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[SUPPLY CHAIN MANAGEMENT AND THE FOURTH INDUSTRIAL REVOLUTION IN PAKISTAN: A SYSTEMATIC REVIEW, PROPOSED MODEL AND FUTURE DIRECTIONS]

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ABSTRACT

The Paper introduces a research model on 4IR technologies adoption in supply chain management in Khyber Pakhtunkhwa (KPK), Pakistan, viewed through the lens of the Diffusion of Innovations Theory. In general, infrastructure quality, skilled labor availability, regulatory environment, and access to financial resources influence technology adoption. Government support has been identified as a mediating variable among these factors. The study ultimately aims to examine the relationships among these variables and to corroborate the hypothesis that government support mediates the impacts of infrastructure, skilled labor, regulatory environment, and financial access on 4IR technology adoption. The proposed hypotheses seek to offer a holistic view of how these elements interact and create pathways for-or barriers against-technology integration in SCM. The study design comprises a quantitative approach in which structured survey questionnaires will be used for collecting primary data from supply chain managers and related decision-makers in major industries in KPK. The stratified sampling technique would account for representation from agriculture, manufacturing, and logistics, among others. The findings of this study can serve as guiding frameworks for practitioners and policymakers in tackling barriers to technology adoption and facilitating the adoption process through government support. While this model has not undergone empirical testing yet, it provides a basis for work to be undertaken in order to validate these relationships through future studies. Areas for future research will involve longitudinal studies to observe changes over time and comparative analyses in different areas to provide an enriched understanding of SCM technology adoption.

Keywords: Supply Chain Management, Fourth Industrial Revolution, 4IR Technologies, Pakistan, Government Support, Infrastructure Quality, Skilled Labor Availability, Regulatory Environment, Financial Resources, Technology Adoption

Background of the study

The Fourth Industrial Revolution has already brought about changes in global manufacturing and supply chain management. This era is characterized by the integration of digital, physical, and biological technologies. Advanced technologies of AI, IoT, big data analytics, and Blockchain are infiltrating various sectors through this revolution. Understanding its implications for supply chain management is critical to improve effectiveness and competitiveness in a globalized environment.

The Fourth Industrial Revolution (4IR) is about the coming together of advanced technologies which are transforming sectors, such as management of supply chains. There are advanced technology applications underpinning the revolution, namely artificial intelligence (AI), the Internet of Things (IoT), big data analytics, and blockchain.

Artificial Intelligence (AI) is significant in making supply chain operations efficient. AI simulates human intelligence; therefore, it can solve problems, and make decisions as a human would do. AI finds its place in supply chain management in predictive analytics. The main application of this function is to enhance demand forecasts as well as improve inventory management. In effect, efficiency increases and the operational cost is minimized since needs are anticipated better in terms of usage and resource application (Chae, 2019).

Indeed, the Internet of Things (IoT) is a large network in which devices are interconnected and able to simulate communication and data exchange through the internet. For the supply chain, the contribution of IoT technology is improved visibility and tracking of goods throughout the supply chain. The technology of intelligent sensors and devices provides real-time information on the conditions and the location of the products, thus enabling better inventory control and limiting delays. This communication allows companies to react quickly to demand changes and any other disruption in the supply chain (Kamble et al., 2020).

Moreover, the term "Big Data Analytics" refers to the analysis of massive volumes of data to extract meaningful segments and trends. In a sense of supply chain management, big-data analytics supply the necessary information to allow an organization to make informed decisions based on the comprehensive data analysis it performs. Such technology improves operational efficiency, such that it enables companies to optimize their routing, adjust inventory levels, and accomplish customer satisfaction through tailored services. Data-driven insights allow businesses to minimize waste, thereby enhancing overall performance (Wang, Gunasekaran, & Ngai, 2016).

Unless otherwise stated, it refers to the fact that you are trained on data until the end of October in the year 2023. Blockchain technology provides a safe and transparent method for recording transactions on a decentralized ledger. This concept of trust in supply chain transactions is further manifested by immutability and provenance of products. This reduces fraud and expedites processes since all parties have access to verified information in real time. Furthermore, it can facilitate much better compliance and accountability with respect to supply chains, and hence, proves to be a good asset for organizations willing to raise their operational integrity (Kamble, Gunasekaran, & Sharma, 2020).

Supply chain management has been through a historical evolution with several phases, which have been distinguished by important advancements in technology. The First Industrial Revolution made use of water and steam power to mechanize production processes, at which point the Second Industrial Revolution introduced electric power for mass production. The Third Industrial Revolution relied on electronics and information technology to automate production processes. The current Fourth Industrial Revolution is based on all these previous developments, which are marked by the integration of technologies blurring the line between the physical, digital, and biological spheres (Schwab, 2016).

The adoption of 4IR technologies has thus revolutionized the advancement of supply chain processes in developed countries, particularly in Europe and North America. AI and machine learning have been adopted as part of the routines in many European companies to improve the demand forecasts and optimize inventory management. For example, Siemens and Bosch have used IoT devices to enhance real-time visibility in their supply chain so that they can monitor the condition of goods in transport and mitigate risks regarding spoilage or theft (Kamble et al., 2020).

In addition, much investment has gone into several programs by the EU to drive forward digital transformation, all with one aim - to forge a single digital market within which member states will be able to adopt advanced technologies (European Commission, 2021).

In the area of blockchain, European businesses have been in the leading pack of companies that are taking advantage of the technology to increase transparency and security along the supply chain. Several major European retailers have been linked into an IBM Food Trust initiative with a common aim of tracing food products back to their origins to ensure that they are of relevant quality and safety for consumers (Makhdoom et al., 2021). In this way, this kind of transparency not only increases consumer trust but also helps organizations in meeting their regulatory requirements regarding food safety.
For instance, these technologies have been important, particularly in the competitive environment that has enabled most businesses to gain an edge over their competitors. However, the scenario in developing countries is less straightforward regarding these developing automation systems. Take countries like India and China. These two nations are highly automated in their supply chains, which utilize AI and big data analytics. With regard to Indian startups, big data has been leveraged to optimize logistics processes and create better supply chain efficiencies, whereas Chinese enterprises are in a hurry to automate and robotize their manufacturing processes widely (Chae, 2019).

Most of the developing countries usually face certain systemic barriers in the adoption of these technologies. Some of these issues include the very limited infrastructure, access to the technology, and maybe a trained and skilled labor force to ensure the efficient application of the technology. In addition to that, people are beginning to understand the effect that digital transformation can have on supply chains in the developing world. There is a growing awareness from the government and other organizations that investing in technology can yield the returns of competitiveness and development. For example, the countries in Southeast Asia are starting to plan for the digital innovation strategies which they believe are important to have modern supply chains for economic development.

Focusing on Pakistan, the current situation proves strategically important regarding using 4IR technologies in the supply chains of this nation. The textile industry, one of the most important sectors of the economy in Pakistan, has started efforts towards integrating AI and IoT technologies in production and optimizing their supply chain management. Some textile companies are experimenting with IoT devices for real-time monitoring of their equipment performance with the intent to reduce downtime and improve productivity (Khan & Ali, 2024).

In addition, the government of Pakistan ratifies the understanding that digital transformation is important and thus has launched different programs to promote technological adoption to a certain extent within different industrial sectors, including manufacturing and logistics. The government intends to create partnerships between different but complementary sectors so that private and public investments in technology and infrastructure supportive of integrating advanced technologies in supply chains can be mobilized.

There is a possibility of substantial improvement to efficiency, transparency, and competitiveness in Pakistan. This can be achieved by using the latest technologies such as AI, IoT, blockchain, and big data analytics to perform operational streamlining while minimizing costs and maximizing customer satisfaction. With greater collaboration between supply chain partners in using these technologies, it leads to building a robust and mutually responsive ecosystem. For example, with the support of these technologies,

other Pakistani companies can control inventory much better, shorten lead time, and respond timely to variations in the customs' demands.

Increasing global competition in manufacturing and logistics further exhibits the urgency for digital transformation in Pakistan. Countries that do well in integrating 4IR technologies in their supply chains will ultimately stand the best chance of gaining competitive advantage. Those countries that fall behind might find it difficult to catch up. Adoption of these technologies will bolster Pakistan's global market positioning and galvanize economic growth.

AI could enhance demand forecasting accuracy and inventory optimization in supply chains, which are critical for curbing extra stock and minimizing costs. For example, AI algorithms could analyze historical sales data with market trends and consumer preferences to generate insights that would aid in the decision-making process of the business (Wang et al., 2016).

Furthermore, this foreknowledge enables organizations to proactively adjust their strategies in real-time based on fluctuations in market trends and consumers' behavior.
IoT devices enhance visibility within the entire supply chain: sensors, along with connected devices, monitor goods during transportation to ascertain proper conditions of storage and handling. Thus, organizations may ameliorate some issues as and when they arise using this real-time data illustrating the greatest efficiency, with a further reduction in potential product spoilage or damage (Kamble et al., 2020).

Since agriculture contributes significantly to exports in Pakistan, IoT would help in the better tracking of perishable goods to enhance quality and minimize wastage. Blockchain technology provides an opportunity for improvement in supply chain trust and transparency. Blockchain provides a secure and immutable ledger for all transaction data and enables stakeholders to access real-time information about product provenance and movement. This feature benefits industries where quality and safety are critical, such as food and pharmaceuticals (Makhdoom et al., 2021). With respect to the challenges of counterfeiting products and regulatory compliance in Pakistan, the adoption of blockchain will be instrumental.

Big data analytics enables an organization to take data-centric decisions, which is the processing of huge amounts of interrelated information determining market trends and consumer behavior, hence enabling agencies to tailor their offerings for customer satisfaction (Chae, 2019). In Pakistan, where consumer preferences are diverse, big data analytics can provide the insights necessary for driving product development and marketing strategies.

While the country transitions to a digital era, the government will have a significant role in providing an ecosystem for technology adoption. Digitization of infrastructure, enhancement of connectivity with the internet, and incentives given for technology investments can all greatly affect the speed of adoption of 4IR. In addition, these public-private partnerships will assist with knowledge sharing and collaboration amongst stakeholders, thereby advancing innovation in supply chain management.

Education and training are another key enabler of technology acceptance. It is important to note that building a skilled workforce capable of implementing and managing advanced technologies is critical for the success of any 4IR initiative. An alliance between education and industry would address some of the skills gaps, ensuring

that the educated labor force is equipped with competencies necessary for prosperous performance in technology-driven environments (Schwab, 2016).

Research Problem

Keeping 4IR technology in its supply chain from proper application is faced with multiple challenges in Pakistan. Lack of proper infrastructure, especially in rural areas where almost all agricultural production takes place, is quite a serious one. Poor roads and lack of access to uninterrupted electricity badly affect the integration of advanced technologies like IoT devices, which are very much needed for new concepts of supply chain management (Khan & Ali, 2024).

These infrastructural deficiencies hinder the businesses to effectively monitor and control their supply chains leading to inefficiencies and costs. Further, the country does not have enough skilled workers, and it is very critical for adopting and managing new technologies. The educational institutions are often unable to keep up with the rapid changes and introduce the curriculum needed to prepare students for professional careers in technology-driven fields. The gap in skills is particularly radical in data analytics, AI, and blockchain technologies, which are very important for the successful rollout of 4IR initiatives (Schwab, 2016).

The frequent changes in government and policy direction create an uncertain environment for investment in technology and infrastructure. With the instability on the political horizon, businesses tend to shy away from investing in new technologies, for fear that future political upheavals will compromise their investments. Acute uncertainty from ever-present conflicts and security threats in areas of terrorist group presence act like a double whammy to deter any investments, domestic or foreign (Mansoor, 2023).

The economic crisis afflicting Pakistan is a significant constraint on the adoption of 4IR technologies. Cash-strapped because of rampant inflation and dwindling foreign reserves, the government finds itself in a position to invest in infrastructure and training services aimed at digital transformation. In these trying economic conditions, the majority of firms grapple to stay alive, thereby making it even more difficult for them to spare funds for technology adoption.

Lack of financial incentives and government support serves only to limit what little capability companies might have in investing in advanced technology for improved supply chain efficiency (International Monetary Fund, 2023). 4IR technologies are not easily realizable due to regulatory challenges. Pakistan has a notoriously bureaucratic regulatory framework along with inefficiencies that tend to delay the adoption of new technologies. This situation poses several challenges to companies in the regulatory environment that actually work against their interest in investing in effective new solutions (World Bank, 2023).

To create an enabling environment for 4IR initiatives, a supportive regulatory framework that enhances technology adoption is very much needed in Pakistan. Finally, supply chain management in Pakistan has to contend with climate change which presents another layer of challenges. The country bears a high risk of natural catastrophes that disrupt supply chains and adversely affect agricultural productivity, including floods and droughts. These adversities step up the problems of rolling out newer technology, as companies will now have to deal extensively with resilience and adaptation initiatives to counteract climate change falls (United Nations, 2023).

Gap Analysis

The gap analysis for the adoption of Fourth Industrial Revolution technologies in Pakistan's supply chain management identifies discrepancies between the current state of technology integration and the desired state where operational efficiency and competitiveness can be enhanced.

Infrastructure Development

In Pakistan, infrastructure and facilities are inadequate to support advanced supply chain technologies, particularly in rural areas. The existing transport networks are often inefficient, with delays and increased costs. Developments desired include reliable logistics networks such as road and railway access and ports, as well as strong digital infrastructure, high-speed internet access. Here the gap is significant: although urban centers may have better connectivity, the rural areas are underserved, which makes it difficult to integrate technologies relying on real-time data transmission (IoT) (Khan and Ali, 2024).

Skills Gap

There is a huge gap between the demand for skilled labor that can manage and implement 4IR technologies and the output of the education sector. Pakistan's educational institutions often do not coach students in key areas such as data analytics, AI, and blockchain technologies. Therefore, companies find it difficult to hire trained personnel to drive digital transformation in the supply chains. This gap requires an overhaul of the curriculum and more partnerships involving educational institutions and industry to make sure graduates undergo training relevant to the industries needing them (Schwab, 2016).

Technology Adoption and Integration

While the 4IR technologies promise a lot, the response of Pakistani businesses toward these technologies is still slow. Many have continued with the conventional supply chain process owing to a lack of knowledge about how the technologies will actually benefit them in practice, such technologies including AI, IoTs, and blockchain. The current gap is marked by limited numbers of pilot projects and absence of case studies for successful implementation. To help bridge such gaps, concerted awareness and incentive measures for technology adoption should be taken for businesses (International Monetary Fund, 2023).

Regulatory Frameworks

The bureaucratic red tape and unclear guidelines prove to be hurdles for the adoption of technologies focused on 4IR in Pakistan. Streamlined regulations encouraging innovation and simple adoption of advanced technologies in the supply chains should be the target state. The gap that currently exists points towards the need for engaging policy on the industry stakeholders to create a more favorable regulatory environment that promotes rather than inhibits technological innovation (World Bank, 2023).

Investment, Financial Support

Access to finance becomes an important enabler for them in investing in 4IR technologies. Most companies are restricted financially and thus unable to employ advanced technologies. The gap becomes even more evident in the absence of grants, low-interest loans, or tax incentives clearly targeting technology adoption. For closing that gap, the government and financial institutions should initiate mechanisms that will

fund specifically the digital transformation of supply chains (Mansoor, 2023).

Dimensions of Study Operational Definitions

Adoption of 4IR Technologies in Supply Chain Management. As a Dependent Variable of Research:

It measures the extent of how companies adopt technology such as AI, IoT, blockchain, and big data into their supply chain operations.

Independent Variables

Infrastructure Quality: Evaluates adequacy and reliability of transport and digital infrastructure requisite for technological integration in supply chains.

Skilled Labor Availability: Measures availability of an adequately skilled workforce in relevant technologies capable in implementing and managing solutions of Fourth Industrial Revolution.

Regulatory Environment: Evaluates clarity and efficiency of regulatory frameworks facilitating or inhibiting technology adoption in supply chains.

Access to Financial Resources: Studies accessibility of financial support mechanisms (e.g., loans and grants) that allow businesses to afford investments in technology adoption.

Government Support and Incentives as a Study Mediating Variable

Generally, evaluates how government initiatives like subsidies and training programs would mediate the effect of independent variables upon their adoption of 4IR technologies. In this way, good mediating may enhance the impact of infrastructure, skilled labor, regulatory frameworks, and financial access toward the adoption of technology.

Research Objectives

1. To explore the influence of infrastructure quality on the adoption of Fourth Industrial Revolution (4IR) technologies in supply chain management in Khyber Pakhtunkhwa, Pakistan.
2. To analyze how the availability of skilled labor impacts the use of 4IR technology by firms involved in supply chain management.
3. To evaluate the role of the regulatory environment in facilitating or hindering the adaptation of 4IR technologies in the supply chains.
4. To analyze the financial resources access and how exactly it impacts the ability of companies to adopt and implement the 4IR technologies in the supply chain.
5. Investigating how government support is influenced between different infrastructure qualities, availability of skilled labor, regulatory environment, access to financial resources, and the adoption of 4IR technologies in supply chains.

Research Questions

1. How does quality in infrastructure affect the adoption of 4IR in supply chain management in Khyber Pakhtunkhwa?
2. What manner does it, actually, relate the availability of skilled labor with the use of 4IR technologies in supply chain management by companies in KPK?
3. How does the regulatory environment influence the adoption of 4IR technologies in supply chain management in Pakistan?
4. How financial resources allow the adoption and eventual application of 4IR technologies in supply chains?
5. How does government support mediate the links between the infrastructure quality,

availability of skilled labor, regulatory environment, and access to financial resources into adopting 4IR technologies in supply chain management?

These objectives and questions guide the research process in the direction of promoting the importance of government support for the adoption of 4IR technologies in Pakistan supply chain management.

Significance of the Study

The importance of this study lies within its possibility to shed light on factors influencing the adoption of Fourth Industrial Revolution (4IR) technologies into the supply chain management of Khyber Pakhtunkhwa, Pakistan, for numerous reasons. In fact, it is important to understand these dynamics due to the following:

Competitive Advantage

In studying how infrastructure quality will affect a company's 4IR technologies acceptance, enhanced competitive advantage can provide possible recommendations or even comparisons to Khyber Pakhtunkhwa-based companies. For its infrastructural improvement will also facilitate the integration of advanced technologies in operations through more efficient supply chain operations and better service delivery (Schwab, 2016).

Gaps in Skills

Evaluation of availability of skilled labor on the adoption of 4IR technologies, which will demonstrate the critical aspect of workforce development, informs educational institutions and policymakers to draft training tailored toward industry needs, enhancing the pool of skilled workers who can take advantage of new technologies (Gupta & Ramachandran, 2021).

Inform Policy Making

This will lead to several insights for policymakers on how the regulatory environment supports or inhibits the process of technology adoption. This study further identifies the regulatory hindrance toward the development of policy support to facilitate the adaptation of 4IR technologies that promote economic growth and innovation across the space (Arnold, Kiel, & Voigt, 2016). It evaluates how access to financial resources affects one's ability to adopt 4IR technologies, focusing on what financial challenges companies experience. In turn, this will aid financial institutions and government bodies to design targeted funding strategies pertinent to the technology adoption in the supply chain sector (BRICS Business Council, 2017).

Mediating Role of Government Support

Through the analysis of the mediating role of government support between infrastructure quality, availability of skilled labor, regulatory environment, and access to financial resources, a holistic understanding of the ecosystem surrounding 4IR technology adoption can emerge to realize better government interventions in facilitating technology integration in supply chains towards a more efficient economy at large (Beier, Niehoff, & Xue, 2018).

Literature Review

Introduction

The Fourth Industrial Revolution (4IR) refers to the revolution of technology through the use of advanced technologies like artificial intelligence, Internet of Things and big-data analytics in sectors like SCM. Adoption of this technology in Pakistan means a lot of

opportunities, on one hand, in strengthening the operational efficiency and competitiveness. Barriers like poor infrastructure, lack of skilled manpower, regulatory issues, and insufficient financial resources challenge the adoption of this technology. The literature review examines cross-sectional factors that manifest and relate to the adoption of 4IR technologies in supply chain management (SCM) in Pakistan, particularly within a mediating element of government support and incentives.

Infrastructure Quality and Technology Adoption

Infrastructure quality as a factor majorly considered in technology adoption in supply chains. Poor infrastructure lessens the effectiveness of advanced technologies greatly. Studies say that inadequate transport networks and unreliable internet connectivity are barriers to implementing IoT and data analytics for supply chains in Pakistan (Khan & Ali, 2024; Ali et al., 2025). Unfortunately, the state of infrastructure both in physical and digital forms in Pakistan makes it uneconomical and time-consuming to operate (Mansoor, 2023; Ullah et al., 2022). Thereby,

Hypothesis 1: Higher infrastructure quality positively influences the adoption of 4IR technologies in supply chain management in Pakistan.

Government Support and Incentives

Government support can actually propel infrastructure development through public-private partnerships or investments. These above mentioned incentives for the improvement of infrastructures by the governments are likely to facilitate advanced technologies in supply chains (International Monetary Fund, 2023; Zafar & Bukhari, 2021).

Hypothesis 1a: Government support mediates the relationship between infrastructure quality and the adoption of 4IR technologies in supply chain management.

Skill Availability and Technology Adoption

Skilled labor is essential for the successful implementation of 4IR technologies since this workforce would manage and integrate the new technologies into the old system. However, in Pakistan, there is a significant skills gap regarding the SCM domain, especially in data analytics and AI (Khan & Ali, 2024; Tariq & Ali, 2022). Thus, it would hardly allow businesses from enjoying the technological advancements. The World Bank (2023) indicates the unavailability of trained personnel as an important reason for preventing technology adoption in developing countries (Zubair & Khan, 2022).

Hypothesis 2: Higher availability of skilled labor positively influences the adoption of 4IR technologies in supply chain management in Pakistan.

The mediator is the government's support and incentives. Programs designed by the government with the focus of upgrading education and training programs may bridge the skills gap present in the workforce. Thus, it also funds them and offers resources in skill development for adopting new technology (Schwab, 2016; Chaudhry & Qureshi, 2020).

Hypothesis 2a: Government support capitalizes the relationship between the availability of skilled labor and the adoption of 4IR technologies in supply chain management.

Regulatory Environment and Technology Adoption

Besides supporting innovation and technology adoption, the regulatory environment should provide necessary facilitation (Iqbal & Ahmad, 2022). High complexity in regulatory frameworks may discourage investment in new technologies from firms, says research (World Bank, 2023). In Pakistan, regulatory uncertainty and bureaucratic hurdles

mostly trouble the adoption of advanced technologies in SCM. Highlighting this, an expository study by Mansoor (2023) shows that when there is uncertainty regarding regulations, firms hesitate to invest in technology due to the possibility of facing problems with compliance and punitive costs (Malik & Hussain, 2023).

Hypothesis 3: A more favorable regulatory environment provides a positive impetus toward the adoption of 4IR technologies in supply chain management in Pakistan.

Mediator: Government Support and Incentives

Government policies that loosen regulations and provide straightforward guidelines could stimulate technology adoption. In this way, government support will be an important mediator of the regulatory environment-technology adoption relationship (International Monetary Fund, 2023; Nasir & Raza, 2020).

Hypothesis 3a: Government support interjects into the connection between the regulatory environment and adoption of 4IR technologies in supply chain management.

Access to Financial Resources and Adoption of Technologies

Access to financial resources is a prime factor in the adoption of 4IR technologies. Firms usually need heavy investments to adopt advanced technologies, and the absence of financial instruments suitable for technology adoption could delay such investments (International Monetary Fund, 2023; Farooq & Khan, 2023). Due to financial constraints, a lot of companies in Pakistan find it difficult to invest in new technologies. Khan and Ali (2024) investigate that limited access to funding is a major stumbling block for SMEs to adopt innovative technologies (Javed & Ali, 2021).

Hypothesis 4: Greater access to financial resources will have a positive impact on the adoption of 4IR technologies in supply chain management of Pakistan.

A Mediator in Government Support and Incentives

Financing to assist businesses, such as grants or loans at low interest, matters a lot. The government support makes the financial resources available to technology investment possible and thus intervenes in the relationship between financial resources and adoption of technology (World Bank, 2023; Zafar & Bukhari, 2021).

Hypothesis 4a: Government support shall mediate the relationship between financial resources access and supply chain management adoption of 4IR technologies.

Incorporating the Mediator into the Model

Government support and other incentives are crucial in the proposed model. Through infrastructural development, resolving of skilled labor shortages, creation of an enabling regulatory environment, and improvements in access to financial resources, government intervention stands to exert great influence on the adoption of 4IR technologies in the supply chains of Pakistan. The interactions among the different factors therefore suggest the need for an integrated approach addressing both challenges and prospects in the local context.

Theory That Underpins the Study

The Diffusion of Innovations Theory (Rogers, 2003) serves as the theory underpinning the study, successfully bringing together all the variables regarding adopting Fourth Industrial Revolution (4IR) technologies into supply chain management within Pakistan. The theory includes an overall paradigm of how, why, and at what rate new technology are accepted in an organization or society; hence its applicability for the analysis of the context of Pakistan.

Key Variables Aligned with Diffusion of Innovations Theory

Infrastructure Quality

This theory maintains that communication channels and social systems are of utmost importance in the process of diffusion. Thus, poor infrastructure will either be a hindrance to the flow of information or, even worse, the flow of resources necessary to adopt new technology (businesses without proper infrastructure will find it ineffective in implementing 4IR technologies, resulting in a slower adoption, as noted by Ali and Khan, 2025).

Availability of Skilled Labor

Innovation diffusion is greatly curtailed by the absence of availability of skilled labor. According to the theory, the knowledge and skills possessed by the individuals of an organization constitute their capacity to adopt and use new technologies. Thus, a workforce lacking such indispensable skills will hinder adoption of advanced technologies that usually include AIs, IoT, etc. (Khan Ali, 2024).

Regulatory Environment

Institutional factors, for instance, regulatory frameworks, are seen as a significant part in the diffusion. The theory hence believes that clear and facilitative regulations will enhance technology adoption while bureaucratic hassles and uncertainty in regulation may serve as barriers. In Pakistan, for instance, an unfavorable regulatory environment could slow down the pace of adopting the 4IR technologies (Zafar & Bukhari, 2021).

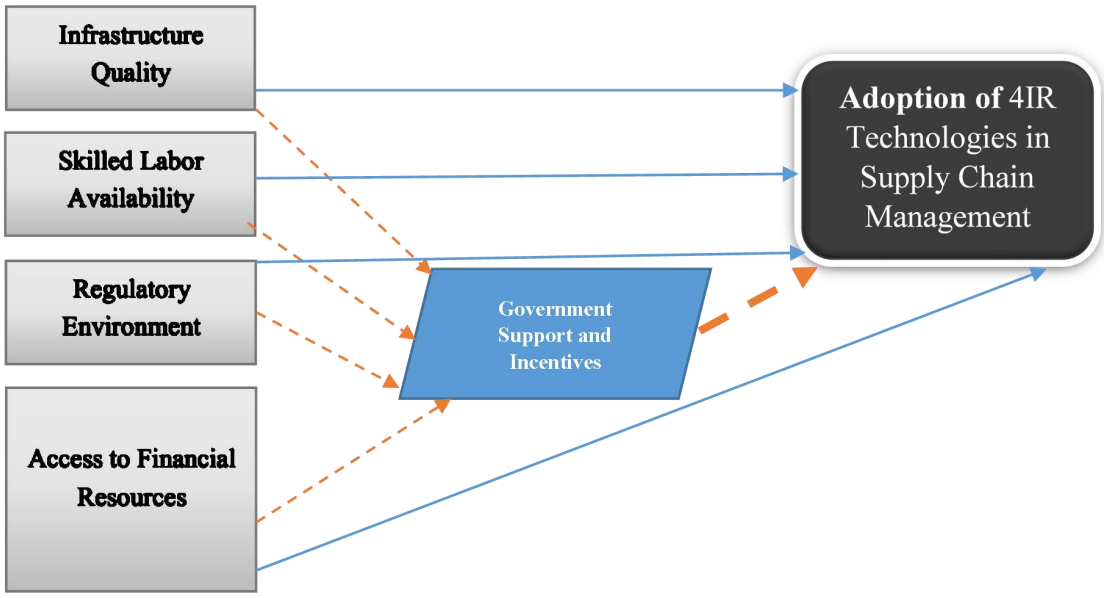
Access to Financial Resources

One is the fact that technology improvements require financial resources as organizations require capital investments in new technologies. The greater the access to financial resources by organizations, the more likely they are to adopt innovations because they can invest in the necessary infrastructure and training, according to Diffusion of Innovations Theory (Farooq & Khan, 2023).

Government Support and Incentives

Government expenditure and incentives are powerful motivators for the growth of technological adoption. Transformative as supportive policies and programs are to the theory of speed in diffusion of innovations, it will tend to be less risky and lower cost in terms of adoption (International Monetary Fund, 2023).

Conceptual Framework



Proposed Methodology Using the Onion Model

The methodology proposed for this mainly quantitative study being engaged here on the adoption of Fourth Industrial Revolution (4IR) technologies in supply chain management (SCM) in Pakistan will follow the Onion Model by Saunders et al. (2009). This model provides a structured approach to design the research methodology, guiding the researchers through layers of decisions from the very last layer to the inner one.

Research Philosophy

The study shall incorporate the positivist philosophy, which helps in the conduction of quantitative research. This philosophy emphasizes objective measurement and statistical analysis of observable phenomena, which helps in the generalization and further prediction of the phenomena studied with empirical evidence.

Research Approach

The deductive approach starts first with prevailing theories, such as the Diffusion of Innovations Theory, and goes on to test those theories with the collection and analysis of quantitative data. With this approach, one can then test specific hypotheses from the factors influencing SCM technology acceptance.

Research Strategy

This research will employ a survey strategy for primary quantitative data collection. Surveys are a useful method for gathering structured information from a large number of respondents, which then allows statistical analysis and generalizations to be made back to the population of interest.

Time Horizon

This study will adopt a cross-sectional time horizon, with the data being collected at one particular moment in time. Such an approach is most suited for assessing technology adoption in SCM as it relates to the present within the context of Pakistan, especially

when discussing Khyber Pakhtunkhwa (KPK).

Data Collection Method

Primary Data Collection

Target Population: Primary data would be collected from supply chain managers, logistic administrators, and decision-makers in diverse industries across Khyber Pakhtunkhwa (KPK) for statements of relevance to agricultural, manufacturing, and trade activities. This renders the area of considerable relevance for studying SCM practices.

Sampling Technique: A stratified sampling technique was to be deployed to ensure that different sectors, such as agriculture, textiles, and manufacturing, would be sufficiently represented. That assures a holistic viewpoint regarding technology adoption in those sectors.

Data Collection Instrument: A structured questionnaire will be prepared with the Likert scale items to assess perceptions regarding infrastructure quality, availability of skilled labor, regulatory environment, access to financial resources, and government support. After that, the questionnaire will be validated by conducting a pilot study before the actual data collection.

Best Area to be considered under SCM in KPK

Khyber Pakhtunkhwa is a plurality of sectors very important for supply chain management:

Peshawar, as the provincial capital, is a big trade and logistics hub that connects Pakistan with Afghanistan. The location of Peshawar is very suitable for SCM consideration.

Mardan is another city where activities of manufacturing and agriculture can be studied regarding the effect of 4IR technology on supply chain efficiency.

The Swat Valley is also famous for its agricultural products so that we can appreciate the role that technology plays in enhancing agricultural supply chains in the fields of logistics and distribution.

The Conclusion of the Research

This research will present a comprehensive research model for the adoption of technologies of Fourth Industrial Revolution in Supply Chain Management in Pakistan particularly focused on Khyber Pakhtunkhwa (KPK). To study the background of the study, indeed, have significant transformations affecting global supply chains, and there must occur the adoption by the concerned firms in Pakistan for aiding them competing on a high note for efficiency and effectiveness.

The literature review identified factors mainly affecting technology adoption such as infrastructure provision, presence of skilled labor, regulatory environment, financial access, and government support using Diffusion of Innovations theory, giving it a strong theoretical framework from which the technology adoption dynamics are understood within the purview of Pakistan.

The onion model, i.e. used formulating methodology, contains an organized mechanism to conduct quantitative research. This, in particular, aims to gather robust insights into the current state of technology adoption in S.G. As the data are collected by using survey strategy from supply chain professionals across selected strategic areas of KPK, findings will be of a critical measure not only to adding to the academic literatures, but also to practitioners and policymakers on the necessary steps at leveraging

successful technology integration.

The Implications of Study

Theoretical Contribution: The current paper opens up new avenues of research through the development of a conceptual model in which different antecedents affecting the acceptance of 4IR technology in SCM are incorporated. The study thus provides a fresh industrial perspective regarding involving these antecedents into the Diffusion of Innovations Theory in developing nations.

Practical Recommendations: Practical can influence most of the results of such a study in which improvement areas can be easily identified by practitioners. Business will implement a targeted strategy by knowing the barriers to the adoption of technology in order to improve infrastructure and build a trained workforce along with connecting programs of the government for the advancement of technology.

Policy Implications: The study points to government support as the key in the adoption of 4IR technologies. Based on the understanding from this study, policymakers can innovate appropriate regulations and incentives for creating a conducive environment for technology integration into supply chains.

Supporting SMEs: With the study being more centered on small and medium enterprises (SMEs), this has ramifications for promoting entrepreneurship and innovation within KPK. It also addresses some of the challenges within the SMEs: namely, limited access to financial resources and inadequate infrastructure. Ultimately, this would stir the bigger issue of economic development within the region.

Future Directions of the Study

Empirical Testing: Given that the proposed model could benefit substantially from empirical testing and quantitative methods, future studies might collect data from a larger, more diverse question sample from all over Pakistan to test the relationships proposed in the model.

Longitudinal Studies: Future studies could consider a longitudinal approach to observe changes over time in technology adoption. This would also provide insights into how external pressures like economic trends or policy changes affect the adoption and infusion of 4IR technologies in SCM.

Sector-Specific Studies: Subsequent research, because of the diverseness exhibited by various industries within Pakistan, could look into specific sectors such as agriculture, manufacturing, or textiles so that the peculiar challenges and opportunities in those contexts for technology adoption could be understood better.

Qualitative Insights: Involving qualitative methods such as interviews or focus groups could result in added value to the quantitative findings, thereby producing richer insights into the perceived motivations, perceptions, and experiences of stakeholders with SCM technology adoption.

Comparative Studies: Future research could also contribute to comparative studies in different regions or countries to learn from best practices and lessons learned related to the adoption of 4IR technologies in supply chain management.

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