

Patterns of Progress: A Comprehensive Analysis of 4IR Readiness in Pakistan's Textile Industry

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Abstract

This study examines how ready Pakistan's textile industry is for the significant changes brought by the Fourth Industrial Revolution (4IR), which is all about using new technology. This industry is vital for Pakistan's economy but faces formidable challenges like insufficient power and intense competition from other countries. This research examines how well the industry performs using machines, new technology, and managing knowledge. The study gathers detailed information from major companies in Pakistan using recognized standards and surveys. It checks how ready the industry is in three main areas: using automation level, using technology level, and level of managing knowledge. This gives a clear picture of what the industry is doing well and where to improve to make the most of 4IR. The results show that the industry is doing well in managing knowledge, with a readiness score of 78%. It means they are good at using what they know to grow. However, they need to improve their use of machines and technology, as their scores in these areas are lower. This information is beneficial because it tells where more work and investment are needed, like better technology, training people, or improving infrastructure. This study is unique because it gives a clear view of Pakistan's textile industry and how it can join the global shift to 4IR. It is a helpful guide for people who make policies, industry leaders, and others involved, showing them what steps to take next. The study also suggests looking more into certain 4IR technologies and how they can be used in different places. In short, this research is a call to action for embracing new technology in the textile industry. Combining technology with good knowledge management shows excellent potential and room for growth. The path forward is complex but full of opportunities to make the sector more innovative, competitive, and robust globally.

Keywords: Fourth industrial revolution 4IR, Pakistan textile industry, Knowledge management, Automation, Technology utilization, Supply chain management,

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Sustainability, Digital transformation.

1 Introduction

This paper elaborately analyzes the readiness of the Pakistani textile industry for the Fourth Industrial Revolution (4IR). With an exclusive emphasis on the industry's supply chain, this article considers the distinctiveness of 4IR in modern industrial processes (Baura et al., [2004](#)).

The textile industry is essential to the Pakistani economy (Aneja, [2019](#)). The largest industry operating in this economy is the country's most significant manufacturing industry. It occupies the focal position within this export-focused economy. The industry is labor-intensive and employs many people (Ali et al., [2021](#)). In the cotton supply chain, this starts from the production of raw material, which is, for the most part, undertaken by the country, then the processing of fiber into yarn, textile, and finally into the finished garment. The first stage is spinning the cotton fiber into yarn (Alacer et al., [2021](#)). Then, the fabric is either woven or knitted. After this, the fabric is dyed and finished to enhance its aesthetic appearance and feel. After which, the garment is produced. The country's economy benefits by selling them. Textile faces severe energy crises, frequent power outages, increasing manufacturing costs, outdated infrastructure, and inefficient equipment. The situation worsens due to complex tax and regulatory rules, severe global competition, and environmental issues associated with resource use and pollution (Bettoil et al., [2020](#)).

However, there are also prospects for expansion employing diversification and modernization. Implementing equipment upgrades, embracing cutting-edge technologies, and implementing sustainable practices can improve efficiency, enhance quality, and reduce environmental impact. Additionally, potential routes for expansion include the exploration of new markets and investment in enhancing workforce capabilities (Capestro et al., [2020](#)). A supply chain can be defined as a complicated system that connects a firm with its suppliers in efficiently manufacturing and distributing a product. This is done through a vast process involving many activities, individuals, organizations, data, and assets, which convert raw materials and natural resources into final goods or services for consumers. Within sophisticated systems, previously utilized items have the potential to be reintegrated into the supply chain for recycling (Cinar et al., [2020](#)).

The textile supply chain specializes in producing and distributing textiles and garments. It covers the entire process, from sourcing cotton, wool, or synthetic fibers to spinning, weaving, and subsequent dyeing and finishing. The global network faces challenges related to logistics, quality control, and compliance with international standards (Cong et al., [2010](#)). 4IR is characterized by interconnectivity, automation, machine learning, and real-time data. It combines physical production with intelligent digital technology, changing operations efficiency, flexible manufacturing methods, and creating new product categories. This is a new mindset for industry, enabling cross-domain thinking that bridges the physical, digital, and biological domains (Gafni et al., [2009](#)).

AI, IoT, robotics, 3D printing, and quantum computing are among the 4IR's transforming technologies. These are fast-evolving, coalescing technologies in the 4IR, and they portend massive changes likely to occur in human-machine interaction and even business operations. From an economic perspective, 4IR may enhance efficiency and the development of new markets. Nonetheless, it must be remembered that such a technological change will substitute many traditional jobs. From a social perspective, high-level technologies can innovate in healthcare and education. However, they introduce some critical problems related to ethics and governance, especially in the case of AI and machine learning (Gonindan et al., [2023](#)). For the environment, 4IR technologies may help support efforts to promote sustainability and pose issues related to energy consumption and electronic waste. In geopolitical terms, this can potentially affect shifts in power structures and aggravate inequities in terms of access to the Internet (hair et al. [1995](#)).

This paper will evaluate Pakistan's textile industry's readiness for Industry 4.0 as the world market accelerates development. This research will evaluate automation, technology adoption, and knowledge management levels in the textile industry and articulate how traditional sectors in developing countries like Pakistan need to adapt to technological change (Baura et al., 2004). This analysis will inform policy and strategic decision-making in Pakistan and similar global contexts.

1.1 Scope of the study

In the realm of 4IR readiness research, a need for a broader geographic focus becomes evident. Khan et al. (2023) comprehensively analyze several industries in Pakistan. Still, it fails to provide specific attention to the textile sector, a crucial business in the country. Our upcoming research aims to fill this vacuum by thoroughly examining the intricacies of Industry 4.0 readiness in the textile industry, providing customized and comprehensive insights. Furthermore, the current landscape of region-specific studies reveals certain limitations in their scope. For instance, Ali (2021) narrows the focus of his research to a specific region within Pakistan, namely Hyderabad. While this study undoubtedly contributes valuable insights, its constrained geographical perspective raises questions about its capacity to comprehensively represent the broader readiness of the Pakistani textile industry for 4IR (Ali, 2021). Additionally, a distinct focal point emerges from the existing body of research. Notably, studies such as the one conducted by Sardar et al. (2022), which centers on environmental sustainability practices within the textile industry, underscore a tendency within previous research to prioritize sustainability considerations over the technological and knowledge management dimensions of 4IR readiness. This observation highlights an area where our forthcoming study can substantially contribute by refocusing the lens on these critical technical and knowledge-related aspects.

1.2 Rationale of the study

This study will explore the significance of 4IR in enhancing competitiveness and efficiency within the Pakistani textile industry. It will examine the industry's preparedness to embrace global industrial developments. An essential component of this evaluation entails assessing the implementation of automation and technology in the textile industry. Moreover, this research will provide insight into how the Pakistani textile sector has incorporated the essential elements of the 4IR. This study will also explore the impact of knowledge management on the adoption and deployment of 4IR technologies. It will provide valuable information on the present status of knowledge management practices in the industry and how they affect readiness for 4IR. The expected results of this study have significant consequences for politicians and industry leaders. They are ready to provide practical insights to guide strategic planning and policy development, ultimately facilitating a seamless transition to the Pakistani textile sector's 4IR. The study evaluates the Pakistani textile sector's preparedness for the 4IR, specifically regarding knowledge management, automation, and technology adoption. Current literature firmly supports this motivation. This research area proves valuable as it addresses a critical juncture where technological advancements intersect with industry-specific challenges. Here's a detailed review of how our study aligns with and adds value to existing literature:

1.3 Justification of the Study Purpose with Previous Literature

Our research surpasses the work done by Ali (2021) in the analysis of the state of preparedness for Industry 4.0 by the Pakistani textile industry. This work has gone further into automation, adoption of technology, and knowledge management. In academic literature, the contributions by Norman (2020) highlighted the international adaptability regarding 4IR preparedness within the textile sector. Our study is innovative and discusses the nature of preparedness within Pakistan, which is a giant within the global textile industry canvas. Building on this research work by Stulga et al. (2022), which brings out the criticality of making 4IR part of sustainable manufacturing practices, our research attempts to be in line with the same by the appraisal of readiness levels, which are a cornerstone for promoting sustainability and efficiency in textile manufacturing. The findings of

research by Aneja et al. (2019) contemplate the trajectory of digital transformation in the textile sector; our study takes a step further. It augments our understanding by offering empirical insights into readiness levels, a fundamental precursor for successfully realizing the digital future envisioned for the industry.

1.4 Value Addition of the Study

The report provides insights into Pakistan's textile sector and excellent lessons that are universally applicable. The developing country focus clarifies the challenges and opportunities in this setting and is an invaluable source of strategic guidance for similar economies across the globe. Moreover, the study uses an all-embracing model of assessment that includes dimensions such as knowledge management, automation, and technology utilization. The model is then given a very solid framework. At the same time, it remains easily reproducible or modifiable according to the specified requirements for practically any industry that would need such an evaluation. The implications of the study findings are of great importance, particularly in terms of policy and strategy. Their existence enlightens policymakers and industry captains in Pakistan and other economies with similar characteristics. They seek to help in decision-making toward readiness for the 4IR and influence the development of policies and investments. It also paves the way for future research activities, such as an in-depth study of the influence of 4IR preparedness in various areas, including business performance, supply chain resilience, and sustainability advancement in the textile sector. Furthermore, the study appeals to the human aspect: competencies required by Industry 4.0. The same aspect further contributes to significant improvements in the general workforce due to technological development. This study critically contributes to detailing the preparedness of the Pakistani textile sector vis-à-vis the 4IR. The paper's uniqueness lies in looking through a particular geographical lens, using a solid evaluation framework, and presenting practical and implementable insights for policymakers and practitioners.

2 Literature Review

2.1 Automation level

Assessing the automation level already in place will significantly help determine an industry's readiness for the 4IR. 4IR is the level of digital technology and automation within manufacturing processes, resulting in intelligent factories and high production efficiency. Automation is vital in achieving the objectives of 4IR since it provides suitable seamless integration of cyber-physical systems, Internet of Things (IoT), and cloud computing into the processes of the industry (Ramanathan & Samaranayake, 2022). Therefore, it becomes very necessary to be aware of the degree of automation of a sector to determine the extent to which that sector is ready for technology adoption under sector 4.0. The scholarly discourse underpins the importance of appraising readiness for the 4IR, as it is a strategic imperative of the organizations themselves (Sony & Naik, 2020). Assessing the level of automation provides valuable information about the existing technical background and the extent to which digital technologies have been brought into operation (Ratnasingam et al., 2019). This basic understanding identifies gaps and requirements for the transition to 4IR (Ramanathan & Samaranayake, 2022). Furthermore, assessing automation readiness is critical in coming up with or at least forecasting technological capacities and limitations that can affect the successful implementation of initiatives of the Fourth Industrial Revolution (Ramanathan & Samaranayake, 2022). Thus, the readiness determinants in the scrutiny of implementing 4IR in small and medium enterprises underscore the importance of the assessment of capabilities for automation to enable the smooth adoption of 4IR technologies (Sriram & Vinodh, 2021). Furthermore, in the context of an approach adopted to assess lean Six Sigma readiness in the manufacturing sector, fuzzy logic emphasizes the need to identify lacking attributes and put into place corrective actions, all in the interest of being more ready, which would manifest in strengthened automation capabilities (Vaishnavi & Suresh, 2021).

This is further confirmed by a survey of the degree of preparedness regarding automation levels

and readiness for the 4IR among Malaysian furniture manufacturers, the results of which indicated that firms are poorly prepared, in general, for incentives and actual, viable economic gains to be realized that can help speed up the process of change, including the upgrading of automation capabilities (Ratnasingam et al., 2019). An assessment of the implementation of the 4IR in the ceramic industry found that readiness model data should be used to implement solutions that provide the maximum value addition at the current level of automation and digitization (Kellner et al., 2020). The level of automation can be assessed to determine how ready the industry is for 4IR. This will establish a clear view of existing technological infrastructure, capabilities, and weaknesses, which is critical in identifying requirements and smoothly transitioning into 4IR.

2.2 Use of Technology Level

Assessing technological readiness for the industry is critical in discussing preparedness for the fourth industrial revolution and is driven by several significant rationales. First, technological readiness by the industry will refer to the degree to which the technological infrastructure, pertinent systems, and technical competencies can underpin the assimilation of advanced technologies, including those synonymous with 4IR (Rahayu & Day, 2015). The findings of this assessment would be very helpful in existing technological strengths and constraints that are basic to the industry's need to understand the requisites and obstacles in transitioning to 4IR (Oliveira & Martins, 2010). Another consideration in assessing technology readiness is how prepared the industry is for the smooth incorporation and adoption of digital technologies, cyber-physical systems, and automation, which are significant proponents of 4IR (Sony & Naik, 2020). Besides, automation and technological readiness are closely linked because the degree of automation in any sector is a significant determinant of its technological level and readiness in the adoption of 4IR technologies and practices (Ratnasingam et al., 2019). Implementing automated technologies is driven by increased capacity in production, associated cost levels, product attributes, and government regulations, elements inherently linked with the technology readiness evaluation (Ratnasingam et al., 2019). Moreover, the lack of adequate and sufficiently skilled personnel managing 4IR technologies has become one of the biggest concerns in various industrial sectors. It further emphasizes assessing technological skills and workforce readiness to implement advanced technologies (Ratnasingam et al., 2020). Further, the assessment of technology readiness assumes a critical role in understanding how companies face challenges related to digital transformation and their views regarding the facilitating technologies underlying 4IR. It offers valuable insights for understanding barriers that stand in the way of the assimilation of these technologies, hence enabling targeted interventions with precision for building technology readiness and fastening the process of adoption of 4IR (Alcácer et al., 2021). Additionally, technology readiness evaluation with TRL application has been used to assess the nexus between the readiness of technology and the adoption of technology in the healthcare domain (Östlund et al., 2023). In essence, assessing an industry's technological status is important in determining its preparedness for the 4IR. It gives essential insights into existing technical infrastructures, capacities, and limitations that would be of prime significance in identifying prerequisites and hurdles during the transition to the 4IR.

2.3 Knowledge Management Level

The need to assess the state of knowledge management in industries as part of the readiness to embrace the 4IR is multi-dimensional. Preparedness of postgraduate Industrial Engineering programs in Brazil for 4IR Tortorella et al. (2023) argue about the role of knowledge dimensions in the critical assessment of preparedness of the postgraduate Industrial Engineering programs in Brazil for 4IR. Knowledge management methods in educational institutions need to be changed according to the Fourth Industrial Revolution needs, as knowledge management is crucial in the industry in general. Similarly, Bettiol et al. (2020) have addressed the subject of knowledge management under the 4IR context; however, their study was mainly premised on understanding

the importance of knowledge management strategically in navigating the complexities of 4IR. In general, the levels of knowledge management need to be assessed to unveil the levels of industry preparedness for the technical and procedural changes brought about by 4IR. This assessment calls for an unveiling of the current practice, alignment of the educational programs with the needs of the industry, and the formation of models measuring readiness for such changes.

2.4 Resource-Based View Theory

According to the Resource-Based View (RBV) hypothesis, internal resources and competencies allow a firm to develop a competitive advantage. Knowledge management, automation, and technology use in Pakistan are essential drivers of internal resources for textile firms. These factors will determine their readiness for Industry 4.0 and hence their competitiveness. The research will use the VRIO framework of the RBV to analyze how internal resources such as knowledge management, automation, and technology utilization could affect the industry's competitive advantage. For example, it asks how vital these resources are in the Pakistani textile industry; are they rare and unique compared to regional competitors? Are they easily re-producible or replaceable? To what extent are these resources well-organized and utilized inside these firms? This study is based on the basic premise of the Resource-Based View (RBV), which emphasizes that strategic resource deployment, in particularly critical areas such as advanced technology and knowledge management systems, determines organizational readiness for the 4IR. This implies that textile firms in Pakistan must invest strategically in these areas to be more prepared and competitive. Huang et al. (2023) also demonstrated that the strategic implementation of 4IR technologies not only enhances the competencies and resilience of supply chains but also results in an overall positive influence in the presence of internal resources as moderators. Consequently, this provides a theoretical foundation for applying the Resource-Based View to the study to understand how Pakistani textile firms' internal resources, knowledge management, automation, and technology utilization are pivotally involved in assessing and being ready to embrace Industry 4.0.

3 Methodology

The study measured the ability of Industry 4.0 data management and automation at the level of Microsoft Excel. We compared the organization's readiness for the implementation of Industry 4.0 using six sets of metrics designed by Pacchini et al. (2019), as shown in Table 3.1, under the International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC) 15504-5.

Table 1: Measurement gauge for the Industry's Maturity Level

Maturity level %	Status	Description
0-10	EMBRYONIC	Practitioners in the industry have a basic understanding of a few key facilitators.
10-25	INITIAL	The industry recognizes several emerging technologies.
25-50	PRIMARY	The industry is fully aware of the technologies but has yet to implement them.
50-75	INTERMEDIATE	The industry comprehensively understands all available technologies and has started implementing some of them.
75-90	ADVANCE	The industry has extensively embraced and is well-acquainted with all available technologies.
90-100	READY	The industry has fully implemented all essential technologies and achieved a high adoption rate.

3.1 Survey-Based Research

This section outlines the rationale for adopting a self-administered survey as the preferred data collection method. This approach is particularly suitable when the research does not require an in-

depth analysis of behavioral outcomes, as Yin (1994) indicated. It offers a reliable means of assessing sample data, enabling extrapolation of results to the broader population (Creswell & Creswell, 2005). Moreover, it facilitates the identification of causal relationships and allows for the rapid, cost-effective dissemination of questionnaires to a large audience, making it practical for widespread use (McCelland, 1994; Sekaran, 2009; Zikmund et al., 2003). The primary advantage of this method lies in its ability to gather data from extensive samples efficiently. However, the survey method faces criticism for relying on self-reported data, which can compromise the validity and reliability of results due to potential biases in respondent reporting (Spector, 1992). Additionally, employing the same instrument to measure both independent and dependent variables may further jeopardize the integrity of the findings (Saunders et al., 1982). Common issues include verifying data accuracy and timeliness, doubts about respondents' honesty, and the superficial insights that surveys typically yield (Hair et al., 1995). Recommendations by Hair et al. (1995) were followed to mitigate these concerns. Furthermore, self-administered questionnaires excel in spanning geographical boundaries, reaching a wide demographic. Their ease of distribution across diverse locations broadens the scope of data collection, thereby enriching the robustness and generalizability of the research findings (Zikmund et al., 2003).

3.2 Items Selection

3.2.1 Automation Level

The term "automation level" refers to the extent of automation incorporated into a system or process, varying from no to complete automation. It denotes explicitly the proportion of a system's automated functions to its total functions (Wessel & Grolach, 2008). Automation can be applied across different tiers, from basic to advanced, covering a wide range of activities from manual operations to completely automated systems. Measures for Automation level are imported from Barua et al. (2004).

3.2.2 Use of Technology Level

"technology level" refers to how individuals or organizations integrate technology into daily operations. This level is evaluated according to multiple factors, such as accessibility, utilization, adaptation, preparedness, effectiveness, and user-friendliness. For example, Loh and Chib (2021) present an operational definition of Technology access, use, and incorporation derived from their digital divide analysis. Items to measure the level of technology use are from Singhry (2015).

3.2.3 Knowledge Management Level

The "knowledge management level" indicates how effectively an individual, group, or organization manages and utilizes knowledge to achieve specific outcomes. This level is evaluated through criteria such as conceptual, contextual, and operational expertise, along with innovation, performance, and infrastructure. We have taken Knowledge management items from (Kearns & Sabherwal, 2006). Our research involves an extensive data collection effort across Pakistan to assess the textile industry's preparedness for 4IR and its influence on supply chain performance. We specifically target companies listed on the Securities and Exchange Commission of Pakistan (SECP), employing purposive sampling to focus on formally recognized and likely more established, thus meeting specific standards. The study aimed to thoroughly understand I4.0 readiness by surveying personnel at various levels within these companies, from staff to executives. Data is gathered through mail and phone to ensure broad participation and gather valuable feedback. Our analysis centered explicitly on incorporating companies registered with the SECP (www.psx.com.pk).

3.2.4 Readiness Level Analysis

The proposed standard will define a systematic process for assessing the readiness of an industry to adopt 4IR. Such a structure will ensure that organizations in the industrial world can self-assess and improve to gear up strategically for future progression. Ideal conditions may be compared with the real state of the organization, which allows the determination of the managerial tactics that would improve the firm's readiness level toward 4IR, considering the specific requirements for

each enabler. Current research adopts a method Lucato et al. (2019) used to measure the degree of a corporation's adoption of an enabling technology. According to this method, the preparedness level for any given element 'n' can be calculated by finding the sum of points obtained from its assessment to the maximum points it can obtain for that element (Lucato et al., 2019).

$gn = (\text{Points obtained from evaluating components of element } e) / (\text{Maximum possible points})$

The methodology can be broken down as follows:

This paper now applies adaptations of two key standards in the literature—SAE J4000 and SAE J4001—in assessing the readiness of the textile industry for 4IR. The adaptation examines how organizations have integrated and implemented the technologies and practices key to 4IR. In other words, this signals a departure from the assessment of readiness from the traditional perception of lean operational practices to one based on readiness for a digital, highly technological manufacturing environment. Lucato et al. (2019) have built an innovation methodology as the very base of this methodology. The approach created a view into an organization's readiness in adopting and preparing for 4IR using structured, quantitative frameworks adopted from standards initially for assessing lean operations. The current study applies such standards to the needs of a digital manufacturing environment in the Pakistani textile industry for an assessment. This paper blends a rigorous analysis with a technique based on quantitative adaptability and a focus on enabling technologies to provide insight into present readiness levels and areas that need improvement for 4IR.

4 Analysis

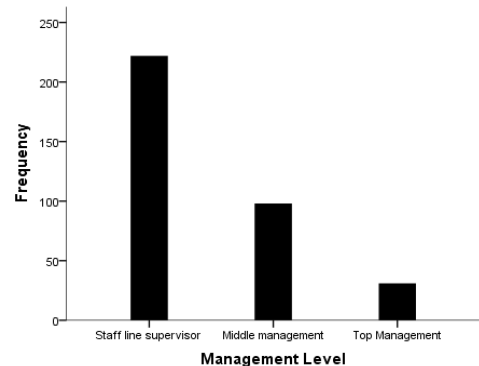
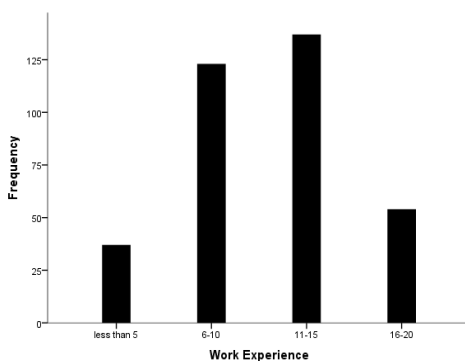
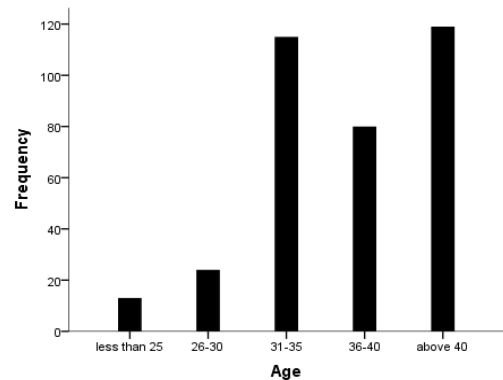
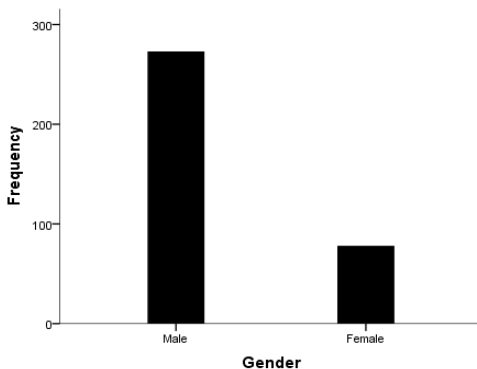


Figure 3: Work Experience of Employees

Figure 4: Management Levels Distribution

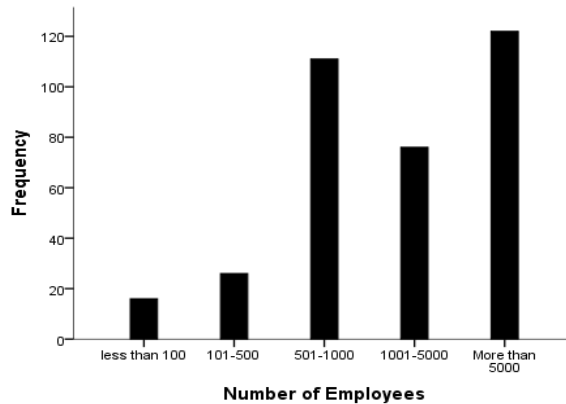


Figure 5: Total number of Employees Distribution

Figure 1 illustrates gender distribution, indicating a male-to-female ratio greater than 2:1. Figure 2's age distribution histogram shows uniformity among the central age groups (26-40), with the lesser representation of the youngest (<25) and a notable presence of individuals over 40. In Figure 3, work experience is predominantly within the 11-15 years range, with fewer entries at the extremes of the experience spectrum. Figure 4 reveals a hierarchical management-level distribution, with Staff Line Supervisors being the most represented, followed by Middle and Top Management. Lastly, Figure 5 displays a bimodal distribution of organizational sizes, highlighting a prevalence of larger organizations (>1000 employees) and a minimal representation of smaller ones (<100 employees).

The dataset appears to represent a predominantly male workforce with a good spread of middle-aged individuals, most of whom have substantial work experience. It includes mainly staff line supervisors and employees from larger organizations, particularly those with over 1000 employees. This dataset could reflect more giant, established corporations with traditional management hierarchies. This perspective gauges an organization's readiness to adopt 4IR through a developed quantitative framework adapted from standards used first to quantify lean operations. When applied to the textile industry in Pakistan, the standards are adapted to a digital manufacturing environment to determine readiness in the textile. The study brings this confluence of comprehensive analysis and quantitative robustness with adaptability to the forefront. It focuses on the enabling technologies that would provide insights into the current readiness and the areas needing improvement for 4IR.

Table 4.3 presents maturity levels of technology adoption in a particular industry or sector. The table is equipped with six unique phases in each organization. Each of the phases is outlined through a percentage range and further supplemented with a descriptive name and description of the phase.

This research suggests assessing the extent of adoption using a model developed by Lucato et al. (2019) to measure a firm's readiness regarding an enabling technology. Following the method outlined the readiness level of a particular element, identified as 'n,' is calculated by dividing the total points garnered from our evaluation by the maximum possible points.

$$gn = \frac{\sum \text{Score obtained as a result of an evaluation of indicators of construct}}{\text{Maximum score possible}} (1)$$

$$DR = g1 + g2 + g3 + \dots + gn / n = \sum n \ 1 \ gm / n (2)$$

Here: DR = degree of readiness of a given company.

g1 = degree of adoption concerning component 1 (first indicator).

g2 = degree of adoption concerning component 2 (second indicator).
 and gn = degree of adoption concerning component n (nth indicator)
 To accomplish this, we compiled the scores of all the received indicators and then divided them by the total of the highest possible values. The resulting numerical number acts as an indicator of the possibility of implementing Industry 4.0. We have also converted this value into a percentage format Table 4.1 for ease and clarity.

Table 2: Potential and Status of Dimensions for Industry 4.0

Dimensions	Potential
Advance	
KM	78.39
Intermediate	
AL	64.61
UTL	58.67

Abiding by the guidelines, we assessed the capabilities of organizations regarding their degree of automation, use of technology, and knowledge management level (figure 6).

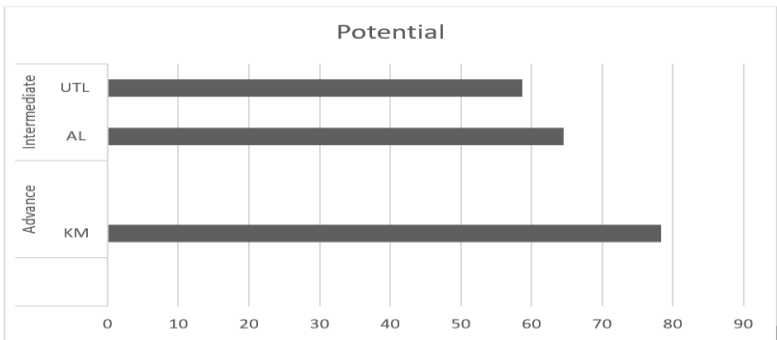


Figure 6: Readiness Level

In summary, our approach to assessing the readiness level of the textile industry in Pakistan for Industry 4.0 using a framework similar to SAE J4000/4001 is well-founded. It provides a comprehensive, adaptable, and quantifiable method that aligns with global standards and focuses on critical elements of Industry 4.0.

5 Discussion

Examining the specifics, the relationship between knowledge management, automation, and technology utilization in the context of Industry 4.0, as indicated by the findings of our study, can be elucidated through different scholarly viewpoints: Much literature has been devoted to the critical issue of knowledge management incorporation in the context of automation and utilization of technology in Industry 4.0. Knowledge management is considered a key enabler for the efficient integration and utilization of advanced technology. The capability for integrated advanced technologies is referred to as knowledge management in the context of 4IR, not information management. The process consists of knowledge acquisition, retention, and the sharing process regarding these technologies to augment the capability and expertise required to apply them correctly. Research by Capestro and Kinkel (2020) indicates the important role played by knowledge management in automation implementation and its best usage. A well-oiled knowledge management system can provide the insights and information crucial for decision-making in automation implementation. For instance, there is a noted interdependence between automation and the use of technology in the landscape of Industry 4.0. Automation heavily depends on

advanced technologies like the Internet of Things (IoT), Artificial Intelligence, and Machine Learning to perform tasks. The evolution in technology adoption will translate to more sophisticated and efficient ways of automation processing. In a nutshell, advanced technologies give the essential tools and platforms to automate complex tasks. On the other hand, literature relates knowledge management to effective technological adoption. Organizations with a strong capability in knowledge management better recognize and understand new technologies' potentials and limitations, leading to more strategic and effective technological implementation. Knowledge management supports learning and adaptation, traits assumed to be important in the dynamic landscape of Industry 4.0 technologies (Khedr & Gohar, 2023). The literature presents a knowledge-based approach toward automation and technology implementation. Automation tasks can be structured and optimized through knowledge management, which promotes better structuring of the deployment process, thus directly enhancing the efficiency and effectiveness of technology utilization in the 4IR environment (Kattepur et al., 2018). This also provides a way to easily adapt and match an organization's needs and capabilities to robotic automation deployment (Kattepur et al., 2018). Our survey results reveal that different critical dimensions of Industry 4.0 readiness in the context of the Pakistani textile industry are recorded at different magnitudes: knowledge management, 78%; level of automation, 64.61%; adoption of technologies, 58.67%.

These findings can be discussed and justified regarding existing literature and research in the field:

1. Knowledge Management (78%): "The high readiness level in knowledge management reflects the industry's strong emphasis on leveraging information for decision-making and innovation, which is imperative for Industry 4.0 implementation". A critical study conducted by Capestro and Kinkel (2020) found that effective knowledge management in Industry 4.0 settings was important for integrating advanced technologies and enhancing organizational learning and innovation but only flourished in such an environment. Our results support this finding as this study concludes that Pakistan's textile industry is advanced in managing knowledge assets, the cornerstone of Industry 4.0.
2. Automation Level (64.61%): Regarding significance, the automation level is not as ready as the knowledge management level. Perhaps this could be because automation technologies require large-scale capital, and the industry has slowly begun to transition to this. Accordingly, the complexity and investment involved in the automation of processes may explain the somewhat lower score compared to knowledge management (Liu et al., 2020).
3. Use of Technology (58.67%): A low readiness score in using technology represents a problem in adopting and integrating new technologies into an existing system. As argued by Ramachandran, adopting Industry 4.0 technology is usually halted due to a lack of expertise, unwillingness to change, and apprehension regarding cost. This is more applicable in developing countries like Pakistan, where the textile industry might face added barriers, such as infrastructure limitations and skill gaps.

Overall, the findings indicate that the Pakistani textile industry is progressively moving toward the standards of 4IR, particularly in knowledge management; however, automation and the use of technology are yet to be developed. Investments in technology, training, and infrastructure, along with policy support, may further assist these readiness levels.

This study, therefore, has some practical and theoretical implications. It is focused on knowledge management, automation, and the use of technologies in assessing the readiness level of 4IR in the Pakistani textile industry.

5.1 Theoretical Implications

The study dramatically contributes to the theoretical framework of 4IR in some areas: This study extends further the basis of SAE J4000/4001 standards, applies them in the context of the 4IR, and moves them forward into a new level of usefulness beyond the evaluation of lean operations,

towards readiness assessment for 4IR. In so doing, this extension should not only enrich the theoretical landscape regarding assessing readiness. Still, it can allow new opportunities for application in many industrial sectors, increasing our understanding of how readiness can be measured in the scope of the Fourth Industrial Revolution. This research deeply investigated various aspects of 4IR, from knowledge management to automation and technology utilization; therefore, it extended the richness of our theoretical understanding regarding how the mentioned elements are interrelated and jointly influence an industry's readiness for challenges and opportunities brought by the Fourth Industrial Revolution. The research showcases the complex interrelations between these components and the aftereffects of their interaction. Therefore, this study of Pakistan's textile industry becomes an indicator of this growing body of localized research, which, in turn, helps to develop theories and solutions suited to the specificity of the problems and opportunities one might face in developing countries and industries. This aids in developing context-specific strategies and models that would need to be developed to embrace 4IR and contributes to our well-researched theoretical understanding of how 4IR can be customized to fit unique circumstances.

5.2 Practical Implications

The findings of this study will have significant strategic planning implications for policymakers and industrial captains in technology adoption and innovation. Understanding the present level of readiness further empowers the specification of definite areas that might require attention and investment. These may include technology integration and automation. Such knowledge empowers the decision-makers to make informed choices and steer their industry toward 4IR. Moreover, this research also provides a critical benchmark for the stakeholders within the textile industry in Pakistan to understand their readiness for 4IR. This will allow them to make proper decisions regarding implementing training programs, investments in new technologies, and organizational changes. Realizing where they stand about 4IR readiness is essential for stakeholders to align their strategies with the changing industrial scenario. This research can be used to inform government policies and support mechanisms. Only deep insight into the industry's level of preparedness can direct the development of policies targeted toward fostering technological development, effective training programs, and infrastructure development tailored to the textile sector's needs. This approach will be generic, not only for the textile industry in Pakistan but also for other sectors and even for countries adopting 4IR. The standardized readiness assessment methodology will help to improve by pinpointing the weak areas responsible for change in increasing efficiency and creativity, both improvements necessary for survival in the future global market under the influence of technological changes. This study will help develop the theoretical frameworks of readiness assessment for 4IR and provide practical insights for textile industry stakeholders, particularly in developing countries like Pakistan. Based on the results and methodology of our study assessing 4IR readiness in the Pakistani textile industry, several gaps can be identified, leading to recommendations for future research:

5.3 Limitations and Future Recommendations

The current study's inferences relate to the Pakistani textile industry's readiness for Industry 4.0. Potential limitations and suggestions for future research exist. The study's geographic limitation has the potential to impact findings in terms of generalization. Future research that will enhance practicality in findings can extend the scope of readiness assessment to other geographical areas or across several industries. From the above, though the study concentrated on automation and the overall technological application of 4IR, more can be researched. Additional studies could be done in areas where 4IR technologies are applied, such as IoT, AI, and Big Data analytics, to understand better how they are transforming various industries. Another reason for the 4IR study to be longitudinal is that it could offer real insights into how readiness levels progress with time and into adoption strategies that capture the dynamic process of digital transformation. Additional studies

may be conducted to examine the impact of 4IR readiness on critical corporate performance indicators, including productivity, profitability, and market share, to illustrate the benefits of implementing 4IR. Furthermore, employee readiness for 4IR is important; thus, it should be considered a priority given the need for future research. This research, therefore, may provide necessary knowledge on successful strategies for workforce development and adaptation.

Such cross-national, cross-industry comparative research results could help find common problems and solutions that can be transposed into different environments, thus accelerating preparedness for 4IR. A more detailed investigation into the factors that influence the acceptance and integration of 4IR technologies in industrial settings is possible by conducting further exploratory analysis. In future studies, a mixed-method approach can be more effective in combining the qualitative techniques applied in the case studies with qualitative techniques, such as surveys and interviews, to better understand 4IR readiness and its implications. The evidence base for the real benefits of adoption would be based on well-illustrated linkages between the level of readiness toward 4IR and a set of core business performance KPIs. Therefore, examining the effect of 4IR on employment, skills needed, and ways to develop and train the workforce would be a high-priority field of research. Future research initiatives should address these gaps and make recommendations to advance the overall understanding of 4IR readiness and its implications in practice. This study can further guide relevant industries through the process of digitalization and automation in the preparation and development of effective strategies.

6 Conclusion

The study makes an important contribution by providing a detailed evaluation of Pakistan's textile industry's readiness to embark on the fourth Industrial Revolution. This work ensured substantial policy and industry insights by profoundly exploring the industry's current state. The paper discusses the challenges, opportunities, and prospective changes engendered by 4IR technologies. Hence, it is critical to note in the findings the strong urge to adopt 4IR technologies like AI, IoT, robots, 3D printing, and quantum computing in support of the fact that the Pakistani textile industry remains in business and competitive in the fast-moving global market environment. However, it goes beyond renewing equipment and is far-reaching as an industry response to these technological improvements, comprehensive transformation to include automation, knowledge, and worker development. The study also suggests urging a strategy dedicated to overcoming some special challenges and capitalizing on special benefits in the Pakistani context. This includes investment in improving infrastructure, encouraging a creative learning attitude, and policy-making that inspires and motivates the implementation of 4IR technology. The report also comments that one of the significant gaps in regional-specific studies regarding preparedness for the Fourth Industrial Revolution lies in sustainability factors and technological and knowledge management aspects. This suggests that future research may be built upon this study's foundation. This study can only contribute to our understanding of the dynamics of the 4IR inside a developing country's textile industry. It will help frame an appropriate strategic trajectory and policy decisions that have become critical for optimally leveraging the power of the 4IR in the pursuit of making Pakistan's textile industry efficient, productive, and globally competitive. The way forward in Industry 4.0 may be complex and varied, but adopting the right strategy can have revolutionary impacts on the sector and the wider economy.

7 References

- Alcácer, V., Rodrigues, C., Carvalho, H., & Cruz-Machado, V. (2021). Tracking the maturity of industry 4.0: the perspective of a real scenario. *The International Journal of Advanced Manufacturing Technology*, 116, 2161–2181. <https://doi.org/10.1007/s00170-021-07550-0>
- Ali, S. (2021). Operational readiness of pakistan textile industry to implement industry 4.0 (A study of hyderabad textile). *International Journal of Engineering Applied Science &*

- Technology*, 5(10), 334–341
- Aneja, A., Kupka, K., Militky, J., & Kadi, N. (2019, June 11–15). *Textile industry 4.0—preparing for digital future* [Paper presentation]. Proceedings of the 19th World Textile Conference on Textiles at the Crossroads. Belgium, China.
- Barua, A., Konana, P., Whinston, A. B., & Yin, F. (2004). An empirical investigation of net-enabled business value. *MIS Quarterly*, 28(4), 585–620. <https://doi.org/10.2307/25148656>
- Bettiol, M., Di Maria, E., & Micelli, S. (2020). Industry 4.0 and knowledge management: An introduction. In M. Bettiol, E. D. Maria & S. Micelli (Eds.), *Knowledge Management and Industry 4.0: New Paradigms for Value Creation*, (pp.1–18). Springer.
- Capestro, M., & Kinkel, S. (2020). Industry 4.0 and knowledge management: A review of empirical studies. Marco Bettiol, Eleonora Di Maria, Stefano Micelli *Knowledge Management and Industry 4.0: New Paradigms for Value Creation*, (pp.19–52). Springer.
- Çınar, Z. M., Zeeshan, Q., & Korhan, O. (2021). A framework for industry 4.0 readiness and maturity of smart manufacturing enterprises: A case study. *Sustainability*, 13(12), Article e6659. <https://doi.org/10.3390/su13126659>
- Cong, H. B., & Gao, C. C. (2010, August 24–26). *Studying the Modern Logistics Enterprise Knowledge Management Capabilities and Enterprise Performance Fit Mechanism* [Paper presentation]. Proceedings of 2010 International Conference on Management and Service Science. Wuhan, China. <https://doi.org/10.1109/ICMSS.2010.5576677>
- Creswell, J. W., & Creswell, J. D. (2005). *Mixed methods research: Developments, debates, and dilemma*. Berrett-Koehler Publishers.
- Estensoro, M., Larrea, M., Müller, J. M., & Sisti, E. (2022). A resource-based view on SMEs regarding the transition to more sophisticated stages of Industry 4.0. *European Management Journal*, 40(5), 778–792. <https://doi.org/10.1016/j.emj.2021.10.001>
- Gafni, R. (2009). Usability issues in mobile-wireless information systems. *Issues in Informing Science & Information Technology*, 6, 755–769.
- Govindan, K., & Arampatzis, G. (2023). A framework to measure readiness and barriers for the implementation of Industry 4.0: A case approach. *Electronic Commerce Research and Applications*, 59, Article e101249. <https://doi.org/10.1016/j.elerap.2023.101249>
- Hair, J. F., Anderson, R. E., Tatham, R. L., & Black, W. C. (1995). *Multivariate data analysis with readings*. Pearson College.
- Hajoary, P. K., Balachandra, P., & Garza-Reyes, J. A. (2023). Industry 4.0 maturity and readiness assessment: An empirical validation using Confirmatory Composite Analysis. *Production Planning & Control* (Latest Article), 1–18. <https://doi.org/10.1080/09537287.2023.2210545>
- Hermawan, S., Abidin, F. I. N., Biduri, S., & Kurniawan, D. A. (2021, March). *Knowledge Management, Information Technology, and Acceptance Students 'Readiness for Industrial Revolution 4.0* [Paper presentation]. In 1st Paris Van Java International Seminar on Health, Economics, Social Science and Humanities (PVJ-ISHESSH 2020). Zoom, Online.
- Huang, K., Wang, K., Lee, P. K., & Yeung, A. C. (2023). The impact of industry 4.0 on supply chain capability and supply chain resilience: A dynamic resource-based view. *International Journal of Production Economics*, 262, Article e108913. <https://doi.org/10.1016/j.ijspe.2023.108913>
- Kattepur, A., Dey, S., & Balamuralidhar, P. (2018, October 21–23). *Knowledge based hierarchical decomposition of industry 4.0 robotic automation tasks* [Paper presentation]. In IECON 2018-44th Annual Conference of the IEEE Industrial Electronics Society (pp. 3665–3672). Washington, DC, USA.
- Kearns, G. S., & Sabherwal, R. (2006). Strategic alignment between business and information technology: a knowledge-based view of behaviors, outcome, and consequences. *Journal*

- of *Management Information Systems*, 23(3), 129–162. <https://doi.org/10.2753/MIS0742-1222230306>
- Kellner, T., Necas, M., Kanak, M., Kyncl, M., & Kyncl, J. (2020). Assessment of readiness for Industry 4.0 implementation in ceramic industry. *Manufacturing Technology*, 20(6), 763–770. <https://doi.org/10.21062/mft.2020.110>
- Khan, U., Ahmad, W., & Imran, M. (2023). A Survey of the Readiness and Maturity Level of Industry 4.0 at Twenty Companies in Pakistan. *Hungarian Journal of Industry and Chemistry*, 51(1), 55–59. <https://doi.org/10.33927/hjic-2023-08>
- Khedr, W. M., & Gohar, N. M. (2023). The role of knowledge management in adopting industry 4 technology: The mediating role of market orientation. *Arab Journal of Administration*, 43(3), Article e21. <https://dx.doi.org/10.21608/aja.2023.214705.1462>
- Liu, J. H., Lu, Y. S., & Yu, Y. T. (2020, October 23–25). *Common management technology of automation equipment in industry 4.0* [Paper presentation]. In 2020 IEEE Eurasia Conference on IOT, Communication and Engineering (ECICE) (pp. 355–358). Yunlin, Taiwan.
- Loh, Y. A. C., & Chib, A. (2021). Reconsidering the digital divide: an analytical framework from access to appropriation. *Information Technology & People*, 35(2), 647–676. <https://doi.org/10.1108/ITP-09-2019-0505>
- Lucato, W. C., Pacchini, A. P. T., Facchini, F., & Mummolo, G. (2019). Model to evaluate the Industry 4.0 readiness degree in Industrial Companies. *IFAC-PapersOnLine*, 52(13), 1808–1813. <https://doi.org/10.1016/j.ifacol.2019.11.464>
- McClland, S. (1994). Training needs assessment data-gathering methods: Part 4, survey questionnaire. *Journal of European Industrial Training*, 18(5), 22–26. <https://doi.org/10.1108/03090599410054317>
- Muhammed, S., Doll, W. J., & Deng, X. (2011). Measuring knowledge management outcomes at the individual level: Towards a tool for research on organizational culture. In *Global aspects and cultural perspectives on knowledge management: Emerging dimensions* (pp. 1–18). IGI Global. [10.4018/978-1-60960-555-1.ch001](https://doi.org/10.4018/978-1-60960-555-1.ch001)
- Norman, F. (2020). Key factors to promote Industry 4.0 readiness at Indonesian textile and clothing firm. *Engineering, Mathematics and Computer Science (EMACS) Journal*, 2(2), 73–83. <https://doi.org/10.21512/emacsjournal.v2i2.6448>
- Oliveira, T., & Martins, M. F. (2010). Understanding e-business adoption across industries in European countries. *Industrial Management & Data Systems*, 110(9), 1337–1354. <https://doi.org/10.1108/02635571011087428>
- Östlund, B., Malvezzi, M., Frennert, S., Funk, M., Gonzalez-Vargas, J., Baur, K., Alimisis, D., Thorsteinsson, F., Alonso-Cepeda, A., & Fau, G. (2023). Interactive robots for health in Europe: Technology readiness and adoption potential. *Frontiers in Public Health*, 11, 979225. <https://doi.org/10.3389/fpubh.2023.979225>
- Pacchini, A. P. T., Lucato, W. C., Facchini, F., & Mummolo, G. (2019). The degree of readiness for the implementation of Industry 4.0. *Computers in industry*, 113, 103125. <https://doi.org/10.1016/j.compind.2019.103125>
- Rahayu, R., & Day, J. (2015). Determinant factors of e-commerce adoption by SMEs in developing country: evidence from Indonesia. *Procedia-social and behavioral sciences*, 195, 142–150. <https://doi.org/10.1016/j.sbspro.2015.06.423>
- Ramanathan, K., & Samaranayake, P. (2022). Assessing Industry 4.0 readiness in manufacturing: a self-diagnostic framework and an illustrative case study. *Journal of Manufacturing Technology Management*, 33(3), 468–488. <https://doi.org/10.1108/JMTM-09-2021-0339>
- Ratnasingam, J., Ab Latib, H., Yi, L. Y., Liat, L. C., & Khoo, A. (2019). Extent of automation and the readiness for industry 4.0 among Malaysian furniture manufacturers. *BioResources*, 14(3), 7095–7110.
- Ratnasingam, J., Lee, Y. Y., Azim, A. A. A., Halis, R., Liat, L. C., Khoo, A., Daud, M. M. M.,

- Senin, A. L., Ab Latib, H., & Bueno, M. V. (2020). Assessing the awareness and readiness of the Malaysian furniture industry for Industry 4.0. *BioResources*, 15(3), 4866–4885.
- Salsabila, S., Radhiana, R., Juwita, J., & Mauliza, P. (2022, December). Challenges of the resource-based view approach in improving business organizational performance. *Proceedings of International Conference on Multidisciplinary Research*, 5(2), 120–125. <https://doi.org/10.32672/pic-mr.v5i2.5416>
- Sardar, S., Mohsin, M., Memon, M. S., Ramzan, B., & Sharif, R. (2022). An empirical study regarding the environmental sustainability practices in the textile industry. *Industria Textila*, 73(4), 384–396. <https://doi.org/10.35530/IT.073.04.202152>
- Saunders, M., Campbell, S., White, H., & Coats, P. (1982, March). *A unique real-time computerised method of obstetric data collection* [Paper presentation]. In Medical Informatics Europe 82: Fourth Congress of the European Federation of Medical Informatics Dublin, Ireland. Springer Berlin Heidelberg.
- Schwab, K. (2015). *Global Competitiveness Report* (2014–2015). World Economic Forum. https://www3.weforum.org/docs/WEF_GlobalCompetitivenessReport_2014-15.pdf
- Schwab, K., & Malleret, T. (2020, March). Covid-19: The great reset. World economic forum. <https://www.weforum.org/agenda/2020/07/covid-19-the-great-reset/>
- Sekaran, U. (2009). *Research Methods for Business: A Skill-Building Approach*. John Wiley & Sons.
- Sensuse, D. I., Hidayat, D. S., & Setyaningrum, I. Z. (2023). Model of knowledge management readiness and initiatives for improvement in government agencies. *VINE Journal of Information and Knowledge Management Systems* (ahead-of-print). <https://doi.org/10.1108/VJIKMS-05-2022-0173>
- Singhry, H. B. (2015). Effect of supply chain technology, supply chain collaboration and innovation capability on supply chain performance of manufacturing companies. *Journal of Business Studies Quarterly*, 7(2), 258–273.
- Sony, M., & Naik, S. (2020). Key ingredients for evaluating Industry 4.0 readiness for organizations: a literature review. *Benchmarking: An International Journal*, 27(7), 2213–2232. <https://doi.org/10.1108/BIJ-09-2018-0284>
- Spector, P. E. (1992). Summated rating scale construction: *An introduction* (Vol. 82). Sage.
- Sriram, R., & Vinodh, S. (2021). Analysis of readiness factors for Industry 4.0 implementation in SMEs using COPRAS. *International Journal of Quality & Reliability Management*, 38(5), 1178–1192. <https://doi.org/10.1108/IJQRM-04-2020-0121>
- Stulga, P., Whitfield, R., Love, J., & Evans, D. (2022). Towards Sustainable Manufacturing with Industry 4.0: A Framework for the Textile Industry. *Proceedings of the Design Society*, 2, 283–292. <https://doi.org/10.1017/pds.2022.30>
- Tortorella, G. L., Cauchick-Miguel, P. A., Frazzon, E. M., Fogliatto, F. S., Godinho Filho, M., & Thürer, M. (2023). Readiness of Brazilian industrial engineering postgraduate programs for industry 4.0: a knowledge dimensions assessment. *Computer Applications in Engineering Education*, 31(3), 501–519. <https://doi.org/10.1002/cae.22595>
- Umachandran, K., Jurčić, I., Della Corte, V., & Ferdinand-James, D. S. (2019). Industry 4.0: The new industrial revolution. In N. Dey & S. Tamane (Eds.), *Big data analytics for smart and connected cities* (pp. 138–156). IGI Global.
- Vaishnavi, V., & Suresh, M. (2021). Assessment of readiness level for implementing lean six sigma in healthcare organization using fuzzy logic approach. *International Journal of Lean Six Sigma*, 12(2), 175–209. <https://doi.org/10.1108/IJLSS-07-2019-0081>
- Wessel, O., & Gorlach, I. (2008). A comparative study of automation strategies at Volkswagen in Germany and South Africa. *South African Journal of Industrial Engineering*, 19(1), 149–168.
- Widzyk-Capehart, E., & Zabłocki, A. (2020). Towards autonomous operations in the mining industry: the role of human factors. *Journal of Mining Engineering and Research*, 2(2),

- 69–79. <https://doi.org/10.35624/jminer2020.01.08>
- Yin, R. K. (1994). Discovering the future of the case study. *Method in evaluation research. Evaluation practice*, 15(3), 283–290. <https://doi.org/10.1177/109821409401500309>
- Zikmund, W. G., Babin, B. J., Carr, J. C., & Griffin, M. (2003). Research methods. *Health Economics Research Method*, 2(3), 56–79.