The Synergistic Consequence of Knowledge Management and Artificial Intelligence on Technological Innovation in Manufacturing Firms of Developing Country

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ABSTRACT

The study examines the synergistic effect of technology-based Knowledge Management (KM) and Artificial Intelligence (AI) on technological innovation in Pakistan's manufacturing sector. It also investigates AI's mediating role in enhancing the relationship between KM and technology innovation. This research fills a gap in the literature by exploring the combined influence of technology-based Knowledge Management and Artificial Intelligence on technology innovation within the context of a developing economy. It uniquely highlights AI's mediating role in driving technological innovation, providing insights specific to the manufacturing sector in Pakistan. A deductive methodology was adopted, using data from 372 employees across four industries: pharmaceuticals, textiles, sports, and cement. Convenience sampling was employed, and data were analyzed using Structural Equation Modeling (SEM) with Smart PLS 4.0. Harman's single-factor test was applied to address common method bias. The results demonstrate a positive and significant relationship between KM and technological innovation, with AI acting as an efficient mediator. The model exhibited strong explanatory power, with R-square values of 0.749 for AI and 0.836 for technological innovation, validating the hypotheses. Moreover, the statistically significant path coefficients support acceptance of all four hypotheses in the study. Manufacturing firms should leverage AI to enhance their KM processes and drive technological innovation. Investments in AI technologies and employee development programs are crucial for fostering innovation and maintaining competitiveness in the manufacturing sector.

Keywords: Technology-Based knowledge management, Artificial intelligence, Technological innovation, Manufacturing sector, Pakistan, Structural Equation Modeling SEM

1. Introduction

In the contemporary global economy, technological innovation has become a crucial driver of competitiveness and growth, particularly within the manufacturing sector [1]. In a country like Pakistan, industrial growth is essential for supporting sustainable economic development [2]. Integrating and leveraging new technologies in manufacturing processes is key to enhancing productivity and maintaining competitive edge [3]. According to Cheah and Tan [4], Manufacturing companies manage their knowledge, especially through Knowledge Management (KM), which is closely tied to technological innovation. Knowledge Management is a critical competency for organizations that enables them to drive innovation by systematically gathering, sharing, and utilizing knowledge [5, 6]. When aligned with technological goals, it allows organizations to optimize their knowledge resources for innovation, providing a significant competitive advantage in their industry [7].

A major development in recent years is the use of artificial intelligence (AI) to enhance technology-based Knowledge Management (KM) systems [8, 9]. AI enables organizations to handle large volumes of data, automate tasks, and forecast future trends[10]. These features not only support better decision making but also streamline the innovation process by providing real-time insights and improve efficiency. [11, 12]. In manufacturing, AI enhance and integrate Knowledge Management, transforming traditional, slow ways of knowledge handling into fast, data-based approaches that encourage new ideas using technology [13, 14].

The use of AI in Knowledge Management (KM) adapt and respond to rapidly evolving industrial demands highlights its potential to accelerate technological progress in manufacturing [15]. However, the manufacturing sector in Pakistan struggles to effectively integrate Artificial Intelligence and technology-focused Knowledge Management due to major obstacles [16].

Problems such as outdated technology, a shortage of trained workers, and insufficient investment in research and development (R&D) have hindered the sector’s ability to fully leverage AI and Knowledge Management systems. These challenges show how important it is to understand that how AI influences the relationship between technology-based Knowledge Management and innovation outcomes. For Pakistan to grow its industries and improve its manufacturing sector, it is essential to overcome these obstacles and fully harness AI to encourage innovation.

This study aims to explore how Artificial Intelligence can serve as a bridge between technology-based Knowledge Management (KM) and technological innovation in Pakistan's manufacturing sector. By analyzing this connection, the research will demonstrate how emerging technologies, particularly AI, can enhance innovation. The findings will provide valuable insights to policymakers and industry leaders in Pakistan on how to foster industrial growth by effectively integrating AI and KM. This research addresses a significant gap in existing studies and offers practical methods to boost technological innovation in a developing economy.

2. Literature Review

2.1 Technology Innovation

Research from around the world shows that adopting emerging technologies is very important for making manufacturing businesses more competitive, productive, and capable of growth. These new technologies are not only important for countries like Pakistan, but also for keeping up with

global industry trends and standards. The manufacturing industry in Pakistan, which contributes approximately 12.13% to the country's GDP, has begun adopting new technologies, but continuous to lags other countries in terms of innovation. Problems like outdated technology, insufficient investment in research and development (R&D), and a shortage of skilled workers are some of the key factors contributing to this gap.

A key driver of innovation in manufacturing is the effective management of technology-focused knowledge (KM). Being able to create, store, share, and utilize information about technology is important for businesses to generate new ideas. In Pakistan, many large manufacturing companies have started implementing Knowledge Management systems to introduce new technology into their operations. For instance, in Pakistan's textile industry, a major contributor of the country's manufacturing sector, companies have been gradually adopting computerized systems for tasks such as designing products, managing supply chains, and ensuring quality. This change is happening because companies need to be more competitive in the global market. However, the widespread adaption of these technologies in other manufacturing sectors in Pakistan is limited by financial constraints and operational challenges.

Artificial intelligence (AI) is transforming the manufacturing industries worldwide. It's revolutionizing the way products are made, how resources are handled, and how decisions are made. In countries with strong economies, AI has greatly reduced costs and improved efficiency by automating tasks and providing accurate predictions [11]. In Pakistan's manufacturing sector, AI is just in its early stages, but there are already some examples of companies using it. Lucky Cement, a major company in Pakistan, has started using AI to predict when machines need maintenance, which helps to ensure a continuous machines operation and improve production [17]. Employing AI technology to manage manufacturing processes and analyze large amounts of data is enabling local companies to become more innovative. However, not many companies are fully adopting these technologies yet. Despite these advancements, the manufacturing industry in Pakistan faces significant challenges in adopting new technologies. While leading global manufacturers spend a lot on research and development to drive innovation, Pakistan's manufacturing sector invests only a small portion of resources to R&D, which limits the development and integration of new technologies [18].

There is a shortage of skilled workers, particularly in high-tech areas like artificial intelligence, data analysis, and advanced manufacturing. This problem is getting worse [19]. Additionally, the complex regulatory environment in Pakistan slows progress in technical innovation. The lack of clear laws and incentives for innovation in manufacturing discourages risk-taking and investing in new technologies [20]. The slow adoption of Industry 4.0 technology in Pakistan's automotive industry is partly due to inefficient policy support for digital transformation [21]. Despite these challenges, many companies in Pakistan have successfully leverages technology to drive innovation. For instance, in the pharmaceutical sector, Getz Pharma, a leading company in Pakistan, has used advanced manufacturing techniques and digitalized its production methods to meet global standards [22, 23]. By adopting the best global practices and cutting-edge technologies, the company has significantly expanded its market share both domestically and internationally. Another example is Pakistan's electrical goods manufacturing sector. Siemens Pakistan has been investing in smart technologies and energy-saving manufacturing systems, helping local producers enhance their production processes

and reduce energy consumption [24]. This approach has positively influenced the company's productivity and market position.

The rise of Industry 4.0, which integrates cyber-physical systems, artificial intelligence, and the Internet of Things (IoT), presents both challenges and opportunities for Pakistan's manufacturing sector [25]. While many businesses in Pakistan are not yet fully ready to use these new technologies, there is growing recognition of their transformative potential. Government initiatives, such as National Science and Technology Park (NSTP), aim to support the growth of high-tech industries and encourage innovation through collaboration between universities, research centers, and businesses [26]. Furthermore, increased foreign direct investment (FDI) and partnerships with international organizations can provide Pakistani businesses with access to advanced technology and knowledge-sharing opportunities [27]. The collaboration among Pakistani manufacturers and Chinese companies under the China-Pakistan Economic Corridor (CPEC) initiative has potential to accelerate technological progress in Pakistan's industrial sector [28].

2.2 Theoretical Framework

Schumpeter's theory highlights that innovation, especially in processes and methods, is crucial for companies to maintain a competitive edge [29]. This research focus on technology-based Knowledge Management and AI aligns with Schumpeter's idea of creative innovation. This means that new technologies (made possible by AI and managed knowledge) will replace outdated practices, driving the manufacturing industry towards more advanced technology. Artificial Intelligence can accelerate improvements in both production processes and the products development, allowing companies in Pakistan to work more efficiently and create innovative items [30]. The Open Innovation Theory suggests that companies should leverage both internal knowledge and knowledge from external sources to improve their technology [31, 32]. Knowledge Management focused on technology supports this idea by highlighting the importance of gathering, combining, and utilizing knowledge from inside and outside the company [33]. AI facilitates this process by streamlining Knowledge Management and sharing knowledge across different domains, which leads to faster innovation. Inbound open innovation involves incorporating external knowledge to generate new ideas, while outbound innovation means taking internal ideas and using them in external markets. AI helps both by making it easier to share and use knowledge efficiently [34].

The Knowledge-Based View says that knowledge is the most important resource for a company, and effectively managing this knowledge contributes significantly to its success [35]. In this research, the manufacturing industry in Pakistan leverages technology-focused Knowledge Management (TOKM) to foster innovation and maintain competitiveness in worldwide market. Absorptive capacity, a concept within the Knowledge-Based View (KBV), refers to a company's ability to recognize the value of external knowledge, assimilate it, and utilize it to benefit their business. This capability is very crucial for manufacturing companies in Pakistan that aim to boost their innovation skills by using TOKM. Another foundational theory, the Dynamic Capabilities Theory emphasizes that manufacturing organizations need not just valuable knowledge but also the ability to integrate, develop, and adjust their internal and external skills to handle rapidly changing environment [36]. AI can help with this by making decisions quicker and integrating new knowledge to drive innovation [37]. Moreover, the theory focuses on sensing, seizing and transforming capabilities in the

manufacturing sector organizations. These are abilities that AI can improve, where AI assists organizations in recognizing new opportunities, quickly taking advantage of them, and changing their operations to encourage ongoing innovation.

The Technology Acceptance Model (TAM) provide a framework to understand how AI can affect the relationship between Knowledge Management and technology innovation [38]. TAM explains the perceived usefulness of a technology (such as AI) and determine its utilization in manufacturing, which in turn impacts overall innovation outcomes [39]. AI can enhance Knowledge Management systems, making them more responsive, adaptable, and predictive [40]. Usefulness and Ease of Use are key parts of TAM that explain how people's views affect AI adoption, thereby boosts innovation [41]. Using AI as a mediator can accelerate the spread of new ideas in manufacturing by making information more useful and accessible, which allows new technologies and processes to be adopted faster under Innovation Diffusion theory. These factors such as relative advantage, compatibility, complexity, trial ability, and visibility influence how quickly AI and other tech innovations are adopted in manufacturing. When AI is well-integrated, it reduces complexity and enhances compatibility, making new technologies more effective in driving innovation [42].

2.3 Technology-based Knowledge Management

Knowledge Management (KM) has become very important factor for encouraging innovation and competitiveness in the manufacturing industry worldwide [43]. Technology-based Knowledge Management (TBKM), which integrates IT tools with KM methods, helps manufacturing companies gather, handle, save, and share knowledge more efficiently [44]. This approach enhances organizational learning, its decision making, and performance. Globally, the manufacturing industry has undergone significant transformation with the use of modern digital tools like artificial intelligence (AI), cloud computing, big data analysis, and the Internet of Things (IoT) [45]. These tools have been integrated into Knowledge Management (KM) systems, enabling companies to manage volumes of data and leverage it to make smart decisions [46, 47]. For example, in the automotive industry, companies like Tesla use AI and machine learning in their KM systems to analyze production data in real-time, improve processes, and predict when maintenance is needed [11]. Similarly, Siemens has implemented cloud-based KM solutions in its global manufacturing, making it easier for teams to work together and share knowledge in real-time [48].

Technology-based Knowledge Management systems offer a well-structured way to manage both explicit and tacit knowledge [49]. Explicit knowledge, like technical manuals, reports, and databases, can be turned into digital form and shared easily within the company. On the other hand, tacit knowledge, which includes the skills and know-how of employees, can be recorded using tools like video, expert systems, and teamwork platforms [50, 51]. Companies such as GE and Toyota have used these systems to stay ahead in their fields by constantly learning and adjusting to new technologies [52]. The rise of Industry 4.0 highlights the importance of Technology-based Knowledge Management. Industry 4.0, which characterize smart factories and cyber-physical systems, depends on the smooth integration of knowledge and technology to boost production efficiency and innovation. For instance, in Germany's manufacturing industry, Industry 4.0 practices have been widely used, utilizing advanced Knowledge Management systems to achieve mass customization and shorten production times [53].

Although the global manufacturing industry has made significant advancement in Technology-based Knowledge Management, this approach is still not widely adopted in Pakistan. Pakistan's manufacturing industry, which accounts about 12% of its economy, faces many problems that hinder the wide adoption of Technology-based Knowledge Management [43]. These challenges include outdated technology, lack of skilled workers, and low investment in research and development. Another example is the cement industry, where companies like DG Khan Cement and Lucky Cement have adopted TBKM systems to improve their operations [54]. By using AI and data analysis, these companies can monitor and adjust their production lines instantly, saving energy and increasing efficiency [55]. These technology-based Knowledge Management methods enable Pakistani companies stay competitive both within the country and globally, despite the challenges of the nation's limited advanced technology infrastructure.

A major challenge in implementing Technology-based Knowledge Management in Pakistan is that many organizations lack a culture that encourages sharing of knowledge, which shows that many factories in Pakistan still use traditional, top-down ways of organizing, where information stays isolated within different departments of the company [56]. This lack of information hinders creativity. Also, companies in Pakistan mostly focus on explicit, documented knowledge and don't pay enough attention to capturing and sharing tacit, unwritten knowledge, which is very crucial for creativity and innovation in the manufacturing industry [57]. Although Pakistan's manufacturing sector has been slow to adopt TBKM, there are many opportunities for future growth. The growth of the digital economy and government programs like "Digital Pakistan" are likely to help the use of advanced KM technologies in various areas, including manufacturing [58]. Also, the China-Pakistan Economic Corridor (CPEC) offers chances for technology sharing, with Chinese companies bringing advanced Knowledge Management technologies and practices to the local manufacturing landscape [59].

Moreover, multinational countries operating in Pakistan, like Siemens Pakistan and Nestlé Pakistan have been great at using TBKM. Their achievements demonstrate other local businesses how to do it too. These companies have leveraged digital Knowledge Management tools to enhance collaboration across different departments, make their operations more efficient, and encourage new ideas. In order to promote the use of TBKM, we need to invest in education and training to create a workforce that can manage and utilize these technologies effectively. Working together, universities and businesses can help connect what is taught in schools with real-world applications. Additionally, government policies should help Technology-based Knowledge Management efforts by offering tax breaks, financial support for technological upgrade, and establishing regulations that encourage digital changes in the manufacturing industry [60].

2.4 Technology-based Knowledge Management and Technology Innovation

In Pakistan, the use of technology for Knowledge Management is still in its early stages, but more organizations have recognized its potential to make the manufacturing industry more competitive and innovative. This sector, which includes businesses like textile, cement, and pharmaceutical companies, has traditionally used traditional outdated ways of managing knowledge, like sharing information informally and handling data manually. But as the world becomes more connected and companies need to meet higher international standards, some Pakistani businesses are adopting more advanced Knowledge Management systems. An example is Pakistan's textile industry,

which plays a big role in the country's economy and exports. Top companies in this field have begun using digital tools to handle complex supply chains, enhance quality control, and make communication smoother between different departments [61]. By leveraging digital tools to share information and analyze large sets of data, these companies can enhance their product design, manufacturing processes, and sustainability efforts. For example, companies such as Nishat Mills have implemented enterprise resource planning (ERP) systems to manage information across different business areas, resulting in improved innovation in areas like material selection and production scheduling.

Another example is the cement industry, where companies like Lucky Cement have implemented AI-based Knowledge Management systems to boost production and reduce energy consumption. Using these systems, they not only make their operations more efficient but also develop innovative products, such as eco-friendly building materials. These examples demonstrate how technology is increasingly being harnessed in Pakistan's manufacturing industry to promote innovation. The impact of technology-driven Knowledge Management (KM) on innovation in Pakistan’s manufacturing industry is multifaceted. Firstly, it enables companies to collect and utilize both tacit and explicit knowledge, which is crucial for creating new products and improving production methods. Through employing advanced KM tools like AI and big data analysis, companies can extract valuable insights from large datasets. This data can help create better products, enhance supply chains, and lead to smarter decision making.

Second, technology-based Knowledge Management promotes teamwork both within and between organizations. For instance, cloud-based KM systems enable manufacturing companies to collaborate more effectively with their suppliers, customers, and other partners, facilitating joint innovation. This collaborative approach to innovation is crucial in Pakistan’s manufacturing sector, where companies often have limited resources and must rely on external knowledge to address their challenges. Moreover, technology-based Knowledge Management supports continuous learning and adaptation, which are essential for organizational competitive edge in evolving industries. In Pakistan, companies that adopt technology-based Knowledge Management systems can more easily respond to market changes and evolving customer demands. For example, pharmaceutical companies like Getz Pharma have utilized digital Knowledge Management systems to meet global quality standards and drive innovation [23]. This capability allows companies to remain competitive in both local and international markets.

Even though there are significant advantages, the use of technology for managing knowledge (KM) in Pakistan’s manufacturing industry faces major challenges. The country has inadequate technology infrastructure, minimal investment in research and development (R&D), and a lack of skilled workers in high-tech fields, making it hard to utilize the advanced KM systems effectively. Additionally, many small and medium-sized companies (SMEs) in Pakistan’s manufacturing sector are reluctant to invest in KM technology due to its perceived high cost and lack of understanding of its potential benefits. Absorptive capacity, a concept in Knowledge-Based View (KBV), highlights a company’s ability to collect, understand, adapt, and use external knowledge is key for innovation. The Theory of Knowledge Management (TOKM) enhances this capability by facilitating the movement and utilization of knowledge within an organization. This directly impacts technological

innovation by supporting companies in integrating new knowledge into their processes and products, leading to novel innovations.

Dynamic capabilities refer to company's ability to change its resources in response to its changing environment. TOKM improves these capabilities by making it easier for companies to gather and use technology knowledge. This enables them to adapt to new technology and generate innovative ideas rapidly. With robust TOKM, companies can more effectively identify technological opportunities (like new trends or external knowledge) and take advantage of them by turning this knowledge into new technologies or processes. This directly impacts technology innovation because TOKM enables companies to keep improving and growing their technological skills.

2.5 Artificial Intelligence (Mediator)

Artificial Intelligence (AI) serves as a bridge between Knowledge Management and technology innovation [62]. This relationship can be better understood by analyzing the Technology Acceptance Model (TAM) and Innovation Diffusion Theory (IDT), within the framework of Dynamic Capabilities Theory. According to the Technology Acceptance Model (TAM), perceived ease of use of AI can significantly influence its adoption in companies [63]. When AI is integrated with TOKM, it revolutionizes the management, storage, and analysis of large amounts of technology-related information more effectively. For instance, AI-based knowledge systems can automatically gather information, spot trends, and predict outcomes, making Knowledge Management more efficient.

AI serves as a vital tool that helps transform the organized knowledge into actionable insights for fostering innovation. While TOKM (Theories of Knowledge Management) handles the organization and storage of knowledge, AI can analyze it on a large scale, uncovering hidden patterns or supporting predictive decision-making that accelerates the innovation process. Without AI, the information may remain underutilized or could be processed slowly, which can slow down and hinder the success of new ideas. The Innovation Diffusion Theory describes how new ideas are adopted in businesses. AI can accelerate the diffusion of new technology by assisting the company in efficient learning and utilization knowledge through TOKM. For example, AI can provide insights about customer preferences, market shifts, or better ways to work, which helps in generating new ideas more quickly and effectively. AI makes it easier to manage large volumes of data, enabling companies to innovate more easily. The main advantage of AI in this context is its ability to analyze and utilize vast amount of organized information faster and more accurately than traditional methods, making the innovation process more efficient and streamlined. AI boosts a company's ability to swiftly adapt and capitalize on new technological advancements by analyzing trends and data to spot these opportunities, using insights for product development, and refining internal processes to align with new innovations. In this way, AI is crucial in linking the knowledge managed by TOKM with its application in creating new innovations based on dynamic sensing theory.

2.6 Technology-based Knowledge Management, Artificial intelligence and Technology innovation

In technology-based Knowledge Management, artificial intelligence (AI) has become a powerful tool for businesses to manage, analyze, and utilize knowledge more effectively. AI tools, like machine learning, natural language processing, and predictive analytics, provide advanced ways to gather,

organize, and analyze large amounts of data, transforming it into useful information. AI-based Knowledge Management systems have transformed global production by enabling faster decision-making and supporting more adaptable innovation processes.

AI acts as a bridge between Knowledge Management (KM) and technological innovation by augmenting human intelligence. It does this by offering insights that would be difficult to detect through traditional methods. AI helps quickly identify patterns and connections in large, complex data sets, enabling companies to develop new solutions and improve their production processes. For instance, in advanced manufacturing, AI-driven KM systems can forecast when equipment needs maintenance, optimize supply chains, and design new products based on customer feedback and market trends [64]. In Pakistan, use of AI in the manufacturing industry is in its early stages, but there is growing interest in leveraging AI to help connect Knowledge Management (KM) with technology innovation. Pakistani companies are beginning to experiment with AI for managing knowledge to encourage innovation, but many factors, like limited access to advanced technology and shortage of skilled workers, are slowing down its adoption[65].

For example, companies in the cement and textile sectors are leveraging AI for tasks such as predicting equipment maintenance and forecasting customer demand. AI systems serve as middlemen, transforming raw data into actionable information that drives new ideas. Lucky Cement, for instance, has employed AI systems that manage production information, reduce energy use, and support the development of new products. These AI tools turn both implicit and explicit knowledge into strategic innovations that boost efficiency and help the environment sustainability [66]. In the same way, in Pakistan's textile industry, AI-based Knowledge Management systems are used to examine production data and customer preferences. This helps companies come up with new designs and optimize production methods. By guiding the Knowledge Management process, AI allows these companies to quickly adjust to market needs and improve product quality, resulting in more successful innovations [67].

Artificial intelligence not only improves the Knowledge Management process but also drives innovation by enabling organizations to make data-driven decisions and develop new solutions more efficiently. Acting as a bridge, AI facilitate the transfer of knowledge within organizations and supports the development of new skills, which are crucial for maintaining a competitive edge in manufacturing industries [68]. In Pakistan’s manufacturing sector, where resources for innovation are often limited, AI offers a cost-effective way to manage knowledge and encourage technological innovation.

Incorporating AI into Knowledge Management systems can help address some of the common challenges to innovation in Pakistan, such as the shortage of skilled workers and limited investment on research and development. AI-driven KM tools enable companies to use their existing knowledge more efficiently, reducing their dependence on human expertise while generating new ideas that boost innovation. For example, AI can identify issues in manufacturing processes or recommend new product features based on customer information, directly supporting technological innovation [69].

Although AI holds a significant potential to bridge Knowledge Management (KM) and innovation, its adoption faces challenges in Pakistan’s manufacturing industry. Challenges like poor infrastructure, lack of technological readiness, and shortage of AI experts are major obstacles. Many

Pakistani companies, especially smaller ones, find it hard to invest in AI-based KM systems because they are expensive and seem complicated [70]. Although, there are opportunities to grow as AI technology becomes more user-friendly, and government programs like the Digital Pakistan Vision and the National Science and Technology Park (NSTP) encourage better technology and new ideas. Working with big companies through projects like the China-Pakistan Economic Corridor (CPEC) gives Pakistani manufacturers a way to use AI-driven Knowledge Management solutions and improve their ability to innovate [71].

2.7 Conceptual Framework

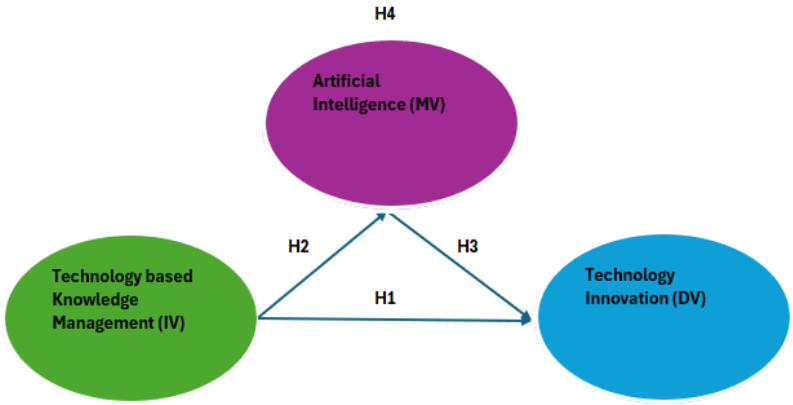

Fig.1. Conceptual framework
Source: Author's Own

2.8 Hypothesis

H1: Technology-based Knowledge Management has a positive and significant impact on technology innovation.

H2: Technology-based Knowledge Management has a positive and significant impact on Artificial Intelligence.

H3: Artificial Intelligence has a positive and significant impact on Technology innovation.

H4: Artificial intelligence mediates between Technology-based Knowledge Management and technology innovation.

3. Methodology

The research paradigm is positive with deductive approach applied to test the theories examining the technology-based Knowledge Management on technology innovation with the mediation of artificial intelligence. The data was collected from manufacturing organizations from pharmaceutical, textile, sports, and cement industries of Pakistan. The sample locale included Faisalabad, Sialkot, Chakwal, and Peshawar. The data was collected from 372 employees working in various

manufacturing units of Pakistan representing manufacturing industries selected through a convenience sampling technique. Convenient sampling is chosen because it's easy to find people who are willing to answer surveys. Information is gathered through face-to-face surveys and then analyzed using both descriptive and inferential statistics. The analysis is conducted using SMART PLS 4.0 software. A standard survey was used to collect responses from the participants. One limitation of survey-based research is common method bias, which occurs when the same process and respondents are used to gather data [72].

The research collected data for both external and internal factors from single source, which caused a problem with common method bias. To address this issue, the researchers used Harman's single-factor test was applied to assess the presence of common method bias [73]. They conducted a principal component factor analysis using SPSS 25.0 software, including all the factors in the analysis. The Harman's single factor test revealed that the common method bias was 34%, which is less than 50%, indicating that there is no common method bias. Technology -based Knowledge Management was measured by using 8 items [74, 75], Technology innovation was measured with 10 items adopted by [75], whereas, artificial intelligence was measured with the help of 7 items based on [76, 77]. All questions were evaluated on 1 to 5 Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree).

4. Results

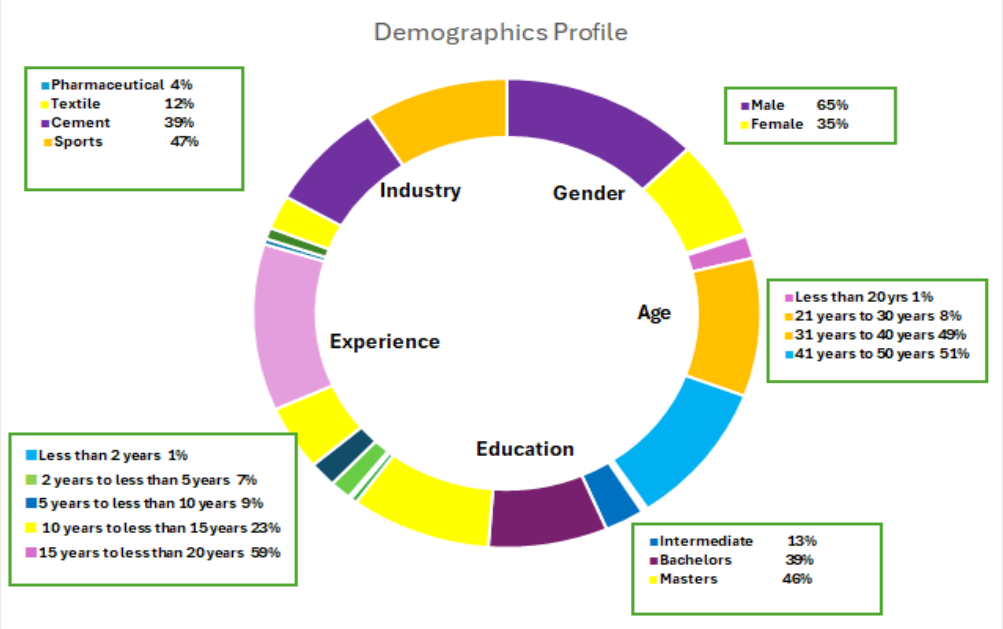

Fig 2. Demographics

Source: Author's Own

Summary of demographics depicted through donut chart were presented in fig 2. Fig 2 clearly addressed the profile of the respondents such as Gender, Age, Education, Experience, and Industry. Fig 2 depicted that 65% of respondents who worked in the manufacturing sector organizations were male, and 35% were female. Most of the respondents (51%) were between the ages of 41 and 50 years old. Many respondents (46%) held a bachelor's degree. Employees representing the manufacturing

sector and majority of them were from the sports manufacturing industry (47% followed by cement industry (39%). The analysis of variance-based SEM involves two stages: the inner model test and the outer model test both covered in this section.

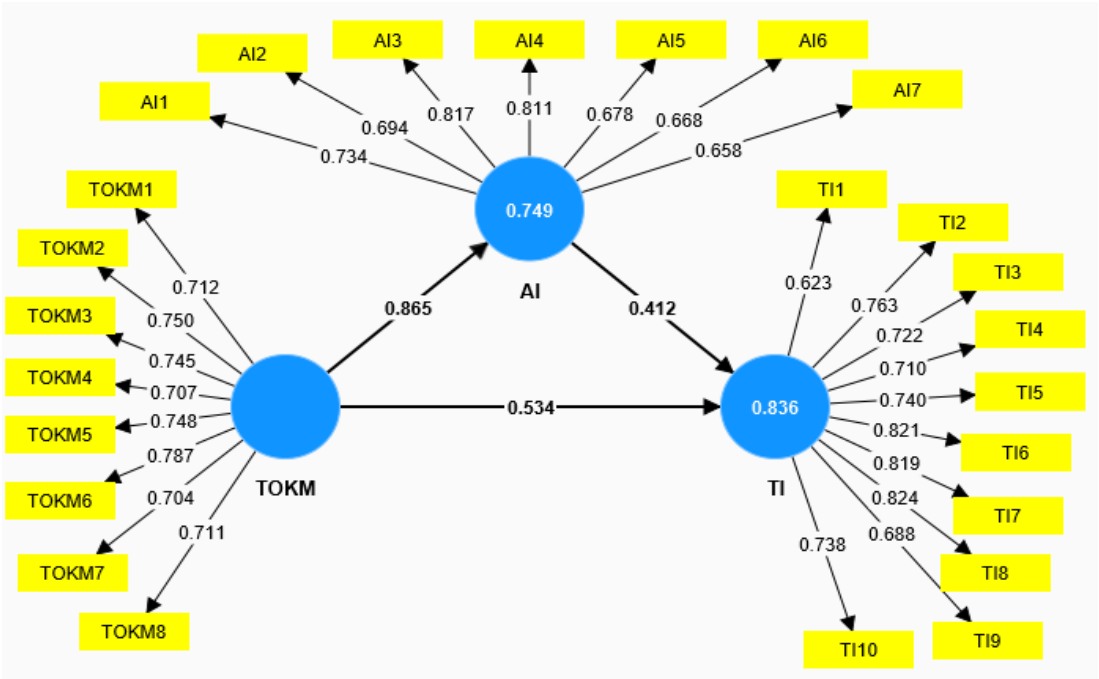

Fig 3. Outer Model (Path Coefficients & Outer-loadings)

Source: Author's Own

The Fig 3 illustrates the path coefficients and outer loadings derived using SMART-PLS 4.0. The software was employed to analyze the outer model and obtain path coefficients, outer loadings, the Heterotrait-monotrait ratio, and the Fornell-Larcker criterion. The outer-loadings were greater than the threshold level and presented in the table 1. The findings indicate that the convergent validity test of the outer model was conducted to assess legitimacy of the indicators that contain latent variables, with a validity value of over 0.70. In addition, Table 4 demonstrated that all Cronbach alpha and average variance extracted values exceeded the minimum threshold, thereby confirming the validity and reliability of all variables.

Table 1. Outer-loadings

	AI	TI	TOKM
AI1	0.734		
AI2	0.694		
AI3	0.817		
AI4	0.811		
AI5	0.678		
AI6	0.668		
AI7	0.658		

TI1	0.623	
TI10	0.738	
TI2	0.763	
TI3	0.722	
TI4	0.71	
TI5	0.74	
TI6	0.821	
TI7	0.819	
TI8	0.824	
TI9	0.688	
TOKM1		0.712
TOKM2		0.75
TOKM3		0.745
TOKM4		0.707
TOKM5		0.748
TOKM6		0.787
TOKM7		0.704
TOKM8		0.711

Table 2. Correlations

	AI	TI	TOKM
AI	1		
TI	0.774	1	
TOKM	0.665	0.591	1

**** Correlation is significant at 0.01 level (2-tailed)**

Table 2 provides information on the bivariate correlation obtained from the SPSS-25 version after calculating the variable. The results indicate that all correlation values between the examined constructs are within the acceptable range of correlations and statistically significant at the 0.01 percent level.

Table 3. R-square & Adjusted R-square

	R-square	R-square adjusted
AI	0.749	0.748
TI	0.836	0.835

Based on the R-square table, it can be concluded that Artificial intelligence is responsible for 75 percent in making Turnover intentions as mentioned in table 3. Adjusted R-square values are lower than the R-square values, which indicates that the conceptual framework does not contain any irrelevant variables. In the inner model test, the reliability test is one of the components, along with hypothesis test. Results reveal that all f-values greater than 0.4 exceed the threshold level.

Table 4. Cronbach's Alpha, Composite Reliability, Average Variance Extracted.

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
AI	0.851	0.867	0.885	0.527
TI	0.91	0.907	0.906	0.559
TOKM	0.877	0.879	0.903	0.538

Table 5. Heterotrait-Monotrait Ratio

	AI	TI	TOKM
AI			
TI	0.768		
TOKM	0.77	0.787	

Table 6. Fornell-Larcker Criterion

	AI	TI	TOKM
AI	**0.726**		
TI	0.674	**0.747**	
TOKM	0.665	0.691	**0.733**

Table 5 presents the HTMT values representing constructs, which are below 0.85 which is acceptable in this research conducted in fast moving consumer goods businesses. Table 6 highlight the Fornell-Larcker criterion showing that all on-diagonal values are greater than off-diagonal values presented in the table 6 representing the constructs.

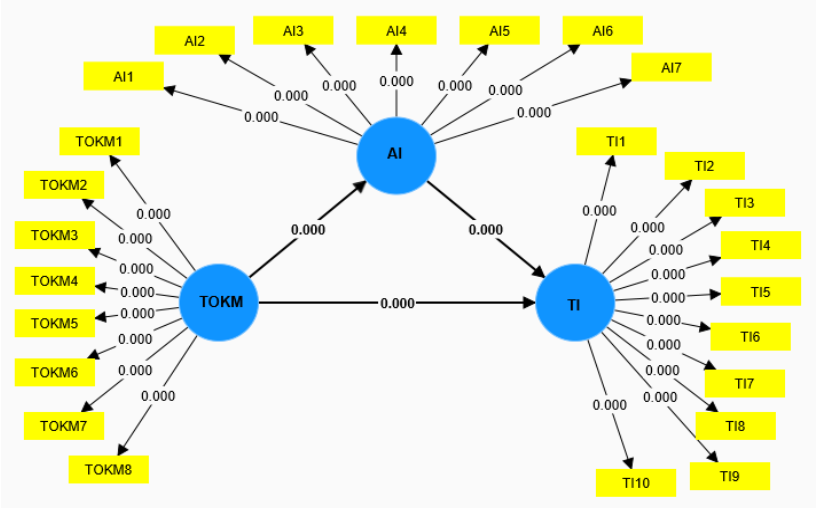

Fig 4. Inner Model (P-Values)

Source: Author's Own

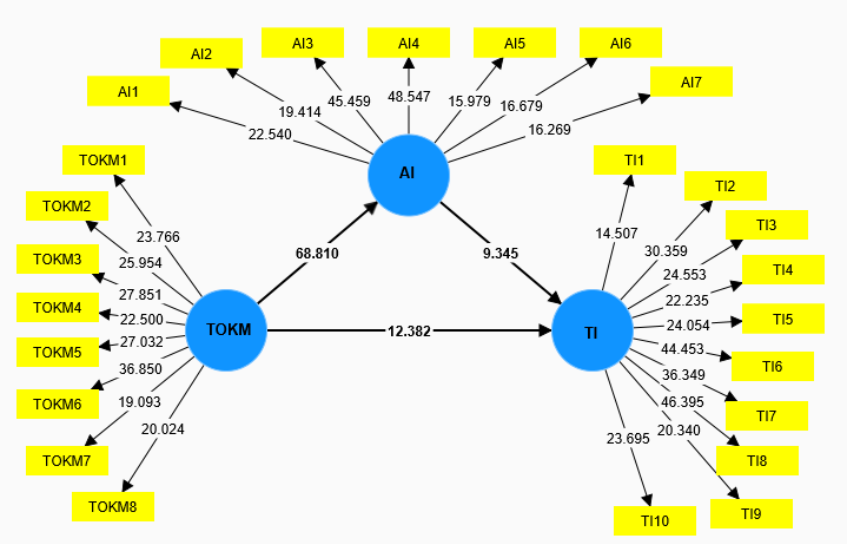

Fig 5. T-Values

Source: Author's Own

As depicted in Fig 4, Fig 5, and Fig 6, the p-values are lower than 0.05. This is also shown by the values of the table that tests hypotheses, all the hypotheses tested in this investigation were accepted as all path coefficients results were positive and p values are statistically significant.

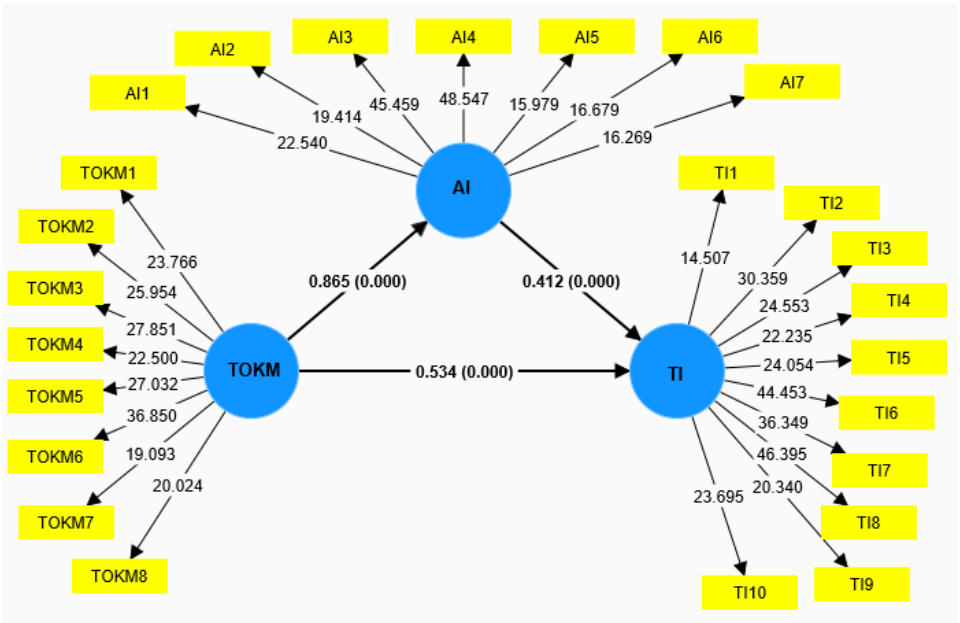

Fig 6. Path coefficients with P values

Source: Author's Own

Table 7. Direct, Indirect, Specific Effects Along with Hypothesis Decisions

	Original sample(O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values	Decision
Path Coefficients						
AI -> TI	0.412	0.411	0.044	9.345	0.0000	**Accept H1**
TOKM -> AI	0.865	0.867	0.013	68.81	0.0000	**Accept H2**
TOKM -> TI	0.534	0.536	0.043	12.382	0.0000	**Accept H3**
Total Indirect Effect						
TOKM -> TI	0.356	0.356	0.038	9.437	0.0000	
Specific Indirect Effect						
TOKM -> AI -> TI	0.356	0.356	0.038	9.437	0.0000	**Accept H4**

5. Conclusion, Implications & Future Research

This research focused on evaluating how Knowledge Management (KM) and Artificial Intelligence (AI) jointly influence technological innovation in Pakistan's manufacturing industry. By analyzing the data from different sectors (like pharmaceuticals, textiles, sports, and cement) and employing advanced analysis methods such as Structural Equation Modeling (SEM), the study demonstrates that both KM and AI play important roles in promoting innovation. AI helps to strengthen the impact of KM on innovation. The results indicate that companies with robust KM systems, supported by AI, are more likely to succeed in innovating. The positive relationships and significant results confirm that AI strengthens the effect of KM on technology innovation, resulting in better productivity and a competitive edge for manufacturing companies. This study contributes to the academic conversation about combining Knowledge Management (KM) and Artificial Intelligence (AI) by addressing a missing piece in the existing research, especially in countries like Pakistan that are still developing. The research supports Schumpeter's theory, the concept of open innovation, and the Technology Acceptance Model by showing that AI can be a valuable tool, improving KM practices and encouraging technological advancements. The results provide new insights into how KM and AI integrate to promote innovation, particularly in the manufacturing industry. It also extends our current understanding by highlighting AI's role as a bridge between KM and technological innovation, which is important for the dynamic capability's theory, which looks at how companies can adapt to rapidly-changing environments. For practitioners in manufacturing, this study shows how important it is to use AI in Knowledge Management (KM) systems to encourage new technology. Companies should focus on investing in AI technologies like machine learning and data analysis tools to improve their KM processes. Leaders should also promote a culture of sharing knowledge and provide training for employees to utilize AI well. This will help organizations use both their internal knowledge and external knowledge, leading to new ideas and greater competitiveness. Additionally, manufacturing companies in Pakistan, especially small and medium-sized enterprises (SMEs), should work with government agencies and international partners to secure

the resources needed for AI adoption. Such collaboration will help create a more supportive environment for innovation.

This study provides valuable insights, but future research could look at how KM and AI function in other areas like healthcare or finance, where technology is also very important. Future studies could investigate KM and AI affect a company's long-term success and how these technologies change employee involvement and customer satisfaction. Researchers should also analyze how AI affects KM practices when using new technologies like deep learning and natural language processing. Comparing how KM and AI work in different countries could give us important insights into how they influence innovation in various cultural and economic environments.

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