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KEYWORDS	ABSTRACT
Cyber-Physical Systems, textile industry, SmartPLS 4	Industry 4.0 (I4.0) refers to the integration of the latest manufacturing technologies, including Cyber-Physical Systems (CPS), the Internet of Things (IoT), Industrial IoT (IIoT), Cognitive Computing, and Artificial Intelligence, with digital systems to enhance industrial automation and data sharing. Although substantial evidence of Industry 4.0 (I4.0) implementation worldwide has been widely documented, there is a notable lack of evidence on the Pakistani textile industry's preparedness for I4.0 adoption. The paper thus aims to assess the status of Industry 4.0 readiness among Pakistani textile firms. The study employed an explanatory-experimental design, and primary data was collected through structured questionnaires administered to 387 respondents representing various textile companies. The collected data were analyzed using SmartPLS 4, applying both descriptive and inferential techniques. Structural Equation Modeling (SEM) was the primary statistical technique employed. The results collectively indicate that the textile industry in Pakistan is at an initial level of 4.0 in preparation, suggesting limited application of enabling technologies. Thus, the research provides practical knowledge and guidance to industry leaders and policymakers on developing strategic interventions to strengthen I4.0 preparedness and harness its full potential in the textile sector.
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Introduction

Digital transformation in manufacturing is now a topic receiving significant attention from researchers and manufacturers across many areas (Hannola et al., 2018; Richter et al., 2018). The

current conceptions of efficiency, innovation, and sustainability are being reinvented using Industry 4.0 (I4.0), with areas of data exchange that are increasingly realized thanks to the application of Cyber-Physical Systems (CPS), Internet of Things (IoT) and Industrial Internet of Things (IIoT), Cognitive Computing, and Artificial Intelligence (AI) (Lu, 2017; Hermann et al., 2016). These technologies integrate to build smart factories, increase supply chain flexibility, save resources, and make production systems more sustainable (Bai et al., 2020; Bonilla et al., 2018). I4.0 is a strategic approach aimed at advancing the Fourth Industrial Revolution (Hermann et al., 2016; Bartodziej, 2017) and originated in Germany. Its three characteristic aspects, which separate it from previous industrial developments, are the unmatched speed of technological advancement, the 'cross-functionality' of a broader range of complex systems, and the systematic impact across the broader economy (Schwab, 2016; Sanders et al., 2016). Unlike traditional automation, the fourth revolution encompasses digital and physical systems that can build smart manufacturing environments capable of making decentralized decisions (Albers et al., 2016). Looking back, the Industrial Revolution brought major shifts in production and economies. The steam engine drove the first industrial revolution in the 18th century. Mass production, power technologies, and chemical treatments marked the second revolution (Bonilla et al., 2018). The third, electronics and information technology, emerged in the latter half of the 20th century as a key element of automation (Acemoglu, 2002). Industry 4.0, by contrast, incorporates a broader spectrum of technologies and two main goals: building and developing an agile, intelligent, and highly responsive digital ecosystem (Chung & Kim, 2016).

I4.0 technologies have advanced significantly in developing countries like Pakistan, the Pakistani business landscape remains in a unique position compared to others. Countries like Pakistan and textile industries are not technologically advanced, especially as digitalization is introduced worldwide. As a major source of GDP and employment, the textile industry must adopt Industry 4.0 (I4.0) to compete in global markets (Raut et al., 2020). The textile industry is strategically important, contributing 60 percent of Pakistan's total exports; it is also a major employer, as more than 15 million people are employed in the industry. However, manufacturing methods are mostly traditional and lack innovation and state-of-the-art technologies (Mainali, 2017; Rajbhandari et al., 2020). In the global economy, an efficient and cost-effective production system is essential. If modern manufacturing paradigms such as Industry 4.0 are not adopted, it may lead to lost competitiveness, inefficiencies, and missed economic opportunities (Castelo-Branco et al., 2019). This poses both a challenge and an opportunity for Pakistan, as neighboring countries like China and India have advanced technologies. These countries dominate regional trade. Still, Pakistan can reap the benefits of Digital transformation because economies of scale enable it to become more productive and meet international quality standards (Tri et al., 2021).

To achieve these goals, the textile industry needs to adopt Industry 4.0. Industry 4.0 offers higher process efficiency, lower costs, better decision-making, and more sustainable resource use (Stock & Seliger, 2016; Bai et al., 2020). These include a shortage of human resources, inadequate awareness, and a lack of strong technology backgrounds (Frank et al., 2019). In addition, barriers to moving to a digitalized manufacturing environment include resistance to change in organizational culture and a lack of strategic leadership (Muller et al., 2018). Under the umbrella of liberalization policies

and government reforms in Pakistan, there is a vision of an industrialized society, but the reality is too weak in practice and in technological advancement (Mainali, 2017; S, 2014). Efforts to improve industry competitiveness have been unsuccessful despite greater digital capacity and a more skilled workforce (Chopra et al., 2019). In this context, monitoring government measures is important. Digital literacy courses, regulatory frameworks, financial side effects, and government-industry partnerships also significantly affect industrial preparation (Kousar et al., 2017; Eilu, 2018). This is because government assistance must go beyond infrastructure; it must also build a culture of innovation, research, and training. According to the literature, states have different levels of digital transformation initiatives, and these initiatives are believed to be an important steppingstone toward implementing Industry 4.0 technologies in several countries (Schumacher et al., 2016; Dachs et al., 2019).

In this respect, the present study has shed light on the textile industry's readiness for Industry 4.0 technologies in Pakistan. It also explores how enabling factors influence technology innovation decision making, such as leadership approach, governance, digital culture, and government support. It also measures the mediating effect of I4.0 preparedness obstacles through government intervention. These findings will provide industry managers, decision-making actors, and stakeholders with valuable input on current readiness and strategies for successful Industry 4.0 implementation. Section 2 presents the literature review, which develops the conceptual framework and hypothesis 2. Section 3 addresses the research methodology, including the types of data to be collected, measured, and analyzed. Section 4 discusses the results and their interpretation, and Section 5 discusses the findings' implications, limitations, and directions for future research.

Literature Review

Our society is becoming more modern, and with the modernizing and inevitable upgrade of production and manufacturing systems, we are challenged by Industry 4.0 (I4.0). Through this seamless computerization and knowledge sharing, technologies like Cyber-Physical Systems (CPS), the Internet of Things (IoT), and the Industrial Internet of Things (IIoT) come into play (Morrar et al., 2017). Therefore, Industrie 4.0 has become an international benchmark for smart manufacturing and industrial digitalization based on support from physical and virtual systems as well as automation and real-time information. This paradigm can revolutionize the possibilities of productivity, sustainability and competitiveness of the textile industry in Pakistan. Several theoretical grounds explain the determinants of technological adoption in industries. The theory of technological paradigms posits that discoveries follow specific paths, as defined by social, economic, and technological circumstances (Dosi, 1982). Equally, disruptive innovation theory (Christensen et al., 2018) explains how breakthrough technologies can disrupt existing market structures and form new value networks. Rogers' (2004) diffusion of innovation theory sheds light on the process of spreading new ideas and technologies to societies and organizations. The Value Chain framework proposed by Porter (1985) emphasizes that technological improvements can enhance the performance of primary and support activities. A Technology-Organization-Environment (TOE) framework, developed by Tornatzky et al. (1990) and further extended by

Abed (2020), presents three key contexts technological, organizational, and environmental that govern the adoption process.

Numerous analytical frameworks have been proposed to explore the adoption and preparation of Industry 4.0. The Technology Acceptance Model (TAM) (Davis et al., 1989) emphasizes perceived usefulness and ease of use as key elements in adoption. The industry 4.0 Maturity Model and Readiness Index (Schumacher et al., 2016) provides standardized tools for evaluating the organizational level of readiness for digital transformation. The other methods of analysis — Partial Least Squares Structural Equation Modeling (PLS-SEM) (Hair et al., 2014), econometric models, have all been used to verify the multidimensional relationships between the variables influenced by digital readiness.

Studies worldwide indicate different levels of readiness for I4.0. McKinsey surveyed 130 manufacturing companies in China and found that only 57 percent are equipped to implement Industry 4.0 fully. In contrast, 71 percent of U.S. companies and 68 percent of Germany's manufacturing companies are ready for Industry 4.0. Some causes include low awareness of the importance of digital transformation, a lack of technological infrastructure, and a shortage of highly skilled employees (Frank et al., 2019). Given this, Lucato et al. (2019) argue that frameworks that include sustainable outcomes and organizational readiness must be considered when evaluating I4.0 systems, as traditional evaluation techniques are insufficient because they do not encompass the dynamics of operational technology (Lucato et al., 2019). Industry 4.0 technologies offer vast potential for productivity and efficiency improvements. CPS enables real-time communication between the digital and physical world; IoT and IIoT support communication with machines and the transfer of intelligent information. As a result, manufacturers can reduce manufacturing cycles, customize products, and adopt predictive maintenance plans (Zhou et al., 2015). It also changes business processes for strategic decision-making by leveraging Big Data, Artificial Intelligence (AI), and Cognitive Computing (Lu, 2017). With the advent of I4.0, entrepreneurial structures undergoing dramatic changes in market model adaptations, workforce competence, supply chains, and governance (Kagermann et al., 2013; Brixner et al., 2020).

Furthermore, Industry 4.0 contributes to sustainable production by improving resource use and reducing waste outputs (Bai et al., 2020). Industry 4.0 improves transparency and efficiency across supply chains, and technologies such as blockchain can support strategic decision-making (Saber et al., 2019). The textile industry in Pakistan accounts for about 60% of total exports. It employs millions, it faces issues such as outdated machines, power scarcity, low labor productivity, and a lack of automation. These constraints can be alleviated by Industry 4.0 technologies and modernized production processes that have lowered expenses and increased quality. Various programs such as the Special Technology Zones Authority (STZA) and the Digital Pakistan program represent the government's strategy to promote the process of industrial digitalization. But there are still some deviations in policy implementation, such as a lack of support in both R&D investment and skills development. Moreover, Kousar et al. (2017) mention that government interventions also have a

moderating effect on the intrinsic motivation for green innovation among the SMEs of Pakistan, and the same applies to the case of digital transformation for the textile sector in Pakistan.

The available literature provides an in-depth overview of what defines I4.0 preparedness and which factors are organizational, strategic, and policy based. Pakistan is still, albeit in infancy, rebuilding and re-drafting its industrial policy and transitioning into the digital era, it is important to review the evidence and acknowledge gaps to inform the transformation process. The textile sector, a prime example of the relevance of Industry 4.0 models and one of Pakistan's most successful industries, is key to Pakistan's manufacturing capacity. Besides this, Pakistani textile firms can implement other methods like know-how adoption in the form of best practices prevalent in other countries. German companies, for instance, and Japanese ones have been successful in smart manufacturing by investing in employee training, standardizing their operations, and implementing Cloud-based manufacturing systems (Min et al., 2019). Through industry-specific innovation areas and cooperation between authorities and industry, it is possible to tailor and develop these plans. Key issues are the cost of implementing the technology, reluctance to change, and legacy system integration. A multi-faceted solution is required, covering technological, human and institutional aspects, to meet the challenges highlighted in Oettmeier and Hofmann (2017). The article concludes by emphasizing Industry 4.0's potential to revolutionize Pakistan's textile industry. However, implementation and uptake will not start well unless there are technological readiness, skills, good governance and vision. The present study aims to resolve the identified gap between the theoretical level of Industrial Digital Transformation from international literature and the level of practice in the local context (Industry Pakistan) by proposing a proven theory, which is done at the later stages of the study.

Conceptual Framework

An industry readiness measurement has been undertaken by the study to observe the industry's readiness for Industry 4.0 in the Pakistani textile industry, which incorporates not only technology adoption through production but also process change based on established theory. The value of these theoretical backgrounds lies in the information that they supply regarding the forces that determine the choice of which firm adopts which NTP. According to the Theory of Technological Paradigm, technological innovations follow paths (paradigms), so that technological innovations follow a path within a paradigm. The paradigms are also relevant in relation to Industry 4.0, which is the view of production processes and business functions different from those known only before, because of new technologies such as the Internet of Things (IoT), Industrial IoT (IIoT) and Cyber-Physical Systems (CPS) (Dosi, 1982).

Similarly, Disruptive Innovation theory aptly demonstrates that new technologies unleash new market dynamics when they enter existing business models and operations in the market. Innovations are often at the regional level, first as a substitute for existing technologies and, over time, can displace sectors of industries altogether (Christensen et al., 2018). Digital innovation is threatening some of the more traditional activities, such as those in the Pakistani textile industry. The sociological theory, the Diffusion of Innovation theory, developed by Rogers, identifies other factors that can either impact people's likelihood of adoption or are consequences of the adoption

process, including communication channels, social systems, and time. It can categorize adopters as innovators, early adopters, early majority, late majority and laggards, which can be used as a convenient framework to comprehend the differential rate of Industry 4.0 adoption in textile companies in Pakistan (Rogers, 2004).

Michael Porter's Value Chain Model is about applying technology to the enterprise to contribute to value creation. Using Industry 4.0 technologies can have major positive impacts on the efficiency and effectiveness of any stage of the value chain, whether it involves inbound logistics, the process of operations, marketing and sales or customer services (Porter, 1985). These technologies should be translated into the textile industry and integrated together in a way to compete with other industries in the international market. The most popular and well-developed theory on technological innovation in the industrial environment, however, is the Technology-Organization-Environment (TOE) theory. It considers three broad contexts that influence the diffusion of new technologies: Technological, Organisational, and Environmental, as described by Tornatzky et al. (1990). Technological context: Internal and external technologies of a firm. Here, we include available technology, technology compatibility, complexity of new technology and perceived benefits. Time reduction can be, for example, the evaluation of possibilities in running automation of manufacturing machines and systems in the textile industry, the possibility of real-time data analysis, and the possibility of automatic quality control (Abed, 2020).

Organizational context is determined by certain key features of the firm, such as size, resources, managerial structure, human capital, etc. All these, such as the existence of qualified human resources, the culture of an organization, and leadership's commitment to innovation, significantly influence the readiness of a firm to adopt this new Industry 4.0 structure (Oliveira & Martins, 2010). Environmental context includes those factors that are outside the firm—influences such as competitive pressures, structure of regulations, customer requirements, and governmental assistance. Segments of the external environment which influence textile companies include government policies like Digital transformation, training & monetary incentives in Pakistan (Henderson et al., 2012). Schumacher et al. (2016) provided a more specific Industry 4.0 maturity model as a follow-on to the TOE paradigm. This model comprises nine dimensions, each with 62 indicators. These dimensions were based on recommendations from the German government and research by scholars on digital industrial transformation. In this case, the model is adaptable to the Pakistani textile industry, encompassing five main dimensions: people, customers, and culture; strategy and leadership; technology; governance and operations; and government intervention.

All these dimensions are determinant in determining the technological innovation decision-making process. The people, customers, and culture dimensions refer to the human factor, including employees' competence, digital literacy, and attitudes toward customers and the organization's culture. These factors affect an organization's openness and how feasible it is for a practical organization to use digital tools. Through reading on leadership and strategy, the key factors in achieving digital transformation are vision and strategic planning, and resources are invaluable at every stage. A clear Industry 4.0 strategy aligns business-oriented targets with digital activities and provides the necessary resources and change-management processes. Technology dimension

aims at the implementation and integration of technologies enabling (CPS, IoT, AI, big data analytics). It considers technological readiness, technological infrastructure and the ability to build and upgrade digital systems.

Governance and operations are areas of the business that are internal to the company, such as inter-departmental coordination, compliance execution and business operations' effectiveness. These characteristics are indicators of a firm's skill in digital transformation and its technology agility. Finally, government intervention acts as a hindrance between the associate of the organizational factor and environmental factor with adoption of technology. Kousar et al. (2017) findings suggest governmental support through financial support, policy inclusion, instructor training and regulation functions could be critical factors in preparing a company for the implementation of Industry 4.0 technologies. The conceptual model is the most important Theoretical Framework, but it also includes practical considerations and theories that must be considered when assessing Industry 4.0 Preparedness. It incorporates elements of organizational factors, technological resources, and environmental issues. In this context, the study aims to understand the barriers and key enablers that significantly affect digital transformation in Pakistan's textile industry.

To summaries, the literature reviewed has addressed that deterministic factors in Industry 4.0 can be analyzed using the TOE framework (Schumacher et al. 2016, Eilu 2018, Ullah et al. 2017). It presents a depiction of the blending of the five elements: strategy, technology, operations, culture, and policy, and provides a perspective on their digital readiness for transformation. It can be used not only in the empirical analysis to reach conclusions, but also to come up with specific interventions to aid practitioners and policymakers in the digital transformation of Pakistani industry.

Hypotheses Formulation

The inappropriate organizational and environmental contingencies impact the utilisation of Industry 4.0 in textile businesses within Pakistan. The Technology Acceptance Model (TAM) (Davis, 1986) is one of the latest theories that explain these dynamics. This model has two general determinants: "perceived usefulness" and "perceived ease of use," which are key to employees' and customers' adoption of emergent technologies. The TAM framework can be applied on a corporate level and emphasizes the critical role of people and customers, and organizational culture, in facilitating an innovation-driven mindset. Based on this, the current study connects these players with relevant contextual factors as mediating ones in the innovation decision-making process.

H01: Technology Innovation Decision-Making is not significantly related to People, Customers, and Culture.

New technologies which are integrated into the product can lead to long-term resource efficiency and competitive advantage as industries are looking into achieving sustainable operation. Oesterreich and Teuteberg (2017) stress that these traditional production systems, plagued by lots of wasted resources and energy inefficiency, must be shifted towards more innovative product design which relies on advanced digital technologies. Within the textile sector, the development of novel fabrics, smart dyeing methods and Putin the smart into the garment pave the way to further

sustainability and productivity. How much product innovation will contribute directly to making technological decisions, however, is an empirical question.

H02: Technology Innovation Decision-Making is not significantly related to Products.

Strategic leadership implementation as a catalyst for digital transformation. With Industry 4.0, many new avenues for business model innovation emerge; therefore, organizations must restructure their processes and revenue streams (Arnold et al., 2016; Müller et al., 2018). In Pakistan, where the transition to Industry 4.0 is still underway, managers cannot merely accept the opportunities Industry 4.0 offers; they must thoroughly interrogate their organization and urgently reposition it strategically, while also investing in enabling technologies. An ongoing academic debate remains about the link between leadership approach and the decision-making process in technological innovation.

H03: Technology Innovation Decision-Making is not significantly related to Strategy and Leadership.

The driving force of Industry 4.0 is the technological system on which it lies, namely (cyber-physical systems), (artificial intelligence), (industrial internet of things (IIoT)) and (advanced data analytics). These are interrelated and, as pointed out by Machado et al. (2019), are all considered sustainable industrial practices. But there is significant gap between technology potential and application in firms in Pakistan, where most of the firms continue to use dated technology and practices in an era when rest of the world has seen a technology revolution. While these technologies must exist for innovation to happen, there is likely to be variation in their role in innovation decisions by organizational environment.

H04: Technology Innovation Decision-Making is not significantly related to Technology.

Organizational structures and governance are other factors that can influence digital transformation success. Müller et al. (2018) and Stock and Seliger (2016) find it significant that there are simulations and real time information that help streamline the production process to exclude redundancies, which is paramount in more labor-intensive manufacturing as opposed to, say, automotive manufacturing. Governance can speed decision-making process and strengthen compliance with global standards. Oettmeier and Hofmann (2017) holds that 4G industry can lay the operating conditions for better production results. Empirically, however, the direct link between governance practices and choices of technologies should be explored.

H05: Technology Innovation Decision-Making is not significantly related to Governance and Operations.

The success of technological transitions is also mediated by external institutional support, especially government support. According to a study by Ghimire (2020), the state of IT education should also be encouraged through public policy that offers incentives and financial support, as well as providing facilities to support the implementation of Industry 4.0. In a developing economy like Pakistan, where many firms lack the capital and capacity to install complex technologies, the

government should act as a mediator between organizational preparedness and implementation by providing training programs, grants, and simplifying regulations.

Accordingly, this study formulates the following mediating hypotheses to investigate the role of government intervention in shaping the relationship between various organizational constructions and technology innovation decision-making:

H06: Government intervention mediates the relationship between Technology Innovation Decision-Making and People, Customers, and Culture.

H07: Government intervention mediates the relationship between Technology Innovation Decision-Making and Products.

H08: Government intervention mediates the relationship between Technology Innovation Decision-Making and Strategy and Leadership.

H09: Government intervention mediates the relationship between Technology Innovation Decision-Making and Technology.

H10: Government intervention mediates the relationship between Technology Innovation Decision-Making and Governance and Operations.

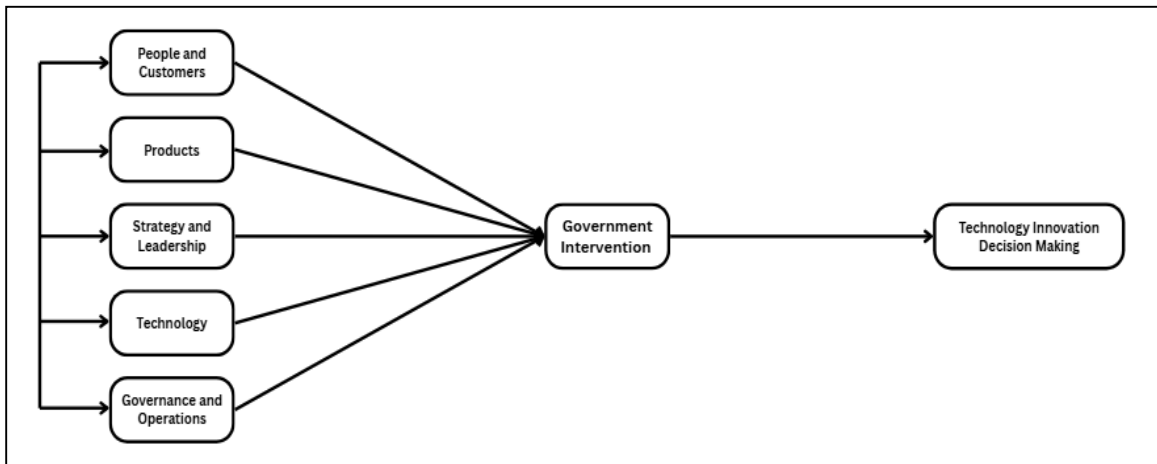


Figure 1: Conceptual Framework

These hypotheses are designed to guide the empirical investigation into Industry 4.0 readiness and adoption in the Pakistani textile sector. By testing these relationships, the study aims to contribute to both theoretical knowledge and practical understanding of the dynamics that facilitate or hinder digital transformation in emerging economies.

Research Methodology

The paper is based on an explanatory research design used to test and extend the hypothesis, aiming to identify the causal relationship between the main variables related to the adoption of

Industry 4.0. According to Shmueli (2010) and Rahi (2017), explanatory research allows the discovery and examination of the direction and magnitude of the influence between independent and dependent variables. Thus, it is most suitable when exploring the extent to which the decision considers significant changes in organizational, technological, and environmental aspects. The research by Kivunja and Kuyini (2017) focuses on uncovering the factors behind Industry 4.0 readiness in the manufacturing sector, an underexplored aspect of the textile industry in Pakistan. The targeted population in this research will be firms operating in the textile and manufacturing sectors in Pakistan's major industrial regions. A total of 387 valid responses were collected via a census to gather information on operational enterprises within the selected industrial clusters. They represent a broad spectrum of small, medium and large enterprises engaged in textile production, processing and technology related services, in a heterogeneous way. Respondents were mostly management-level people who are responsible for introducing the technology and operation planning. The broad geographic distribution of research can offer a picture of what is the level of digitization in the industry and how involved industry is in the transition to industry 4.0.

Instrument and Data Collection Procedure

The Data were collected on a structured survey instruments based on various dimensions to assess the Organization preparedness towards the fourth industrial revolution (Industry 4.0). The instrument was adapted from the validated constructs, and scale was of five-point Likert-type scale from 1 to 5; (1 - Strongly disagree; 2 - Disagree; 3 - Unknown; 4 - Agree; and 5 - Strongly agree). The survey was composed of seven constructs, the variables which emerged in the conceptual framework:

Construct	Item Code	Statement
People, Customers, and Culture	PC1	Organization is digitalizing sales/service for buyers/customers.
	PC2	Customers are competent with digital media.
	PC3	The organization placed high value on ICT.
	PC4	Employees are competent with ICT.
Product	PR1	The organization's products integrate seamlessly with other systems to create innovative solutions.
	PR2	The organization differentiates products using new technology.
	PR3	The organization's product positioning strategy supports the adoption of new technology.
Strategy and Leadership	SL1	The organization uses an Industry 4.0 roadmap for strategic planning.
	SL2	Organization has resources available to realize Industry 4.0 activities.
	SL3	The organization has adapted business models for Industry 4.0 activities.
Technology	TE1	Organization has advanced ICT to support Industry 4.0.
	TE2	Organization utilizes mobile devices for data transformation.
	TE3	Organization has sufficient technology for innovative production activities.
	TE4	Characteristics of existing technology support Industry 4.0.

Governance and Operation	GO1	Organizational processes are decentralized to adopt new technologies.
	GO2	The organization uses modeling and simulation for managerial or technical decisions.
	GO3	Organization fosters interdepartmental collaboration for Industry 4.0.
	GO4	Organization has labor regulations for Industry 4.0 implementation.
Government Intervention	GI1	Government provides financial support for new technologies.
	GI2	The government encourages businesses to develop innovative products utilising new technology.
	GI3	The government organises training and workshops to promote technology.
Technology Innovation Decision Making	TD1	Top-level executives are supportive of new innovative technology.
	TD2	Managers are interested in adopting new technologies.
	TD4	The organisation fosters an open culture for innovation and creativity.
	TD5	Managers can make decisions regarding technology adoption.

Data was collected through both physical and digital distribution to enhance response validity and maximize completion rates. Four hundred and twenty respondents were asked to complete the questionnaire, and 387 valid questionnaires were returned (a 92.1% response rate). Several tests were conducted to ensure model quality, convergent and discriminant validity, and the consistency and completeness of the data collected.

Data Analysis and Structural Equation Modeling (SEM)

To explore the research assumptions and confirm the conceptualization, Structural Equation Modeling (SEM) was conducted using SmartPLS 4. Moreover, SEM allows researchers to model complex relationships between observed and unobserved variables and test direct and indirect effects in a single model while controlling for multiple measurement errors. Given these merits, SEM is a suitable research methodology, particularly for research involving latent variables and multivariate analysis (Chin, 1998), and for models robust enough to test the validity of the research model. Two measurements were taken to analyze the SEMs established as follows: (1) the reliability and validity of the constructs, and (2) the structural model to test the connecting paths expected between the constructs. For the measurement model, we examined factor loadings, composite reliability, Cronbach's alpha, and Average Variance Extracted (AVE) to assess internal consistency and validity.

Results and Analysis

To investigate the strength of associations among constructs and validate the proposed hypotheses, we used a comprehensive inferential statistical approach. This study used Confirmatory Factor Analysis (CFA), Structural Equation Modeling (SEM), and mediation analysis in SmartPLS on data from 387 industrial respondents to assess measurement model reliability and validity and analyze relationships among variables in the structural model.

Confirmatory Factor Analysis (CFA)

The measurement model was evaluated using CFA to determine whether it adequately captured the theoretical constructs. This ensures the measured variables accurately reflect the unmeasured constructs. Model fit was assessed using the Comparative Fit Index (CFI), Root Mean Square Residual (RMR), and Root Mean Square Error of Approximation (RMSEA). CFI close to or better than 0.90, RMR close to or below 0.08, and RMSEA close to or below 0.08 indicate acceptable model fit, according to Harrington (2009) and Brown (2015).

The chi-square-to-degrees-of-freedom ratio (CMIN) was 2.8, indicating acceptable model parsimony, as per Hair et al. (2014). In fact, CFI was 0.937, well above the 0.90 threshold, indicating a good fit of the model structure. The RMSEA was 0.069, which fell within the medium acceptable range. RMR also complied with the benchmark values. These metrics confirm the model's suitability for the collected data (CMIN/DF = 2.351, $P < 0.01$; CFI = 0.937; RMR = 0.069; RMSEA = 0.069).

Convergent Validity

Convergent validity refers to the degree of "convergence," or the shared variance among a construct's indicators. Hair et al. (2014) described the validation criteria as follows: factor loading (preferably >0.7), Composite Reliability (CR >0.70), and Average Variance Extracted (AVE >0.50). The study assessed internal consistency and confirmed construct reliability by meeting or exceeding these standards. As shown in Table 6, the People, Customers, and Culture (PC) construct met the CR (0.926) and AVE (0.758) criteria. Factor loadings are > 0.7 for all displayed items. Acceptable convergence indicators were also found for other constructs (Product (PR), Strategy and Leadership (SL), Technology (TE), Governance and Operations (GO), Government Interventions (GI), and Technology Decision Making (TD)).

Table 6: Factor Loading, CR (Composite Reliability), and AVE (Average Variance Explained)

Constructs	Items	Loadings	Cronbach's Alpha	Composite Reliability	AVE
P&C	PC1	0.811	0.925	0.926	0.758
	PC2	0.720			
	PC3	0.819			
	PC4	0.756			
Pro	Pro1	0.837	0.939	0.940	0.839
	Pro2	0.845			
	Pro3	0.825			
SL	SL1	0.930	0.892	0.894	0.738
	SL2	0.847			
	SL3	0.775			
Tec	Tec1	0.808	0.797	0.799	0.500
	Tec2	0.902			
	Tec4	0.819			
	Tec5	0.849			

GO	GO1	0.952	0.867	0.867	0.620
	GO2	0.849			
	GO3	0.870			
	GO4	0.713			
GIn	GIn1	0.923	0.861	0.862	0.676
	GIn2	0.705			
	GIn3	0.868			
TIDM	TIDM1	0.819	0.957	0.957	0.846
	TIDM2	0.714			
	TIDM4	0.957			
	TIDM5	0.995			

All constructs demonstrated satisfactory convergent validity.

Discriminant Validity

To assess discriminant validity, which implies that constructs are distinct from one another, we used the Fornell-Larcker (1981) criterion. The method compares the square root of the average variance extracted (AVE) for each construct with the correlation. The correlation between constructs of the same latent variable should be below the square root of each AVE. As shown in Table 7, each diagonal value ($\sqrt{\text{AVE}}$) was greater than the corresponding correlations in the rows and columns. For instance, the highest $\sqrt{\text{AVE}}$ correlation with another construct was with Technology (TE), at 0.707. This result confirms discriminant model validity, that is, each variable identifies a different facet of the industry 4.0 readiness concept. Conceptual development of simple models and hypothesis testing. SEM was used to test the relationships among the structures and constructs. The model's predictive power was assessed using R². Chin (1998) suggests that R² values of 0.67, 0.33, and 0.19 represent high, moderate, and low, respectively. According to this model, the R² values for Government Intervention (0.37) and Technology Decision Making (0.33) were moderate, indicating that the independent variables accounted for a moderate amount of variance in the models. We used a general bootstrapping methodology (5000 samples) for hypothesis testing. Table 8 presents the path analysis findings from the SEM.

Table 8: Results of Structural Path Model

Hypothesized Path	Path Coefficient (β)	t-value	p-value	Decision
PC → TD	0.409***	5.875	<0.001	Supported
GO → TD	0.022	-0.247	<0.05	Supported
PR → TD	0.042	0.786	<0.05	Supported
TE → TD	0.281**	3.506	<0.01	Supported
SL → TD	-0.201**	-2.870	<0.01	Supported
GI → TD	0.172*	2.302	<0.05	Supported

Note: *p < 0.05, **p < 0.01, ***p < 0.001

Mediation Analysis

Mediation testing examined whether GI served as a mediator in the relationship between exogenous constructions and TD. The bootstrapping procedure (Preacher & Hayes, 2004) was applied using 1000 samples and 95% bias-corrected confidence intervals.

Table 9: Mediation Analysis Results

Relationships	Path (β)	Coefficient	t- value	95% CI	p- value	Decision
P&C → GI → TDM	0.044		2.200	0.014, 0.118	0.011	Supported
PRO → GI → TDM	0.009		0.800	-0.005, 0.029	0.336	Not Supported
SL → GI → TDM	0.006		0.273	-0.018, 0.060	0.574	Not Supported
TEC → GI → TDM	-0.084		2.667	-0.139, -0.011	0.012	Supported
GO → GI → TDM	0.091		3.080	0.016, 0.181	0.032	Supported

The results indicate that Government Interventions (GI) significantly mediate the relationship between People, Customers and Culture (PC), Technology (TE), and Governance and Operations (GO) with Technology Innovation Decision-Making (TD). However, the mediating effects of SL and PR were not statistically significant.

Discussion

The study's analysis and findings on industrial readiness for the adoption of Industry 4.0 technologies in Pakistan yield several important insights that contribute to the academic discourse on decision-making related to technological innovation in developing countries. The structural and inferential analysis emphasized significant correlations between variables that included People, Customers, and Culture (PC), Strategy and Leadership (SL), Technology (TE), Governance and Operations (GO), Product (PR), and mediator Government Interventions (GI) in terms of constructing Technology Innovation Decision Making (TD). The results are not only statistically significant but also practically valuable because they contribute to findings in the industry 4.0 transition area, where the dynamic interaction between technical factors coinciding with innovation adoption and organizational readiness factors have been explored. A strong positive correlation was established between PC and TD, further reinforcing Davis (1986) and Davis et al. (1989) that intention to use is central to the TAM. Given Pakistan's manufacturing sector and this connection, the sector should build a people-oriented technological culture in parallel as it moves toward Industry 4.0. As organizations attempt to change, the only thing that will tip the balance toward innovative industry paradigms is employee flexibility and customers' positive attitude toward the change that's coming. This aligns with the end of the Muller et al. (2018) study, which revealed that internal dynamics and organizational culture play a crucial role in digital transformation. Somewhat surprisingly, there was no significant relationship between Technology

Decision-Making (TD) and Product (PR). This does not necessarily mean this information translates into opportunities to implement innovative technologies, but businesses do know about potential innovative products. This confirms Oesterreich and Teuteberg's (2017) finding that product innovations do not always, and not even often, bring significant changes in technology use unless accompanied by an organizational change strategy. The Pakistani industrial environment, characterized by small and medium-sized enterprises (SMEs), may lack the necessary infrastructure and research and development to convert product awareness into a functioning technology. This realization is a call to action for those in policy and business leadership to reconsider how resources might be spent, not only in product innovation but also in systematically and strategically reinventing processes.

One of the most interesting findings is the negative, albeit considerably significant, influence of Strategy and Leadership (SL) on Technology Decision Making (TD). This finding contradicts the primary observation in the literature, which holds that strategic leadership is typically viewed as an enabler rather than a barrier to innovation (Arnold et al., 2016). A potential cause of this paradoxical finding is that management in most companies in Pakistan practices a top-down form of decision-making, where revenues and finances overrule the need to be creative with experiments. The resistance can also be attributed to the slow pace of implementing new strategies and the lack of digital transformation champions within management. Therefore, despite the view that Industry 4.0 technologies can be worthwhile, the leadership style fails to prioritize realizing what it means to go digital and comprehending Industry 4.0, including its benefits and drawbacks, for an entity. Positive relationships between TE and TD demonstrate that technological capability and infrastructure are essential to the innovation process. As soon as companies understand digital platforms, automation systems, and the interconnection of smart devices, they are more likely to make decisions that presuppose technological changes. Machado et al. (2019) contend that Industry 4.0 is cemented on the intertwined nature of technology, and sustainability Pakistan's industrialization is maturing and likely to reach maturity soon. This provides a strong platform for the general industry to improve their capability to 'manage intelligent systems', make them more tech-savvy, and slowly integrate them. But it also implies that even that limited awareness of technology can catalyze a move, given an enabling environment in such factors as training and education.

The inclusion of Government Interventions (GI) as a mediator variable was one of the significant steps in this research study. The results demonstrate that the cross-effect of TD and other anticipators (PC, GO, TE) significantly took place through GI. Ghimire (2020) also contended that public sector initiatives contribute hugely to reducing the digital divide. The role of government is even more significant in Pakistan, where the lack of infrastructure, regulatory uncertainty, and fiscal constraints are discouraging innovation from the private sector. Intervention tools and measures related to technology, such as subsidized technology training and education, tax measures for technology acquisition, National Industry 4.0 trajectories, etc., can increase the level of readiness of local industry for technology. For example, the adoption of technology is a task for education, but it is also something that needs to be institutionalized together with regulation and industrial policy, which GI can help to do.

The influence of GI in PR and SL seems to have had little effect. This implies that the government efforts or initiatives cannot resolve the lack of strategies and capabilities towards product innovation. The government can do its part to provide a “favorable” environment, but the ability and strategic orientations of the firms need not be overlooked. This further reinforces that the process of Industry 4.0 is lateral: the inside must be ready for it, and the outside must support it, and while introduced together, the challenge is to realize and implement Industry 4.0. For instance, even though the government is providing training options, it must have a long-term plan for digital transformation – otherwise, it will be of no use. This reliance on both renders it even more crucial to develop a structure for effective public-private sector collaboration. The value of the preparedness index in the study highlights the level of preparedness of Industry 4.0 in Pakistan. As far as firms are concerned, most of them (and virtually all (57.1%)) were classified as being in the embryonic phase and being very conscious about enabling technologies. This is in line with the low level of digital maturity in companies found in Nepal by Rajbhandari et al. (2022). The significant underrepresentation of intermediate firms in firms at higher stages suggests that there are enclaves of excellence, related to export orientation, foreign investment, and more powerful and/or better links with international knowledge networks. Most, however, must deal with simple limitations, ranging from poor internet access solutions to hardware that is too old, lack of technical training or lack of Research and Development investment. This is an alarm bell that policymakers must heed to see digital infrastructure as an important element of the country's industrial policy.

Based on the CFA and SEM results, the model proposed showed good reliability and validity. The empirical validation of this similarity in the structures between the different forms of readiness is important. But theoretical validation is seldom given in detail when it comes to studies from developing countries, which restricts opportunities to further study and application of the results. In addition to using advanced statistical techniques (SmartPLS, bootstrapping procedures, and so on), the study also followed best practices recommended in the literature on model evaluation and fit measures (CFI; Hair et al., 2014). This methodologically contributes to general solidity and verifies the figures, which also helps to standardize further studies in similar situations. The paper conceptually investigates the impact of which technology an Industry can plan to select, despite the considerations of different factors. It is based on the absence of strong singular multifaceted decision making. Beyond that, it underscores contextual factors in developing economies; some of them are as important as the above in developed markets such as government sponsoring or culturally ambivalent attitudes to change. For example, in South Asia, the stimulus to innovation might come from state policy, while in the West it might come from the private sector.

This study found that organizational culture is important in the technology adoption process. People, Customers, and Culture (PC) play a major role in Technology Decision-Making and make it clear that change is not purely technical; it is socio technical. This aligns with Urbach and Ahlemann (2010), who found that cultural compatibility is a vital element in improving the success rate of IT implementation. Enterprises that adopt an experimental, open-minded approach and constantly seek new learning methods are better suited to cope with turbulence when new disruptive technologies are introduced. However, a significant percentage of Pakistan's SME are family firms, and their management style is often hierarchical and conservative and may require

changes in processes, better management and more intensive training programs; the results highlighted the knowledge-technology practice gap. Sometimes, some businesses might know about the factors Industry 4.0 brings but fail to apply them. This can be for reasons of perceived risks, cost or difficulty in achieving 'successful completion'. But in this regard, an innovation station could be regarded as one of the potential success factors, because it will bring together government, business, industry, academia and the knowledge exchange society to overcome these "psychological" and budgetary barriers. These forums can give real-life support. An interesting observation is that regional comparisons and policy benchmarking may be possible. While the third and fourth industrial revolutions are in progress, Pakistan needs to learn from other countries and nations in South Asia how to structure its approach to Industry 4.0, as outlined in the future directions by Rajbhandari et al. (2022). Reviewing contrasting research studies could provide clues as to what interventions worked and how they were modified, and how they were established. In this regard, industry-specific 4.0 policies can be seen in, for instance, Malaysia and Germany, and could be useful templates that, with a tweak to the cultural and economic context in Pakistan, could be implemented.

In sum, this research contributes to the understanding of Industry 4.0-readiness of industries in Pakistan and brings a more complex perspective on the factors that influence technology acceptance. The findings indicate that human, strategic, technological and governmental aids are of critical importance. To develop a digitalization strategy, one must be ready, have an effective strategy, and empower the social side. Given the state of Pakistan's industry, which works in fits and starts, the policymakers and businessmen (those interested in sustainable and inclusive technological change) may be able to learn from this study and suggest policies.

Practical Implications for Pakistan

Based on the Industry 4.0 readiness scores, several strategic implications can be drawn for government bodies, industry, policymakers, and business leaders to consider:

National Policy for Industry 4.0:

To roll out innovative technologies in a systematic, formal and comprehensive manner, a policy roadmap is required. Given the absence of government-provided institutions like the Ministry of Industries, SMEDA and PITB, it will be difficult to establish a coordinated framework between national goals and Industry 4.0 efforts.

Capacity Building- Education and Training:

A proficient approach towards automation, AI and digital transformation is among the major gaps identified by readiness information. Funds for Vocational and University technical education are extremely urgent. Programs must incorporate a workforce that allows potential workers to work with and/or manage high technology.

Public-Private Collaboration and incentives:

Clearly defined incentives are vital to investments in Industry 4.0 technologies. The financial support must comprise tax exemptions, R&D support, as well as digital transformation support to soften the burden of infrastructure upgrading, notably for SMEs.

Improving Digital Infrastructure:

The AMC sector faces challenges with the implementation of the 'digital revolution' with existing infrastructure for both ICT and energy. Also critical are Internet access, power sources, and cloud computing in support of innovative manufacturing systems.

Develop Model Digital Industrial Areas:

Development of overhaul industrial estates with digital facilities can also be used as a model which can be replicated in important industrial loci across the country, including Karachi, Lahore and Faisalabad. All of these zones must be integrated with IoT and data analytics features and robotics along with AI systems, for optimum productivity.

Strategic role of Government intervention:

Government facilitation, regulatory and policy enablers require strengthening in Pakistan. The Government must promote and facilitate technological innovations in infrastructure, policies, and digital preparedness.

Customs & Import Reforms:

One of the main problems reported by companies in Pakistan is the logistics and bureaucracy problems associated with the introduction of new equipment. A need for customs reforms, import duty exemptions for digital devices, and quicker customs processing of imported industrial technology.

Conclusion

The current research investigates issues of Industrial Preparedness for Industry 4.0 in Pakistan and identifies gaps that exist in the awareness, preparedness and practice of industry. Today, the industrial sector, which has an impact on many small- and medium-scale enterprises (SMEs), is at a turning point, and the time to digitize. The level of national preparedness is still low, with many cities still not ready in education, infrastructure, finance, and implementation of policies, although there is increased sensitivity in some cities. This calls for concerted efforts from the government, ongoing initiatives of fast-track actors in the private sector, schools and international development partners. Human capital investment, along with investments in modern infrastructure and innovative ecosystems, is crucial to start the transition from traditional to innovative manufacturing. Industry 4.0 can play a major role in Pakistan's growing productivity, competitiveness, and economic power in the global economy, but only when the right enabling factors are in place.

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