establishing efficient SC.

The technology significantly boosts operational performance by decreasing and stabilizing inventory levels and expenditures. The fundamental reason for this enhanced level of inventory management is the increased visibility made possible by real-time inventory monitoring and information sharing among SC members. A company's responsiveness, responsiveness, and responsiveness will all benefit from this enhancement. Using such technology improves forecasting, production planning, order fulfilment, and responsiveness to disturbances by providing real-time visibility and transparency of information. Findings from studies on SC-level adoption of Industry 4.0 reveal the actual cumulative effect of this technology transformation on corporate operations. Realizing the full potential of this digital transformation at the SC level, therefore, necessitates comprehensive strategies and the implementation of frameworks. To achieve this goal, SCs must adapt their management methods, network architectures, and training programs for their workforce to better align with the goals of Industry 4.0.

The time has come to focus on creating a different method for introducing new technologies. Industries in Pakistan need to catch up in terms of adopting cutting-edge technologies. Creating a different system to facilitate technology adoption within the industrial sector is a priority for all parties involved. However, one of the most significant obstacles for businesses is training workers to use the new technologies. Pakistani factories struggle due to insufficiently trained personnel to use cutting-edge machinery. Therefore, the research will aid managers and policymakers in understanding the strategic steps that can be taken to boost the company's preparedness level and thereby maximize the benefits gained from adopting I4.0 paradigms (Lucato et al., 2019).

This study sheds light on the prospects for introducing Industry 4.0 in Pakistan's textile sector. What is more pressing is how this influences SC productivity. Researchers examined how a company's level of maturity affects SC performance. This approach will aid academics and corporations in their pursuit of Industry 4.0, identification, and elimination of obstacles to improved SC efficiencies.

FUTURE RECOMMENDATION

There is a need for a more in-depth study to discover the reasons for the unexpected repercussions that have arisen because of the enhanced potential of industry 4.0 in Pakistan's textile SC. The increasing average workforce age is one potential explanation for this phenomenon. Staff members with an age barrier of over 40 are less inclined to accept new technology. Altering one's point of view can have the effect of fully turning it around.

This study's findings and methods might apply to other fields, such as the automotive business, which is frequently considered one of the most technologically sophisticated industries and depends on its channel partners to reach its sales quota. It is feasible to determine whether the data from the sample supports the model that has been hypothesized. When comparing two different sectors, it is possible to understand better the factors contributing to both positive and bad outcomes.

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