IMPACT OF KMP ON GREEN TECHNOLOGICAL INNOVATION AND SUSTAINABLE PERFORMANCE IN SME'S PAKISTAN

By

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ABSTRACT

Environmental sustainability has become the need of the hour. It has been emphasized immensely because of globalization and the scarcity of natural resources due to the negligence of human beings. The increasing environmental challenges Pakistan faces highlight the urgent need for sustainable industrial practices, particularly among Small and Medium Enterprises (SMEs), which constitute a major part of the country's economy. This study investigates the impact of Knowledge Management Practices (KMP) on Green Technological Innovation (GTI) and Sustainable Performance (SP) in manufacturing SMEs located in Islamabad and Rawalpindi. Drawing upon the Resource-Based View (RBV) and Natural Resource-Based View (NRBV) theories, the research further explores the mediating role of Absorptive Capacity (AC) and the moderating effect of Environmental Awareness (EA). Using a quantitative approach, data were collected from SME high and middle-level managers through structured questionnaires and analyzed using SPSS and AMOS. In the analysis, 320 employees who participated voluntarily in the survey were invited; out of those, we received only 280 questionnaires, and 256 were valid. The purposive sampling technique is used for data collection for statistically testing the hypotheses. Structural equation modeling (SEM) is used to measure the mediation and moderating relationships of variables. The result of the study shows that there is a positive and significant relationship between KMP and Green technological innovation, and KMP and sustainable performance. At the same time, Absorptive Capacity mediates the relationship between Knowledge Management Practices, Green Technological Innovation, and Sustainable Performance.

Keywords: Knowledge management practice, Green technological innovation, Sustainable performance, Environmental concerns, Environmental awareness.

Table of Contents

List of Tables

List of Figures

CHAPTER NO 1

INTRODUCTION

Due to limited resources and current environmental conditions, the operations of sustainable development and the problem of pollution are considered the main global issues facing the world. A low level of resource availability and a contaminated environment have threatened the survival of human life in the future (Pham et al., 2023). Although with the high use of natural resources, climate change exposes the emerging progress of the economies (Shehzad et al., 2023). The increase of globalization has led 'United Nations ‘develop and adopt the Sustainable Development Goals (SDGs) that will be beneficial to save and improve the environment from factors that are harmful to human survival (2021). In Pakistan, 98% of manufacturing units are based on SMEs, of which an estimated 80% are in urban areas, which are situated near riverbanks. Many of them have failed to control the emission of greenhouse gases (Ali et al., 2019).The 72% disposal of waste into the river water is a reason for great pollution stress to the marine life, and is the reason for lung cancer in people located in nearby areas (Li et al., 2022). Small and Medium organizations are forced to adopt environmentally friendly practices due to environmental awareness and environmental concerns in the nations.

It is observed that SMEs in Pakistan have failed to adopt sustainability and green innovation as per the directions of the regulations. Small and Medium Enterprises (SMEs) are critically important for Pakistan’s economy, both in terms of economic growth and social development. Higher authorities need to know deeply why SMEs fail to adopt environmentally friendly strategies. Incorporating these policies Government and high authorities play a crucial role in motivating SMEs to adopt methods of production that can save the environment (Zhang et al., 2022). It has been observed in Malaysia and South Korea that SMEs transfer their production process from traditional to the latest technology when the government itself is involved in policy-making. So, government support and intervention policies are important to maximize the willingness of SMEs to adopt green technological innovation and sustainable performance. Similarly, Debrah et al. (2021) investigated the motives of organizations for introducing clean innovation and found that policy interventions are a more powerful tool to implement clean technologies. Environmental issues are being prioritized by academic professionals. With rising customer demands, state and industrial companies are now becoming

more aware of innovative green techniques that help reduce environmental harm and gain a competitive advantage.

Pakistan is ranked poorly and is known as one of the least innovative countries in the world. Researching an emerging country like Pakistan might give further insight into recommended environmental control strategies. Degradation and redesign of environmentally friendly products that reduce industrial waste and protect the environment from pollution (Shehzad et al., 2023). Businesses and manufacturers must change their behavior to become more environmentally friendly to keep up with the trends. Numerous marketing, corporate ethics, and environmental management scholars have devoted considerable attention to green innovation (Wu et al., 2022). Given the severity of current environmental challenges, Pakistan's government must implement more urgent and stringent environmental regulations, as the adoption of restrictive policies has been identified as essential in addressing these concerns (Jiang et al., 2018).Daily, the strain on the climate and environment is increasing owing to the rapid usage of natural resources and dangerous pollutants. This poses a significant threat to emerging countries such as Pakistan. As more scientific proof of the negative consequences of this trend emerges, the external pressure on organizations to address the challenges of environmental degradation has increased (Awan et al., 2021).

Green technological innovation and sustainable performance are key enablers for achieving long-term sustainability goals, particularly those outlined in the United Nations Sustainable Development Goals (SDGs) 2021. Green Technological Innovation involves the development of eco-friendly technologies, such as renewable energy systems, energy-efficient manufacturing, and waste-reducing solutions. At the same time, sustainable performance reflects how well organizations reduce their environmental footprint over time, lower emissions, better resource efficiency, and less waste promote inclusive and sustainable economic growth. It aids in the strategy of environmentally friendly products and manufacturing practices (J.-W. Huang & Li, 2017). IKEA, Whole Foods, Unilever, Tesla, and Nike are among the international companies that have adopted and integrated green technological innovation into their operations (Lee et al., 2015). Adopting green technological innovation and sustainability helps them achieve a competitive advantage over their competitors. Keeping the effect of these variables on the environment, the present study is to investigate the association between Knowledge management practices and green technological innovation and sustainable performance in Pakistani SMEs. In the age of globalization, different organizations have recognized the importance of knowledge management practices (KMP), which have emerged as a gauge for organizational competitiveness (Ooi, 2014). Even

though SMEs are the backbone of Pakistan's economy, efforts have been focused on large enterprises while disregarding SMEs. According to the World Bank report (2021), when economic pressure is at its peak or as a coping mechanism, people andcorporations cause environmental concerns. The Global Innovation Index (GII) identifies knowledge and creativity as the two most crucial variables. With a mediocre score, Pakistan is known to be one of the least innovative countries in the world. Through a study on emerging economies like Pakistan, we may acquire a better knowledge of how KMP-supported tactics can be used to manage environmental degradation, reform eco-friendly products, and adopt cutting-edge technologies to reduce industrial waste.

This research will be beneficial for academics, industrialists, business owners, and many other stakeholders, as it will help them to be better prepared to use Knowledge Management Practices to achieve ecological sustainability and Green technological innovation goals. To recognize the impact of knowledge management practices and their main implication or effects on sustainable performance and green technological innovation. There exist numerous matters that should be highlighted in this research. The rise in environmental concerns, along with the need for absorptive capacity and environmental awareness, has become a critical global issue addressed in this study. The study also focuses on the potential links between knowledge management practices (KMP) and green technological innovation, sustainable performance, and the mediating and moderating roles of absorptive capacity and environmental awareness.

There is a growing awareness of how the company's ethical judgments interact with the ethical concerns of its personnel to impact their behavior within the firm (Lin & Chen, 2017). Individual and organizational characteristics influence employees' discretionary participation in the management of organizational environmental effects, according to a growing body of studies on the topic. To take advantage of organizational green innovation, businesses should promote ecologically responsible employee conduct (Zibarras & Coan, 2015). Employees are increasingly urged to practice environmentally conscious behaviors for the sake of the environment.

1.1 Background of the Study

In every economy, the manufacturing sector plays an important role in the development of business and its growth and helps increase the GDP of the country. Countries that have a strong manufacturing sector can perform better than non-manufacturing-oriented peers based on growth. SME's not only help in the creation of employment in the country, but they also increase the wealth and decrease the poverty of the country. It is a good source of

competitiveness and increases economic evolution. There will be good practice of material and human resources in an economic system where SMEs of the country are integrated and play a positive role in the local economy. The survival of SMEs in developing countries is still questionable, and towards a survival stage. Studies focusing on SMEs in developing countries are still limited, and this topic deserves more attention (Bhutta et al., 2022). The development of strong SME's is typically a central component of the industrialization process in developing countries. It includes the shift of resources and labor from traditional agricultural activities to more modern industrial activities. Most of the empirical research attentive the effect of large-sized organizations towards environmental problems and examined the motivational factors that are helpful towards the adoption of green innovation and a few researchers established a relationship between the adoption of green technological innovation in SME's in developing countries, which is an important part of the economy (Al-Hawari et al., 2021).

The main issues that indicate why SMEs fail to adopt green innovation and sustainable performance are a relatively less-researched area (Cantele & Zardini, 2018).According to the economic survey, the SMEs of Pakistan 23-24 shows that the growth of the sector was 2.38% in the fiscal year 2024, which was a moderate recovery from the recent year's contraction of 0.21%. In the SMEs manufacturing sector, it grew by 2.42% in the fiscal year (FY) 2024. This was a positive trend compared to last year, when the sector declined by 5.3%. The manufacturing sector is a significant contributor to Pakistan's industrial sector, making up 11.9% of the GDP. It means that the industry starts growing, but still, it faces some challenges, and due to this, its exports are lower. The lack of transparency is the biggest challenge for social compliance when sourcing for Pakistan. The limited number of labor inspectors significantly hampers the effective enforcement of labor laws and safety regulations, leading to inadequate monitoring of workplace conditions and increased vulnerability of workers to exploitation and occupational hazards. While the industry has a great impact on GDP, it is important to make a proper strategy to increase GDP.

Recently, by realizing that SMEs, both in developing and developed economies, have important environmental impacts, scholars are becoming keen to have a solid understanding of the issues that are influential to pro-environmental strategies among SME (Blundel et al., 2013). The main focus of this study is to overcome the gap and analyze how the SMEs of Pakistan increase their performance by less threatening the environment and increase their contribution to the GDP of the country.

1.2 Study Research Gap

Gap No 1

Knowledge Management is a significant and well-known component in today's world. It is also a vital component to understand the performance of innovation and performance (Dávila & Dos Anjos, 2021). While the relationship between KMP and innovation has been explored globally, there is a scarcity of empirical studies focusing specifically on how KMP influences GTI within Pakistani SMEs. Most existing research either concentrates on large enterprises or examines general innovation without a green focus. Abbas & Sağsan, (2019) investigated the role of KMP in green innovation and corporate sustainable development but did not specifically target SMEs in Pakistan.

Gap No 2

Green innovation has received increasing scholarly attention in recent years due to escalating environmental challenges and resource constraints. A recent study suggested that the implementation of green technological innovation in the SME sector is required (Luo et al., 2025). While Green Technological Innovation (GTI) has been studied extensively (Zhang, Meng, & Yuan, 2022), and Sustainable Performance has been explored through various mediating and moderating mechanisms (Ben & Lubica, 2017), most studies focus on these constructs in isolation. In the context of Pakistani SMEs, the direct relationships between Knowledge Management Practices (KMP), GTI, and sustainable performance have been somewhat examined; however, the literature lacks comprehensive models that integrate these variables through indirect pathways. Specifically, the role of Absorptive Capacity (AC) as a serial mediator explaining how KMP translates into GTI and then into sustainable performance remains underexplored. Moreover, few studies have assessed moderating variables that may influence the strength or direction of these relationships. Thus, there is a pressing need for empirical research that simultaneously examines the effects of KMP on both GTI and sustainable performance within a unified framework, incorporating mediation and moderation mechanisms to reflect the complex realities of SME operations in Pakistan.

Gap No 3

In the past, most of the empirical research mainly focused on large-sized firms in environmental humiliation and investigated the factors that help firms adopt green innovation (Aftab et al., 2023), and very less researchers recognized the relationship between the adoption

of green technological innovation, sustainable performance, and SME's financial development (Kousar et al., 2022). Existing literature focuses on specific industries, such as manufacturing or textiles, when exploring KMP and green innovation. This sector-specific approach limits the applicability of findings across the diverse range of SME sectors in Pakistan. (Ul-Durar et al., 2023).Many studies lack a cohesive theoretical framework integrating KMP, GTI, and sustainable performance. This absence hinders a comprehensive understanding of how these elements interact within SMEs. The study by Abbas and Sağsan (2019) utilized structural analysis to examine KMP's impact on green innovation and corporate sustainable development, but did not propose an integrated theoretical model encompassing all three constructs.

1.3 Problem Statement

Environmental degradation is one of the most pressing challenges faced by Pakistan today. According to the Climate Risk Index 2025, Pakistan ranked among the top ten countries most affected by extreme weather events in 2022 (Global Climate Index, 2025). In the 2024 Environmental Performance Index compiled by Yale University, Pakistan was ranked 178th out of 180 countries. This low ranking reflects challenges in areas such as air quality, waste management, and climate change mitigation. The EPI assesses countries based on 58 indicators across 11 categories, highlighting Pakistan's need for significant improvements in environmental health and ecosystem vitality (EPI, 2024). Rapid urbanization, industrial expansion, and increased vehicular usage have significantly contributed to rising carbon emissions, air pollution, and environmental hazards. Despite the growing urgency to combat climate change, Small and Medium Enterprises (SMEs) in Pakistan, which constitute over 90% of all industrial units, face significant challenges in adopting green technological innovations.

Many SMEs lack environmental awareness, technical capacity, and strategic knowledge towards environmentally sustainable practices. This lack of innovation contributes to the continued emission of pollutants, ineffective waste disposal, and inefficient resource use, exacerbating the country's ecological crisis. Most SMEs are located near the riverbanks or coastlines, and industrial pollutants immediately enter the water, putting animals and marine life in danger. Moreover, the emission of CO2 is one of the largest causes of air pollution, which is very high in the SME sector. Lack of ignorance and the inadequate application of environmental legislation cause a large impact on the environment of small and medium-sized businesses. A qualitative study involving semi-structured interviews with thirty manufacturing SMEs in Pakistan revealed that these enterprises struggle with environmental issues such as air

pollution and energy crises. While some measures like energy saving and limited water recycling have been undertaken, there is a general lack of comprehensive sustainability strategies among SMEs, particularly smaller businesses. The study underscores the importance of integrating environmental sustainability into SME practices for long-term viability and economic development (Kasi et al., 2019).

Knowledge Management Practices (KMP) such as knowledge acquisition, sharing, and responsiveness have the potential to empower SMEs by improving decision-making, fostering innovation, and aligning business strategies with environmental goals. However, the relationship between KMP and green technological innovation (GTI) in SMEs remains underexplored, particularly in developing countries like Pakistan. Furthermore, the influence of absorptive capacity (AC) as a mediator and environmental awareness (EA) as a moderator has not been fully investigated in this context. Given the critical role SMEs play in Pakistan's economy and environmental footprint, there is an urgent need to explore how effective knowledge management can drive green technological innovation and sustainable performance (SP). This study addresses this gap by examining how KMP influences GTI and SP in Pakistani SMEs, contributing to both the academic literature and practical solutions for sustainability.

1.4 Scope of Study

This study focuses on exploring the impact of Knowledge Management Practices (KMP) on Green Technological Innovation (GTI) and Sustainable Performance (SP) in the context of Small and Medium Enterprises (SMEs) operating in Pakistan. The research investigates how Absorptive Capacity (AC) mediates the relationship between KMP and both outcome variables and further examines the moderating role of Environmental Awareness (EA) in strengthening or weakening these relationships.

The study covers the following key dimensions:

1. **Sectoral Focus**: Focus on SMEs in Pakistan that play a major role in economic development by boosting domestic production, exports, and service delivery.
2. **Geographic Focus**: Selected urban regions in Pakistan with a high concentration of SMEs (e.g., Rawalpindi, Islamabad).
3. **Thematic Focus**: The influence of knowledge acquisition, sharing, and responsiveness on innovation and performance.

- The capacity of SMEs to absorb, assimilate, and exploit external and internal knowledge (AC).

- The moderating role of organizational and managerial Environmental Awareness in enabling or constraining green technological innovation and sustainable outcomes.

4. **Methodological Scope**: Questionnaires are used to collect the data that are supported by statistical techniques such as structural equation modeling (SEM) to test mediation and moderation effects.

By delineating this scope, the study aims to contribute to theory development in knowledge-based and resource-based views while offering practical insights for policymakers and SME managers seeking to align knowledge practices with environmental and performance goals.

1.5 Research Objectives

Current research emphasizes affairs between knowledge management practices (Independent variables), absorptive capacity (mediator), and green Technological innovation and sustainable performance (dependent variable). Environmental Awareness in this study is taken as a moderator among Knowledge Management Practice and Absorptive Capacity

The objectives of the research study are as follows:

Objective No. 1: Determine the impact of Knowledge Management Practices on green technological Innovation.

Objective No. 2: Assess the impact of knowledge Management practice on Sustainable performance.

Objective No. 3: Examine the moderator role of the environmental awareness between knowledge Management Processes and Green Absorptive capacity.

Objective No. 4: Evaluate the mediating role of Absorptive capacity between knowledge Management practice and Green Technological Innovation.

Objective No. 5: Explore the mediating role of absorptive capacity between knowledge Management practice and Sustainable performance.

1.6 Research Questions

In every study research question plays a vital role as it is an inquiry to address the answers to the questions. It provides pace for the research. In this study, every variable has a limited literature present regarding the combination of variables projected in the present study. The

literature in the study is mainly focused on the relationship between dependent and independent variables. The study shows the effect of mediating and moderating variables in the framework

The following specific research questions of this study are given below:

RQ 1: To what degree does knowledge management impact green technological innovation?

RQ 2: How do knowledge management practices impact Sustainable Development practices?

RQ 3: In what ways does environmental awareness influence the strength of the relationship between knowledge management practices and absorptive capacity in firms?

RQ 4: Is the impact of knowledge-management practices on green technological innovation transmitted through a firm's absorptive capacity?

RQ 5: Does the Absorptive capacity act as a mediator between knowledge management practice and sustainable performance?

1.7 The Significance of the Study

For the researchers and academics, the present research will provide an initial content to study the framework with novel constructs. This study advances the current literature by incorporating absorptive capacity as a mechanism mediating and environmental awareness as a moderating factor in the relationship between Knowledge Management Practices (KMP), Green Technological Innovation (GTI), and Sustainable Performance (SP). It will provide them a critical and logical thinking to promote the firm's absorptive capacity and the importance of environmental awareness through research. While prior research has acknowledged the importance of KMP and GTI in driving sustainability, limited attention has been paid to how firms' ability to absorb, assimilate, and apply external knowledge (absorptive capacity) influences this dynamic.

By investigating absorptive capacity as a mediator, the study deepens the understanding of the internal cognitive and organizational processes that enable knowledge to translate into effective green innovation and improved sustainable performance. Additionally, introducing environmental awareness as a moderator addresses the contextual factor that can strengthen or weaken these relationships. This is particularly important in emerging economies like Pakistan, where varying levels of environmental consciousness among managers and employees significantly affect sustainability outcomes. Pakistan, the fifth most populous country in the

world, faces numerous environmental challenges, including water pollution, air pollution, and land degradation. Following agriculture, the manufacturing sector is a critical contributor to national employment (Syed et al., 2012). SMEs contribute around 40% to Pakistan's GDP and play a key role in employment generation (SMEDA, 2021), thereby serving as key drivers of economic growth (Anwar et al., 2020). However, the significant presence of manufacturing SMEs also implies that they contribute substantially to environmental degradation, particularly in terms of pollution and resource consumption. Additionally, the impacts of climate change have further strained Pakistan's economy by reducing agricultural yields, affecting public health, and threatening biodiversity.

Through combining these constructs, the study offers a more nuanced, comprehensive model that not only clarifies how knowledge management leads to sustainable innovation but also under what conditions this process is most effective. This approach fills critical gaps in the literature regarding the mechanisms and contextual variables influencing SME's sustainability, providing valuable theoretical and practical contributions. The study also helps the SME's organizations and the government to create laws and policies that are more environmentally friendly. Moreover, the study provides guidelines to organizations, mainly those with a sublime population of knowledge workers, to design the curriculum of training to inculcate these variables as subjects. In Pakistan the business environment innovation can only be achieved through traditional means by only incorporating the strengths associated with the academic qualifications. The present study diversifies the manager's attention to ponder upon the means of career development of the employees related to the behavioral and social constructs. Only a few organizations have an interest in the conclusion of the study to implement in their training manuals. This study will act as a thought-provoking model in organizations.

1.8 Commercialization of Research

This research offers significant commercialization potential for enhancing the competitiveness, innovation capacity, and sustainability of Small and Medium Enterprises (SMEs) in Pakistan. By establishing the critical role of Knowledge Management Practices (KMP) in driving Green Technological Innovation (GTI) and Sustainable Performance (SP), the findings can be translated into practical tools, strategies, and services with wide application in industry and policy. This research model will be used in providing the consulting and strategic framework that helps SMEs implement effective KMP systems aimed at improving green innovation and sustainability. It will help in designing knowledge-sharing mechanisms,

capturing and applying environmental best practices, and embedding sustainability into business operations will also help create customized training programs for SME managers and employees focused on:

- Knowledge creation and sharing
- Eco-innovation practices
- Sustainability

Universities, incubators, or private training providers can offer these programs to strengthen Pakistan's SME ecosystem. The study can also guide government agencies (like SMEDA, MoST, or the Ministry of Climate Change) in formulating policies to promote green innovation through KMP, designing incentive programs for SMEs that adopt sustainable and knowledge-driven practices, and integrating KMP into national SME development plans. This research has strong commercialization potential through consulting, training, digital tools, and policy advocacy. Addressing a critical gap in Pakistan's SME sector can help transform traditional businesses into knowledge-driven, environmentally responsible enterprises, contributing to economic growth and sustainable development goals (SDGs). The research will be beneficial for the following stakeholders.

Table 1 Benefits of the stakeholder group through this research

Stakeholder Group	How They Benefit
SMEs	Improved performance, adopt innovation, and sustainability (long-term sustainable performance)
Government & Policy Makers	Helps design evidence-based policies that promote knowledge sharing, employee training, and documentation systems in SMEs.
Industry Associations	Training, advocacy, and SME support programs. Associations can use this data to guide their member firms in adopting practices that lead to green growth and long-term competitiveness.
Researchers & Academics	Literature contribution, future research opportunities. Builds on Knowledge-Based View (KBV) and Natural Resource-Based View (NRBV) theories. Offers a model for further research in emerging economies.

1.9 Overview of Industry

Small and Medium Enterprises (SMEs) are recognized globally as vital contributors to economic development, innovation, and employment generation. They represent the majority

of businesses in both developing and developed countries. According to the World Bank, SMEs account for over 90% of businesses and more than 50% of employment worldwide. Small and Medium Enterprises (SMEs) are recognized globally as vital contributors to economic development, innovation, and employment generation. They represent the majority of businesses in both developing and developed countries. According to the World Bank, SMEs account for over 90% of businesses and more than 50% of employment worldwide (World Bank, 2019).

According to SMEDA (2023) and the State Bank of Pakistan, an SME in Pakistan is defined based on employment size, annual sales turnover, and paid-up capital.

Small Enterprise:

Annual Sales Turnover: Up to PKR 150 million.

For a Small enterprise, the number of employees should be 10-49.

- **Medium Enterprise**:

Annual Sales Turnover: Between PKR 150 million and PKR 800 million.

For Medium enterprise, the number of employees should be 50-250.

In academic research, SMEs are often studied due to their unique characteristics, limited resources, flexible structures, and adaptability. These traits make them particularly important when examining knowledge management**,** green technological innovation**,** and sustainable performance, especially in developing countries where environmental regulations and technological readiness may differ significantly from larger firms.

1.10 The Structure of Thesis

The study contains a total of five chapters that are:

Chapter One: This chapter will provide a complete introduction to this study.

Chapter Two: This chapter uses variables, which are comprised current study, i.e., knowledge management practice, green technological innovation, sustainable performance, environmental awareness, and absorptive capacity.

Chapter Three: This chapter contains the basic conceptual framework that is projected in this study. This framework highlighted different independent variables and their impact on the dependent variables. It also defines the different approaches towards the data collection

instruments as well as the procedures related to the research design. This chapter provides definitions and a description analysis.

Chapter Four: This chapter is mainly based on data analysis, providing summarized methodologies and demographics that are based on the measurement model. This chapter contains the fit indices techniques, the path analysis, and the measurement model that are used in the model for data analysis.

Chapter Five: Mainly, this chapter is based on the conclusion of the study. It provides a detailed review of the major findings of the study. Indicates the suitable recommendations and suggestions that are used in the study. Also, it discusses the academic and practical implications of the present study. Provide mainly and directed towards future action.

CHAPTER NO 2

LITERATURE REVIEW

The literature review is defined as information that is discussed in a specific subject area within a certain period. It is a valuation report that consists of previous studies of researchers' selected areas. In research, it evaluates and summarizes according to the scholarly field of study. It is a summary and contains crucial information. It is a combination of previous and new information. It provides directions to researchers related to the topic and assists in the study. It contains the acknowledgment and connection between variables in past research. They built a theory and a conceptual framework based on previous studies. The literature review may vary from study to study. Literature review also allows to take the knowledge from the previously conducted studies on the selected topic; it provides detailed that how previously the selected variables have been studied and what flaws should be studied now and cover the gap.

2.1 Theoretical Background:

2.1.1 Resource-Based View Theory

Wernerfelt (1984) introduced RBV, which soon became a significant part of the literature. Altaf et al. (2019) state, RBV recommends that the success of a business is based on internal resources, which are the assets and capabilities of any business. This perspective contends that the firm's distinctive resources, whether material or intangible, produce the firm's competitiveness.(Kull & Mena, 2016). Particularly, any assets, competencies, organizational procedures,knowledge, firm features, and data that enable the organization to conceptualize and implement plans that enhance its effectiveness and efficiency are referred to as organizational resources (Barney, 2018).

NRBV highlights the need for firms to develop dynamic capabilities, such as environmental awareness, stakeholder engagement, and innovation, which support adaptive and learning organizations. These are essential for improving absorptive capacity, which helps organizations integrate sustainability-related knowledge into strategy and operations. RBV is restricted to firm-level repercussions and ignores the effect of environmental behaviors on green performance. It was discussed that the traits and characteristics of business resources that are (i) valuable, (2) rare, (3) inimitable, and (4) non-replaceable encourage long-term competitiveness (Andersén, 2021). Hart (1995) as a result, established natural RBV (NRBV).

The Natural Resource-Based View (NRBV) acknowledges the importance of environmental considerations, extends the traditional Resource-Based View (RBV), and is often regarded as a 'competitive advantage theory' that emphasizes the relationship between business and the natural environment (Hart 1995).

Diverse scientists and environmentalists have proposed that GI and sustainable performance can boost a business's prosperity and long-term success by adopting an NRBV perspective. Mills and Smith, (2011) argued that one of the main drivers of economic growth is knowledge resources. In today's knowledge-driven and environmentally conscious economy, the most effective approach to fostering green innovation is through leveraging organizational behavior and a firm's strong absorptive capacity for new knowledge, supported by Knowledge Management Practices (KMP). According to the Resource-Based View (RBV), firms pursuing environmental objectives strategically seek valuable resources such as knowledge to build critical capabilities like absorptive capacity. By regulating environmental awareness in an organization, an RBV supports the structure of a higher KMP to increase green innovation by firm absorptive capacity.AC plays a crucial role in developing and maintaining a firm's resources and capabilities as outlined by RBV. A firm with high absorptive capacity can effectively acquire and leverage external knowledge, enhancing its existing sources and creating new capabilities. This, in turn, strengthens its competitive position in the marketplace.

Green innovation, according to Knowledge management environmentalists who share the RBV perspective, can increase an employee's work performance and long-term performance (Barney 2021). Industry managers frequently utilize the RBV hypothesis as a tool to determine how a firm's resources and performance relate to one another. The researchers provided evidence to support the claim that knowledge resources are intangible, dynamic, challenging to duplicate, and helpful in achieving long-term competitive advantage (Curado & Bontis, 2006). To measure green technological innovation and sustainable performance, this study examined a few intangible resources, including KMP, absorptive capacity, and environmental awareness among employees. Knowledge is seen as an intangible resource that may make the difference between a company's success and failure (Ooi, 2014).Absorptive capacity is considered a firm's competitive advantage (Tufan & Mert, 2023). Environmental awareness is a resource for businesses that may be used to increase environmental awareness among employees. Environmental considerations affect environmental performance; thus, organizations cannot disregard them (Rehman et al., 2021). This study adds KMP, AC, and EA to RBV to assess green technological innovation and sustainable performance

2.1.2 Knowledge-Based View Theory

The KBV of the firm is the extension of the RBV theory of the firm (Curado & Bontis, 2006). The KBV of the firm suggested that knowledge is the most important strategic resource and, in that sense, this perspective is an extension of the RBV of the firm. It posits that firms gain a sustainable competitive advantage by effectively creating, integrating, and applying knowledge. Organizational capabilities such as KMP and AC are central to knowledge development and application. KMPs, such as knowledge acquisition, sharing, and responsiveness, are mechanisms through which organizations convert individual and tacit knowledge into organizational action. These practices stimulate innovation, including green technological innovation (GTI), which aligns with ecological goals. By managing knowledge effectively, firms can generate new ideas, redesign processes, and develop green products and technologies, directly boosting both GTI and SP (economic, environmental, and social performance) (A. N. Khan et al., 2024).

Firms with strong knowledge management capabilities show higher innovation and performance. Absorptive capacity reflects an organization's ability to leverage external knowledge, which is a key dynamic capability in the KBV framework. AC is both a function of prior knowledge (enabled by KMP) and a mechanism through which firms innovate and improve performance (Hernández-Linares et al., 2024). KMP strengthens AC that enhances the firm's ability to interpret, assimilate, and apply green knowledge, which leads the organization to achieve GTI and SP as its competitive advantage. Environmental Awareness enhances the strategic alignment of knowledge practices with sustainability goals. it ensures that the knowledge being managed is not generic but environmentally relevant, making AC more effective for innovation and sustainability. Environmental awareness shapes firm resources and capabilities toward sustainability (Tan et al., 2022).

Knowledge Management Practices:

Knowledge, a simple word, is defined by different authors in many ways. The authors recommended that knowledge is definite as per the purpose it serves. Gupta et al. (2000) advise that creating a simple definition for knowledge is challenging due to the purpose to which the term is applied. Most of the time, Knowledge is considered an asset for the organization. Like, 85% of organizations that are part of a survey on Knowledge Management "identify knowledge as a strategic asset for the organization" (Wiig, 1997). Knowledge is a benefit used by some individuals rather than the person who created it, and most importantly, its ownership exists within an organization (Welschen et al., 2012).Knowledge is an important resource of an

organization; it enables the company to achieve a competitive advantage compared to its competitors.

While Knowledge Management Practices refer to the systematic methods and strategies used by organizations to identify, create, capture, store, share, and apply knowledge effectively to achieve business objectives. These practices are designed to enhance organizational learning, improve efficiency, foster innovation, and maintain a competitive advantage. To get maximum benefit from the knowledge, organizations have to maintain their focus on staff and their training systems. The focus should be on the specific knowledge, skills, abilities, or helping employees to take maximum output from the knowledge.

At the core of KM practices is knowledge acquisition involves identifying, gathering, and capturing valuable information from both internal and external sources. This foundational step ensures that the organization possesses the necessary knowledge to address challenges and seize opportunities (Darroch & McNaughton, 2003). Once acquired, the knowledge is organized and stored using content management systems, digital repositories, and classification tools to ensure easy retrieval (Kunze et al., 2011). The next crucial step is knowledge sharing, where knowledge is disseminated across the organization. This is achieved through both formal and informal channels, such as communities of practice, mentoring, collaborative platforms (like internets or Microsoft Teams), workshops, and seminars. Equally important is knowledge responsiveness refers to the organization's ability to act upon the disseminated knowledge promptly and effectively. This involves applying the knowledge to make decisions, solve problems, or innovate, thereby translating information into tangible outcomes and then knowledge application, which ensures that the right knowledge is used at the right time to make better decisions. It helps in improving processes and solving problems. This includes integrating knowledge into daily workflows, using it in decision-support systems, or embedding it into training and development programs. Finally, evaluation and improvement are essential KM practices (Lin & Chen, 2017). Organizations must assess the effectiveness of their KM initiatives through metrics such as knowledge reuse rates, user satisfaction, and performance outcomes. Successful KM practices rely on strong leadership, supportive culture, effective technology, and appropriate incentives to encourage knowledge sharing and use. When implemented well, they lead to smarter working environments, reduced duplication of effort, and sustained organizational growth.

Sustainable Performance:

Sustainable performance refers to the ability of an organization to achieve long-term success while balancing economic, environmental, and social responsibilities. Sustainable performance is the ability of the organization to fulfill the needs and expectations of its customers in the long run through the use of effective management and organization (Kamble et al., 2020). It encompasses not just financial performance but also the impact an organization has on the environment and society. Sustainable performance aims to ensure that business operations are efficient and profitable today, while also safeguarding the well-being of future generations by minimizing negative environmental impacts and promoting social equity. In practical terms, sustainable performance involves integrating sustainability into business strategies, operations, and decision-making. This includes reducing environmental footprints, such as minimizing energy consumption, waste, and carbon emissions, as well as adopting circular economy principles that focus on reusing, recycling, and repurposing resources. Social sustainability is also a critical aspect, involving the fair treatment of employees, promoting diversity and inclusion, and contributing positively to the communities in which the business operates (Henao et al., 2019).

Economically, sustainable performance means finding ways to maintain profitability while reducing environmental and social costs (Imran et al., 2021).This often requires innovation, such as developing new, eco-friendly products, improving operational efficiency, or investing in green technologies (Al-Abbadi & Abu Rumman, 2023). The sustainable performance of the organization through different ways, which include economic, social, and environmental, as these scopes have already been discussed in many studies (Stanciu et al., 2014). These concepts are known as sustainability pillars. They help organizations achieve sustainable performance. It gives valuable information to managers and scholars, which will help them in making effective decisions which is beneficial for the betterment of the organization and society (Alam & Tariq, 2023). Organizations that are committed to sustainable performance set specific goals, targets, and metrics to estimate their impact on environmental, social, and economic dimensions. Monitoring and reporting progress transparently allow for accountability and continuous improvement. Achieving sustainable performance requires an approach that integrates sustainability principles into all characteristics of business strategy and operations. Organizations that prioritize sustainability are better positioned to build resilience, enhance reputation, and build a positive impact on the environment (Boons et al., 2013).

Ultimately, sustainable performance is about creating value that is not just measured in financial terms but also in how well an organization contributes to the overall health of the planet and society. Sustainable performance is about balancing profitability with environmental and societal contributions, ensuring that businesses operate in a way that promotes long-term sustainability rather than short-term gains at the cost of the planet or people.

Green Technological Innovation

Green technological innovation refers to the development and application of new technologies, processes, and products that aim to reduce environmental impact, promote sustainability, and support environmental stewardship (Li et al., 2022). These innovations focus on using resources more efficiently, minimizing waste, reducing carbon emissions, and promoting renewable energy sources. Green technological innovation plays a critical role in addressing global environmental challenges, such as climate change, resource depletion, and pollution, while also enabling economic growth and improving the quality of life (He et al., 2023). Green technologies often prioritize environmental sustainability, which is achieved by designing and implementing solutions that minimize negative ecological effects. This includes innovations in energy efficiency, renewable energy, sustainable agriculture, eco-friendly manufacturing processes, and waste management systems. Continuous advancements in technology, particularly in fields such as renewable energy (e.g., solar and wind energy), energy storage, and materials science, have made green technologies more efficient, cost-effective, and viable for widespread adoption. Research and development in these fields are key enablers of green innovation. In an increasingly environmentally conscious global economy, businesses see adopting green technologies as a means of differentiating themselves from competitors. Early adopters of green technologies can capitalize on reputational benefits and potentially lower operational costs (e.g., energy efficiency). The goal is not just to get a competitive advantage or create environmentally friendly products, but also to drive systemic change within industries and society by encouraging sustainable practices and reducing reliance on non-renewable resources.

Due to high concerns related to the environment, there is pressure from regulatory authorities on organizations to focus on green technology to protect the environment, reestablish past environmental damage, and mainly to conserve the available natural resources. Government policies, regulations, and incentives play a crucial role in driving green

technological innovation. The implementation of stricter environmental standards and regulations, such as carbon taxes, emissions caps, or renewable energy mandates, can create a compelling case for innovation. Green technological innovation has now become a prosperous business that includes enormous investment capital. Green technology is different from other innovations because it is not only about producing new products but producing them while less damaging natural resources (Parekh & Wright, 2024).

Environmental Awareness:

Environmental awareness refers to the understanding and recognition of the importance of protecting the natural environment and the impact human actions have on ecosystems, biodiversity, and the planet's overall health. It involves being conscious of environmental issues such as climate change, pollution, deforestation, resource depletion, and loss of wildlife, and understanding the role individuals, communities, and organizations play in contributing to or mitigating these problems (Mei et al., 2016). Environmental awareness encourages responsible behaviors and sustainable practices, such as reducing waste, conserving energy and water, using eco-friendly products, recycling, and supporting policies and initiatives aimed at environmental protection. It is often promoted through education, seminars, media campaigns, school curricula, and community programs that aim to inform people about the consequences of environmental degradation and inspire positive action (Takala, 2007).

Raising environmental awareness is essential for fostering a culture of sustainability, where people make informed choices that benefit both current and future generations. It also plays a critical role in driving environmental policies, corporate responsibility, and global cooperation on environmental challenges. Ultimately, environmental awareness is the first step toward creating a more sustainable and resilient world. As the planet faces unprecedented challenges like global warming, plastic pollution, deforestation, and species extinction, fostering environmental consciousness has become crucial for individuals, businesses, and governments alike. Environmental awareness from an organization's point of view refers to the degree to which a company understands values and responds to the environmental consequences of its operations. In academic literature, this concept has been widely studied within the fields of sustainability, strategic management, corporate social responsibility (CSR), and organizational behavior (Rani & Devi, 2024). This awareness drives critical behavioral changes, from reducing single-use plastics and conserving water to supporting renewable energy and sustainable agriculture. It also influences corporate responsibility, pushing companies to adopt

eco-friendly practices like carbon-neutral manufacturing and circular economy models, while pressuring governments to implement stronger environmental policies such as carbon pricing and conservation laws. Employees with high environmental awareness understand how the activities of humans, such as industrial processes, transportation issues, agriculture, and waste disposal, contribute to environmental degradation.

Absorptive Capacity

Absorptive capacity refers to an organization's ability to identify, acquire, assimilate, transform, and apply external knowledge effectively to enhance its operations, innovate, and maintain a competitive edge (Zahra & George, 2002). This concept, first introduced by Cohen and Levinthal in 1990, emphasizes the importance of leveraging external information, whether from new technologies, market trends, or research, and integrating it into the organization's existing processes and strategies. Absorptive capacity is not just about acquiring knowledge but about transforming it into something actionable and useful, which requires a combination of prior knowledge, skilled personnel, a culture of learning, and supportive infrastructure. It means that the organization should have to make a mechanism in an effective way to gain the maximum benefit from new knowledge. Once the organization has understood that useful external knowledge, it should determine how to use that knowledge effectively (Sancho-Zamora et al., 2022).The process involves several stages: first, acquisition, where an organization identifies and gathers relevant knowledge. It means that the organization should have to make a mechanism in an effective way to gain the maximum benefit from new knowledge. Once the organization has understood that useful external knowledge, it should determine how to use that knowledge effectively. It is further followed by assimilation, where this knowledge is understood and integrated with existing systems; then transformation, where new insights are combined with existing knowledge to create something innovative; and finally, exploitation**,** where the knowledge is applied to improve processes, products, or services.

Several factors influence an organization's absorptive capacity, including its prior knowledge base, organizational culture, internal resources, and external networks, all of which shape its ability to process and utilize new information. Companies with high absorptive capacity are more agile and adaptive, enabling them to innovate, respond to changes in the market, and make better decisions (Lane et al., 2006). However, challenges such as resistance to change, complexity of new knowledge, and the resource-intensive nature of building

absorptive capacity must be navigated carefully. Organizations that master absorptive capacity can leverage knowledge as a strategic asset, leading to improved performance and long-term success**.** This concept is crucial for organizations aiming to adapt to changing environments, technologies, and market conditions. Absorptive capacity enables an organization to respond to changes in the external environment, such as market shifts or technological disruptions, more effectively (Barratt-Pugh et al., 2013).By integrating new knowledge, organizations can make better decisions based on a wider range of data and insights. In the tech industry, companies like Apple or Google exhibit high absorptive capacity by continuously integrating cutting-edge technology and knowledge from external sources (e.g., acquisitions of smaller firms, collaborations, research partnerships) to innovate and stay ahead of competitors. Manufacturing companies like Toyota use absorptive capacity to continually improve their production processes. Through practices like lean manufacturing and just-in-time (JIT) systems, they assimilate new knowledge about operational efficiencies and apply it to improve productivity (Rani & Devi, 2024). Hospitals and healthcare providers use absorptive capacity to stay updated with the latest medical research and treatments. By applying the latest findings in medical research, they improve patient care and develop new treatments. Absorptive capacity is a main source of the organization through which the organization can gain a competitive advantage.

Explanation of Research Hypotheses

2.2 Relationship between Knowledge Management practice and Green Technological Innovation:

Knowledge is being learned, applied, and shared to achieve and gain a competitive advantage and improve organizational Performance (Firdaus et al., 2024).KMP helps and supports organizations to sustain and change operational sustainability, which helps in shareholders' and customers' trust (Arsawan et al., 2022).In today's fast-growing world, KMP has been acknowledged as an imperative component in producing and creating new products and services while managing and handling efficiently the operational process(Sahoo et al., 2023). As a result, organizations endeavor and strive to espouse innovation and effective KM practices to achieve long-term business goals (Wang et al., 2022). Modern economies are built using innovative ideas from human intellectual capital, contributing towards sustainability and profitability (Ogiemwonyi et al., 2023). Knowledge management enhances the capabilities that are essential for green innovation. Green technologies are derivative from KMP as Green

technological innovation refers to the development and application of new technologies that aim to reduce environmental harm, improve sustainability, and support the transition to a low-carbon economy (Javeed et al., 2022). It spans a wide range of sectors, including energy, transportation, construction, agriculture, and manufacturing. Knowledge resources and capabilities are the main building blocks for an organization's ability to innovate sustainably (Nisar et al., 2021).

Knowledge Management is crucial in getting a competitive edge and represents a substantial strategic potential for organizations that embrace green technological innovation. In recent years, the organization's decision makers have placed more focus on innovation as a means of ensuring a green environment. Green innovation nowadays is getting more attention from researchers in marketing, business ethics, and the environment (Ogiemwonyi et al., 2023). Green technologies would increase environmental sustainability while also helping organizations to operate in the long run and achieve a highly competitive edge (He et al., 2023). The value of KMP has long been recognized, and past research has found it to be an important aspect to consider when examining organizational performance, especially knowledge-based innovation (Abbas & Sağsan, 2019).Over time, a lot of studies and research have been done and explored that the impact of knowledge management (KM) practices on green technological innovations (GTIs) is significant, as KM directly influences how organizations generate, share, and apply knowledge to develop environmentally sustainable technologies. For instance, Siemens integrates KM in its sustainability strategy by using global knowledge-sharing platforms to accelerate the development of smart energy systems and eco-friendly infrastructure (Abdulmuhsin et al., 2024).

Another study also explores the relation of knowledge management and green innovation, as the study focusing on small and medium-sized enterprises (SMEs) in the UAE found that KM practices, specifically knowledge acquisition, dissemination, and responsiveness, positively influence green innovation. The results of the study indicated a positive and significant association between knowledge acquisition, knowledge dissemination, and knowledge responsiveness with green innovation (Shrafat, 2018). Another study in Nepal's cement industry shows that green knowledge management was identified as a predictor of green innovation, with green innovation culture serving as a partial mediator (Bhattarai, 2023). A study in Malaysia's public sector highlighted that KM strategies positively influence green innovation practices, with knowledge sharing having the most substantial impact (Tangaraja et al., 2015).

Another study by A. N. Khan et al. (2024) investigates how Green Knowledge Management (GKM) influences Green Technological Innovation (GTI) and sustainable performance in construction firms. It also examines the moderating role of Artificial Intelligence (AI) in the relationship between GKM and Green Human Capital (GHC). The findings highlight that GKM significantly enhances GTI and long-term performance, with AI playing a crucial moderation role.

Therefore, from the above studies, we can illustrate our hypothesis that knowledge management practices have a significant and positive impact on green technological innovation.

H1 Knowledge Management practices serve as a pivotal driver of green technological innovation, yielding a demonstrable and positive impact.

2.3 Impact of Knowledge Management Practices on Organizational Sustainable Performance:

An organization's ability to manage knowledge is an essential factor supporting the company's competitiveness (Ramos Cordeiro et al., 2024). When improving its quality, the company also improves its competitiveness, relying on knowledge-based competitiveness (Rasheed et al., 2025). Knowledge management is a function that helps identify and manage the organizational knowledge for a long-term benefit (Durrani et al., 2024). Knowledge management is an essential tool to create the organizational future, including efforts to ensure its sustainability (Nasyiah et al., 2024). Knowledge management does not merely aim to incorporate the low-cost production methods, considering its ability to create and develop added-value products. (Al-Hawari et al., 2021). Many researchers have claimed that the source of competitive advantage is knowledge assets. The organization has obtained benefits by adopting or implementing the knowledge management practices (Al-Abbadi & Abu Rumman, 2023). Specifically, knowledge management helps organizations optimize their organizational performance. Empirical studies show that knowledge management processes positively affect organizational performance (Shahzad et al., 2020). Many organizations have identified that knowledge plays a very important role in gaining sustainable performance for the organization. Many authors stated that in achieving a competitive advantage, a firm must acquire knowledge and use that knowledge in the best and efficient manner. (Mohammad Rashed Hasan Polas, 2021). For many organizations, achieving sustainable advantage lies in the capability to make and apply intellectual capital. Many authors offered literature on the direct relationship between

Knowledge Management Practices and sustainability performance. (Hussain et al., 2022) discussed that Knowledge Management is vital for generating a distinctive form of innovation (Ben & Lubica, 2017).

The concept of sustainable performance emerged some thirty years ago in response to global environmental issues, particularly those on natural resources and energy (Kun, 2022).An organization's sustainable performance shows how well it can meet the long-term goals and expectations of customers (Wang et al., 2022).Sustainable performance can be achieved through smart management, knowledgeable employees, a dedication to ongoing learning, and a willingness to make the right changes and improvements. That is why it is important to identify opportunities that support an organization's sustained success while integrating quality management system models (M. S. Khan et al., 2020). Organizations aiming to maintain strong performance must recognize their responsibilities to various stakeholder groups and continuously adapt their activities, strategies, and tools to drive ongoing improvement (Parekh & Wright, 2024). From this, it is evident that KMP can play a fundamental role in attaining firm Sustainable performance. Knowledge resources and capabilities are the building blocks for firms' abilities to innovate sustainably (Al-Abbadi & Abu Rumman, 2023).

Research conducted in Vietnam demonstrated that KM processes, including creation, acquisition, sharing, and application, significantly impact green innovation and sustainable performance. This study investigates the function of knowledge management (KM) in fostering sustainable performance through green innovation actions and strategies. Data were gathered for the study from managers at several organizations in the services and manufacturing industries. To examine how knowledge management processes, green innovation strategies, and sustainable performance are related using structural equation modeling (SEM). The findings indicate that knowledge management has a substantial and positive impact on green innovation and sustainable performance (Sahoo et al., 2023). Another research in Malaysian SMEs indicated that KM practices influence performance through green practices, with green innovation mediating the relationship between KM and sustainable performance (Saman et al., 2025). A study in Pakistan's manufacturing sector revealed that KM processes acquisition, dissemination, and application lead to green innovation, which in turn influences corporate sustainable performance. Organizational agility was also found to positively affect both green innovation and sustainability outcomes (Shahzad et al., 2020).

Therefore, from the above studies, we can illustrate our hypothesis that knowledge management practices have a significant and positive impact on green technological innovation.

H2 Knowledge management has a substantial and positive impact on the sustainable performance of the organization.

2.4 The Mediating Role of Absorptive Capacity

Absorptive capacity is defined as the capacity of a firm that provide the importance of new information integrated into it in a better way, and put it to its better use (Shafait & Huang, 2024).Huy et al. (2023) identified four sub-capabilities of absorptive capacity, including acquisition, assimilation, transformation, and knowledge exploitation to influence Knowledge management. The concept of absorptive capacity plays an important role in the creation of knowledge (Shah et al., 2023). Absorptive capacity is a firm's capability that enables the management to use knowledge more effectively, creating a seamless knowledge system. To increase the organization's absorptive capacity, the firm may seek to boost its internal research and development (R&D) endowments, draw on external R&D, acquire new technology, or improve the training of its workforce (L. Huang et al., 2023). Knowledge is inherently considered an intangible asset of business. Knowledge management is always done to preserve, increase, and apply knowledge to operational aspects of the business (Qu et al., 2022).

From that, it can be seen that the essence of absorptive capacity is to increase knowledge and create better conditions for applying that knowledge in business activities (Talaja & Hajdić, 2015). Research on the topic of absorptive capacity, as well as its influence on management aspects, is limited. However, there is still reliable scientific evidence to confirm the existence of a positive relationship between absorptive capacity and knowledge management (Dabić et al., 2019).A firm's ability to absorb new information is crucial in its capacity to create new ideas, products, and services with external knowledge, setting it apart from rivals and leveraging it in terms of knowledge attainment (Aboelmaged & Hashem, 2019). Knowledge sharing, as an absorptive capacity, is key to the success of green innovation, is significantly impacted by leaders' capacity to acquire internal and external information (Albort et al., 2018). Such a measure entails creating new ecologically friendly goods and methods for recycling, decreasing waste, and preventing pollution. Firms must embrace internal and external expertise to seek new ecologically friendly processes and address environmental issues (Gluch et al., 2009).

Most recent research has been conducted on green innovation and green performance through the mediation of absorptive capacity, which indicates that the green absorptive capacity has a major impact on firm green innovation (Akhtar et al., 2024). Another study by Chen et

al. (2014) used structural equation modeling to examine how green services provided by the Taiwanese electronics sector relate to absorptive capacity. Their results indicate that absorptive capacity positively affects green radical, incremental, and other innovations. More external information and expertise are encouraged for green innovation (Sancho et al., 2022). Effectively utilizing external knowledge is crucial for boosting a firm's situation into viability. Firms must combine their internal expertise with external knowledge as a green innovation strategy. Absorptive capacity facilitates a firm's capacity to absorb and integrate external knowledge at the organizational level (Lam et al., 2021). It will likely accelerate the frequency, speed, and scale of a firm's green innovation practices. A firm's ability to absorb external forces provides the freedom to select the best course of action. Implementing green technological innovation practices requires the management of substantial amounts of internal and external knowledge, frequently originating from many areas. It is necessary to internalize external knowledge, combine it with relevant past internal knowledge, and alter it. Therefore, firms must build their capacity to learn new information (Shao & Xu, 2025)

Absorptive capacity is the ability to acquire, assimilate, transform, and use external information that helps in providing knowledge about sustainability and how to implement it (Van et al., 2025). In this way, absorptive capacity can have an impact on a firm's ability to develop sustainable innovations and influence sustainability (Gamero et al., 2025).In terms of knowledge through contacts with other firms and meetings with customers, suppliers, and other stakeholders, a firm can acquire new, useful knowledge, for instance, for training employees in sustainability, selecting environmentally friendly products, promoting the preservation of the region's heritage, and contributing to the development of the local community, among others (Nureen et al., 2023). This requires continuous monitoring of sustainability demands and legislation. The firms must be able to quickly analyze and interpret changes in demand and rapidly understand new opportunities that arise to better satisfy their customers and stakeholders, to develop sustainability strategies and plans that meet the corporate interests of these stakeholders (Cho et al., 2011). Specifically, this approach leads to the implementation of sustainability, which benefits society. The process of achieving firm sustainable performance is faced with a variety of different obstacles. First, stakeholders exert pressure on firms to implement sustainable practices and allocate resources to fulfill the variety of sustainability needs (Ibrahim et al., 2024). Second, to gain a competitive advantage (Fan et al., 2023).

In his research Uniyal et al. (2021) identified a positive association between knowledge capacities and sustainable performance. Moreover, supplier relationship management plays a mediating role between corporate performance and knowledge capabilities. Knowledge not only promotes green product development but also improves the firm's value in the sustainable environment. Many researchers have investigated the association between KM attributes and corporate performance in various sectors, such as construction, high-tech industry, and education. According to Lane et al. (2006) organizations improve their sustainability with the help of absorptive capacity. The AC of organizations can persuade the company to profit from green practices.

Absorptive Capacity participates in the firm's innovation process in two ways: apparatus for handling new external knowledge and impetus for exchanging new knowledge for inter-corporation innovation practices (Silvianita & Pradana, 2022).AC has a direct association with green organizational performance. Gholami et al. (2013) studied the relationship between KM attributes and SMEs' performance and stated that the adoption of knowledge absorption significantly influences their performance. In this era of globalization, companies are striving to recognize their employees' potential and knowledge, and use them as a resource against their competitors, which will lead to sustainable performance. Another research examines the effect of absorptive capacity on green innovation adoption in SMEs, focusing on the mediating role of sustainable organizational capabilities. The study finds that absorptive capacity significantly predicts sustainable capabilities and green innovation adoption, emphasizing the importance of internal knowledge processes in facilitating green innovation (Aboelmaged & Hashem, 2019).

Thus, from the above literature, we can illustrate that:

H3: Absorptive capacity functions as a mediating mechanism through which Knowledge Management Practices influence Green Technological Innovation.

H4: The influence of Knowledge Management Practices on Sustainable Performance is transmitted through the mediating role of absorptive capacity.

2.5. Moderating role of Environmental Awareness towards knowledge Management Practices and Absorptive Capacity

Environmental awareness within organizations refers to the degree to which an organization recognizes environmental issues and integrates ecological considerations into its decision-making processes. It includes understanding the environmental impacts of business activities, fostering a culture that values sustainability, and committing to practices that protect and

preserve natural resources. Environmental awareness is an important component, and it means that people have an understanding of the present environmental issues and how the actions of individuals impact them. Due to these issues, there is pressure on organizations to produce products that consume fewer natural resources (Hussain et al., 2022). The environmental awareness among employees helps the tendency for green behavior, which will lead to the organization's capacity (Rani & Devi, 2024). It can further lead towards a significant decrease in a firm's environmental impact through encouraging the green and sustainable performances in the organization, increasing the morale of employees, bettering the firm's reputation, attracting the environmentally conscious customers, and leading to cost savings through resource efficiency (Appiah-Kubi et al., 2024). The Absorptive capacity (AC) refers to an organization's ability to recognize, assimilate, and apply external knowledge for commercial purposes (Cohen & Levinthal, 1990). This capacity is pivotal for effective knowledge management practices (KMP), which encompass the processes of acquiring, sharing, and utilizing knowledge within an organization (Makhloufi et al., 2024). Organizations that actively seek and acquire knowledge through environmental scanning, partnerships, and learning mechanisms are more likely to recognize valuable external knowledge and enhance their potential absorptive capacity (Zahra & George, 2002).

Organizations with heightened EA are more likely to prioritize environmental knowledge, facilitating better integration of such knowledge into organizational processes. EA can drive organizations to seek and implement environmentally friendly innovations, which requires effective knowledge management and a strong absorptive capacity. EA fosters a culture that values continuous learning about environmental issues, thereby enhancing the organization's ability to absorb and apply relevant knowledge. A previous research (Hussain et al., 2022) indicates that environmental complexity moderates the relationship between absorptive capacity and customer knowledge management capability. This implies that external environmental factors can influence how organizations manage and utilize knowledge. Another study Hashem & Aboelmaged (2024), reveals that environmental awareness mediates the relationship between knowledge dissemination and green innovation. This suggests that heightened environmental awareness can enhance the effectiveness of knowledge management practices and absorptive capacity in fostering innovation.

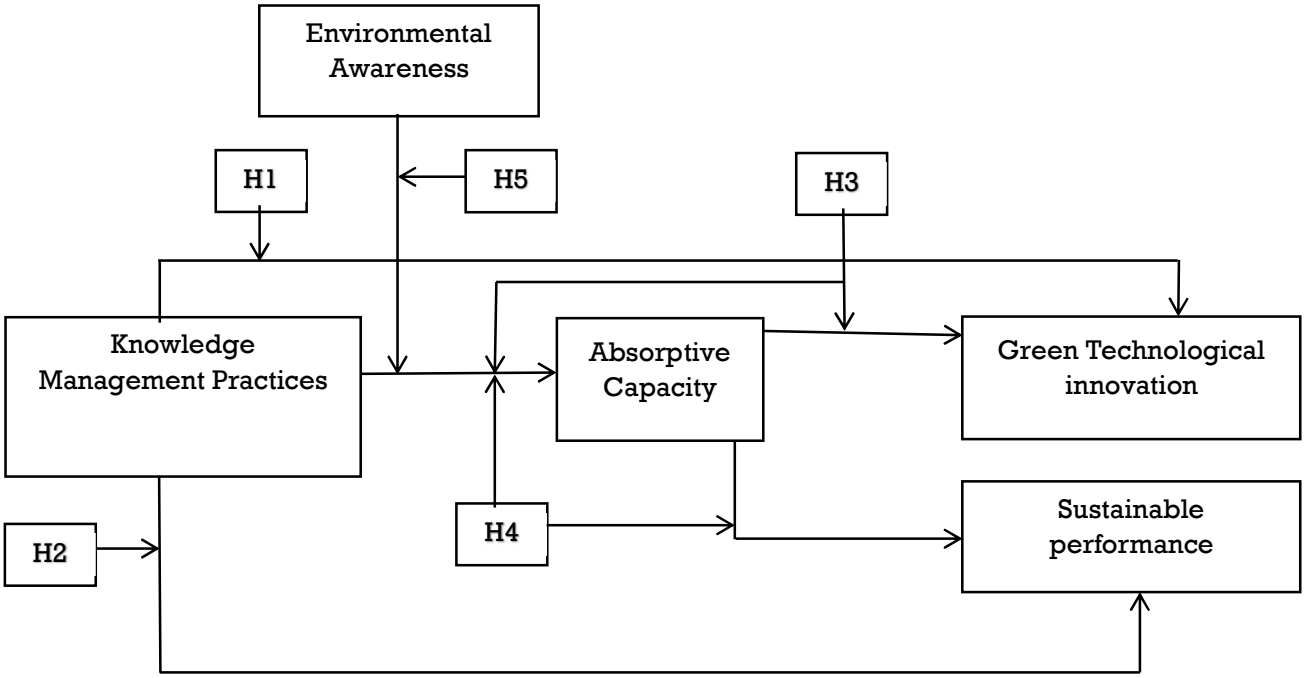
Hence, from the above literature, we illustrate that

H5: **Environmental awareness positively moderates the relationship between knowledge management practices and absorptive capacity, such that the relationship is stronger when environmental awareness is high.**

2.6 Conceptual Framework

The conceptual framework provides the readers with a picture related to the relationship between dependent and independent variables. It shows the main area of research, which will be conducted on the elements or variables that are discussed in the current study. A conceptual framework provides the standards to identify the main research questions and find their answers. Conceptual framework is also known as a "theoretical Framework". The conceptual framework in the study deals with the ideas or beliefs of the scholar about his study in the form of descriptive as well as graphical representations. The basic purpose of the framework is to create a model related to the topic the researcher wants to study and make possible relations. It creates accurate and related queries of the research and helps in adopting the valid research technique. In the present study, sustainable performance and green technological innovation are dependent variables, and relationships are established with an independent variable that is knowledge Management practices through the mediating effect of Absorptive Capacity. Environmental awareness is considered a moderator in the study. The conceptual framework that is built in the present study is as below:

Conceptual Framework



2.7 HYPOTHESIS DEVELOPMENT

Hypothesis development is defined as a relationship among two or more variables. It defines the phenomenon by providing a possible solution to a problem. The hypothesis in the study provides a relationship in the study through the connection of the present theory. Building a hypothesis is a crucial step in research as it is based on the hypothesized model, which, through the outcome, accepts or rejects the developed hypothesis.

As per the literature and theoretical support, we have built the following hypothesis in this study

H1: Knowledge Management practices have a positive impact on Green Technological innovation.

H2: Knowledge Management practices have a positive impact on Sustainable Performance.

H3: Absorptive capacity acts as a mediator between knowledge Management Practices and Green Technological Innovation.

H4: Absorptive Capacity acts as a mediator between Knowledge Management Practices and Sustainable performance.

H5: Environmental awareness positively moderates the relationship between knowledge management practices and absorptive capacity, such that the relationship is stronger when environmental awareness is high**.**

CHAPTER NO 3

RESEARCH METHODOLOGY

This chapter consists of an appropriate research methodology that we have built. The research methodology is based on a systematic method that is used when we need to solve a specific problem. This is the step that should come first. According to the author Rajasekar et al. (2013) the research method is an effective strategy that is used by the researcher to resolve the problem that they face in their work. The problem may stem from the subject of the research being done. In this particular stage, the researcher used to communicate with others to make their work more authentic and to analyze the consequences of their work. It has also been claimed that research is a mechanism through which uncommon information can be found. The most important purpose of this is to provide a complete examination of the techniques, methodology, and research plan that are further used in the study. It will be helpful to analyze how KMP has an impact on green technological innovation and sustainable performance as inspiring, as this evaluation is important. The impact of KMP, Absorptive capacity, and environmental awareness on its overall impact on sustainable performance and green technological innovation was analyzed. The empirical results align with the theoretical basis that was laid forth before. The hypothesis that KMP has a significant impact on green technological innovation and sustainable performance was empirically examined through quantitative research. It will lead to the formation of a sustainable and green technological innovation that was then subject to analysis. The findings of the research are more details below. In this chapter, we examine the research design, theoretical framework, population constructs, and analyze the sampling strategies, different data collection techniques, and methodology used to analyze the data.

3.1 Research Design

Research design is an important foundation of the study. It provides guidelines for the investigation and plays a vital role in the interpretation of the research findings (Sreejesh et al., 2014). Study design refers to the strategies that are used to collect answers to the research questions and to successfully carry out their objectives. Moreover, it is also helpful in the research procedures for collecting data for the analysis. (Saunders & Thornhill, 2011). It has details related to the size of the sample and the method that are used to test them. Testing of

hypotheses and determining the extent to which the research influence was the primary focus of the investigation. Thus, it is all about the research done into brand-new and natural occurrences. If the nature of the present research is descriptive, then it uses the deductive methods, which entail presenting a general theory via the theme assumption and concluding with a specific assumption relevant to the topic supported by evidence. In other words, if the research is descriptive, then the deductive method is used. In the present research, questionnaires were used solely for the objective of data processing and verifying the hypothesis. (Albaum & Murphy, 1988). The questionnaire is based on the Likert scale, which has a range from (1 Strongly Disagree to 5 Strongly Agree). Each item that is part of the questionnaire was related to the feature of the natural world that was being investigated. The present research is exploratory, which determines the impact of KMP on green technological innovation and sustainable performance, along with the mediating effect of absorptive capacity and moderator Environmental awareness. The instruments were modified by the results of different studies; to fulfill the survey needs, this questionnaire was sent to some small and medium-sized businesses situated in Rawalpindi and Islamabad.

3.2 Sampling Techniques

Many factors play an important role that leading to the conclusion that the purposeful sample method is the most suitable approach in data collection due to the following reasons.

- This technique is inexpensive.
- Effective in terms of time.
- Easy and simple to use.
- It's easy to get volunteers to serve as a sample.

This strategy is helpful when it is difficult to identify the population and collect precise data. This strategy is shown to be highly effective. This process demonstrated positive results in many situations. In this research, volunteer individuals are picked for the study on how well they know each other, rather than the person being typically representative of the community. If the researchers approach this method, it will increase the chances of getting their insightful ideas and points of view from the participants. In the research part, the variables in the theoretical framework are associated with one another; the employees from SMEs in Islamabad and Rawalpindi filled out a total of 256 questionnaires. I have no choice but to make sure that I use it due to the limited amount of time. Only able to collect a significant number of completed surveys promptly while keeping the acceptable level of efficiency and cost effectiveness,

Hair et al. (2010), argued that SEM analysis typically requires a minimum sample size of

150 to 200 for reliable model testing, depending on model complexity. Additionally, purposive and convenience sampling methods were used to target high and middle-level managers within SMEs who are directly involved in decision-making in the organization. The inclusion criteria for SMEs followed the standard SME definition by the Small and Medium Enterprises Development Authority (SMEDA**)** of Pakistan, i.e., firms with up to 250 employees and/or annual turnover not exceeding PKR 800 million. The population for this study comprises manufacturing Small and Medium Enterprises (SMEs) located in Islamabad and Rawalpindi, which are the most industrially active and administratively significant regions in Pakistan. These cities were selected due to their diverse mix of formal SMEs, better access to data, and presence of relevant industry clusters such as pharmaceuticals, food processing, electronics, and light engineering. This regional focus allows for controlled data collection while still providing insights applicable to broader urban SME sectors in Pakistan. As per the SMEDA corresponding person, the total manufacturing SMEs in Rawalpindi and Islamabad is more than 1000. Khan and Qureshi (2007) reported that a total of 1,855 SMEs were registered in Islamabad and Rawalpindi. For their study, a sample size of 30–50 SMEs was determined, guided by previous empirical studies, the statistical requirements of Structural Equation Modeling (SEM), and practical feasibility.3.3 Unit of Analysis

The population for this study comprises manufacturing Small and Medium Enterprises (SMEs) located in Islamabad and Rawalpindi, among the most industrially active and administratively significant regions in Pakistan. The data collection from several middle-level and top-level SME sectors in Pakistan They are involves both strategic decision-making and day-to-day operations, making their insights valuable for research. They interact with senior leaders and front-line employees, offering a dual perspective on organization dynamics, communication, and culture. Their feedback can highlight gaps or strengths in the process that might not be visible to other hierarchical levels. The cities were selected due to their diverse mix of formal SMEs, better access to data, and presence of relevant industry clusters such as pharmaceuticals, food processing, electronics, and light engineering. This regional focus allows for controlled data collection while still providing insights applicable to broader urban SME sectors in Pakistan.

Sample Size on literature basis, a significant sample size is used, and the methodology was selected for the evaluation of two hundred and fifty-six employees working in SMEs of Islamabad and Rawalpindi, which are trustworthy. The sample size of 256 SMEs was determined based on a combination of previous empirical studies, statistical requirements for Structural Equation Modeling (SEM), and practical feasibility. In comparison to the actual

sample size, the size of sample size is considered good if it is larger than the sample size used in the study (Green, 1991). For the analysis of Multivariate, it is suggested that the sample size has to be ten times larger than the actual sample size of the research that was provided permission to be carried out. To do multivariate analysis, the sample size has to be ten times larger than the actual sample size of the research that was granted permission to be carried out (Sekaran & Bougie, 2016).

The size of the study sample has been addressed by different academics. The sample of the study is 256 for a particular reason. While doing the power analysis on research that has four and five independent variables, the probability level has to be assumed to be 0.05, and the suggested statistical power level has to be 0.80. which will permit you to make more accurate predictions about the results. It is because of the high number of participants in the research study. In that scenario, the sample size has to be more than 200. For the analysis according to Hair et al. (2010), SEM analysis typically requires a minimum sample size of 150 to 200 for reliable model testing, depending on model complexity. Additionally, purposive sampling methods were used to target decision-makers within SMEs who are directly involved in innovation and knowledge management practices. The inclusion criteria for SMEs followed the standard SME definition by the Small and Medium Enterprises Development Authority (SMEDA) of Pakistan, i.e., firms with up to 250 employees and/or annual turnover not exceeding PKR 800 million.

The table that follows provides more clarification about the sample size used for the investigation that is currently being carried out.

Table 3.1: Sample Size Clarification

	Frequency	**%**
Total	320	100%
Received	280	87%
Valid	256	96.87%
Rejected	24	6.25%

The information about the size of the sample may be found in the table that follows. As a direct consequence of this, there was a total of 256 questionnaires spread out over the population. Despite this, a total of 280 out of the 320 surveys were filled out and returned, which equates to a response rate of 87%. Even though 24 out of 280 questionnaires were thrown away, and a

percentage were discovered to be lacking the needed information, the study was nonetheless successful. As a direct consequence of this, the regression analysis will use a total of 360 questionnaires, each of which has a validity rating of 91.42 percent.

3.4 Methods of Data Collection

The approach for taking the data is the preparation of the questionnaire with closed-ended questions to get the quantitative data. For the comprehensive review of the literature, the questionnaire was modified to incorporate the findings from a variety of different studies after being informed by the results of the review. All questionnaire items were graded on a 5-point scale. On the Likert scale, the extremes of disagreementand agreement are strongly disagree and strongly agree, respectively. The various SMES employees were provided physical copies, which they were tasked with filling out and returning. During the data collection process, quantifiable information was collected via the use questionnaire that contained the questions with predetermined answers. After the comprehensive analysis of the literature, the questionnaire is further revised to incorporate the changes. Every question on the survey received a score between 0 and 5 on a Likert scale that ranged from strongly disagree to agree. The reliable and authentic employees working in departments (management, production, HRM, marketing, finance) of Pakistani small and medium-sized businesses were the recipients of physical copiesof questionnaires that were sent to them.

3.5 Summary of Operationalization of Variables

The table below shows the measurement of each variable. Responses of the respondents are recorded on the five-point Likert scale. A score of 1 indicates strongly disagree, while a score of 5 indicates strongly agree.

Table *3*.2: Instrument Adaptation

Variable	Item	Sources
Knowledge Management Practices	08	Darroch and McNaughton (2003
Green Technological Innovation	05	Upadhyay, Kumar, & Sahoo (2022)
Sustainable Performance	05	Bansal (2005)
Absorptive Capacity	04	Flatten et al. (2011)
Environmental Awareness	05	Mostafa (2007) Haron et al. (2005)

3.6 Data Collection

We used self-administered questionnaires in this study. The questionnaire was distributed to the employees. The organization's Cronbach's coefficient alpha method is used to determine the reliability of the study. It is hypothetically supposed that the data set will only be acceptable if the values are .7 or more (Cronbach, 1951). From the table below value of all present variables is more than 0.90. It shows that the variables present in the study are identical to each other. They belong to the same constructs and have a high degree of consistency. If a number is less than 7, it indicates data collection that was acquired is dubious and may be insufficient for obtaining the required or proper results. In a similar vein, acceptable outcomes are those that are relatively near to the value 0.7. Table 4 shows all the values of each item for Cronbach's alpha.

Table 3.3: Cronbach's Alpha

Scale	Cronbach's Alpha
Knowledge Management Practices	.812
Sustainable Performance	.803
Green Technological Innovation	.79
Environmental Awareness	.765
Absorptive capacity	.731

3.7 Data Collection and Procedure

The questionnaire is used in this study as a means of instrument for collecting the primary set of data for analysis. The questionnaire, which includes different questions, is used to recognize knowledge management practices on green technological innovation and company sustainable performance. The questionnaire method has been selected for data collection. Through the filled questionnaire, knowledge management practice and its effect on green technological innovation and Sustainable performance in SMEs that are in Islamabad and Rawalpindi, Pakistan, are analyzed. The questionnaire was used to fulfil the goal of data collection. Utilizing the questionnaire helps enable the identification of green technological innovation and sustainable performance, KMP, absorptive capacity, and environmental awareness. To complete the data gathering, it is essential to visit the organizations. Respondents who are available at workplaces were invited to fill out the questionnaire. It is also giving surety to the respondents that their response will only be taken for the research

purpose, and the response will be safe and it will keep secret and can be used only for the research purpose. It was a somewhat difficult task to take secret data directly from the staff while they were busy performing their office task. Though employees were asking many times, and most of the time waited for them to complete their task and provide us with their opinion. Unfortunately, in this task, some employees and some companies apologized while mostly appreciated and filled it in a quite friendly way, while asking some questions about the related project.

It was difficult to adjust the time, as time was the main hindrance in data collection, as some firms refused to provide this data from their employees. Some upper-level managers played a vital role and were kind in taking questionnaire data as they requested some of the employees on their behalf to fill out the questionnaire. From some organization, I get a few questionnaires from the next day from some employees who were very busy performing their tasks and failed to fill out the questionnaire at the very moment. Some organizations are visited for more than two days to collect data due to employees' unavailability. Despite this, a conclusion on the size of the sample was reached after several visits were made to a representative sample of manufacturing SMEs. Some of the respondents who were offered remuneration in exchange for completing the questionnaire declined the offer, citing the possibility that the findings may be skewed as a justification for their decision. When it came to the collection of data, managers' coworkers played a significant and useful part in the process. They specifically requested that particular managers fill out the questionnaire, and the next day, they received a limitednumber of completed surveys from managers who had been in a hurry and were unable to finish it atthe time. Because of this, we were able to get a more precise picture of the manager population.

3.8 Data Analysis and Processing

The next step after the collection of data was its analysis and processing of data. For this task, the software used is SPSS, which is the latest version (version 20). It is mainly used for data analysis processing. It supports a broad range of statistical techniques, including descriptive statistics, regression, ANOVA, and non-parametric tests. It is ideal for exploratory and confirmatory analysis. It offers robust tools for handling cleaning and organizing data, making it easier to prepare a dataset for analysis, and also helpful to support multiple data formats and process large datasets efficiently for this investigation. An additional phase, called SEM analysis, and the AMOS software are employed. The present data was analyzed using the

software that is called the Statistical Package for Social Science (SPSS), and the final coding was done based on the Likert scale defined in the questionnaire. Additionally, the responses are inputted by the requirements of this research. By the specifications, structural equation modelling (SEM), which will be carried out using SPSS, is also utilized to analyze the data using moment structures (AMOS). To measure the study reliability in the present study the SPSS is used. Furthermore, the software SPSS helps examine the data in terms of the analysis of the descriptive statistics. Towards the authorization of outcomes accomplished using the two analyses, which are exploratory factor analysis and confirmatory factor analysis. Furthermore, SEM is employed to analyze the given hypothesis that is put out in the study and model. As a fundamental feature of AMOS, structural equation modeling is also applied to extract values from SPSS data sheets and evaluate the proposed model.

3.8.1 Benefits of Using SPSS

- Easy-to-use GUI with menus and dialog boxes—ideal for researchers with limited coding experience.
- Supports a wide range of analyses like descriptive statistics, Reliability testing (e.g., Cronbach's Alpha), Correlation and regression, ANOVA, t-tests, and factor analysis
- Efficient for data entry, screening, missing value analysis, and transformations.
- Helpful for testing internal consistency of constructs before SEM modeling.

3.9 AMOS and Structural Equation Modeling (SEM)

3.9.1 AMOS

The two main components available for the analysis in the present study are Moment structure as a (AMOS, version 5), which is included in the module for SPSS, are AMOS Graphics and AMOS Basic. Using AMOS Graphics, model specifications can be expressed visually, assisting in the display of a visual representation of the model. Model specifications may additionally be obtained from equation statements utilizing AMOS Basic. The potential of AMOS to present confidence intervals for bootstrapped standard error and parameter estimations is an essential capability. AMOS has a graphical interface that makes SEM modeling easier compared to the coding-based approach in R (layaan). Researchers without programming experience often prefer AMOS. SPSS and AMOS are recognized as industry standards, increasing the credibility and acceptance of research findings

3.9.91.1 Benefits of Using Amos

- It allows researchers to test complex theoretical models involving relationships among latent variables.
- Tests hypothesized relationships between multiple dependent and independent variables simultaneously.
- Suitable for mediation and moderation analysis.
- Offers a drag-and-drop interface to build path models visually helpful for clearly communicating theoretical frameworks.
- Measurement model (via Confirmatory Factor Analysis - CFA)
- Structural model (hypothesized paths and relationships)
- Provides goodness-of-fit statistics such as: CFI, TLI, RMSEA, GFI, Chi-square/df, which help in assessing how well your model fits the data
- Models unobserved (latent) variables like Knowledge Management or Environmental Awareness using multiple indicators.

The selection of SPSS and AMOS for data analysis in this study is based on both the nature of the research objectives and the analytical requirements of the proposed model. SPSS is widely recognized for its robustness, accessibility, and efficiency in handling large datasets, conducting descriptive statistics, reliability analysis, and initial data screening. Its intuitive interface and comprehensive set of statistical tools make it particularly suitable for social science and business research, where user-friendly data management and standard inferential tests (e.g., correlation, regression, t-tests) are required. While AMOS, an extension of SPSS, was chosen specifically for its capacity to perform Structural Equation Modeling (SEM), which is central to this study's aim of analyzing complex relationships among multiple latent variables such as Knowledge Management Practices, Green Technological Innovation, Absorptive Capacity, Environmental Awareness, and Sustainable Performance. Compared to other SEM tools like LISREL or Smart PLS, AMOS offers a visual path modeling interface that facilitates clearer theoretical modeling and interpretation, especially for mediating and moderating relationships. Moreover, AMOS provides comprehensive model fit indices (e.g., RMSEA, CFI, TLI, Chi-square/df) for validating the measurement and structural models. Thus, the combined use of SPSS and AMOS ensures a rigorous, transparent, and statistically sound approach to quantitative data analysis, aligning with the study's methodological requirements and enhancing the reliability and validity of the findings.

3.9.2 Structural Equation Modeling (SEM)

As per the analysis of Lei and Wu (2008), Many statistical models are explained by structural equation modelling, which is useful for evaluating the generality of underlying theories to empirical data. It is a statistical extension of the Multiple Linear Regression, and the other is the Analysis of Variance (ANOVA) techniques employed in General Linear Modelling (GLM). When contrasted with other GLMs, SEM is better. The cause for this is that it may examine haphazard correlations between latent variables, which are defined by many processes. The ability to model intricate interactions between observable and latent variables of analysis is one of the key reasons. It can be used to perform the analysis of cross-sectional as well as longitudinal data in calculating the analysis of experimental and non-experimental data. For the latent construct, it can be additionally involved in the calculation of the latent construct

Simply, the SEM analysis involves the review of two models that are called the path model and the second is called measurement model. In the path model analysis, the virtual presented diagram provides the relationships of the variable's different estimates and, with the aid of SEM, builds the model fit. SEM's primary goal is to understand whether if model is proposed or consistent with the gathered data or not. A model fit can be used to quantify this consistency. The degree to which the proposed links are reasonable is indicated by the model fit.

3.10 Data Coding and Technique

Data coding is done using SPSS (version 20), and the analysis is conducted with SEM using AMOS. Both analyses were performed on the data. Structural Equation Modeling (SEM). It is more versatile than other multivariate methodologies because it enables researchers to investigate simultaneous, multiple dependent interactions between dependent and independent variables. This is one of the reasons why SEM is more versatile. This assumption exists for several reasons, one of which is that it allows researchers to investigate causal linkages. To put it another way, factors that were dependent in a previous study may be recast as independent variables in later investigations, provided that the context allows for such a transformation. The use of Cronbach's alpha with a value that is higher than 0.7 is utilized to evaluate the validity and reliability of the instrument. Analyses are also performed on the descriptive statistics of the instrument, which include the mean, percentage,and standard deviation.

CHAPTER NO 4

DATA ANALYSIS

This section includes three different steps. The first part of the analysis explains descriptive analysis in detail, and the demographics analysis of the study. The second step is based on the Confirmatory Factor Analysis (CFA). In the third and final stage, the emphasis should be placed on hypothesis testing that shows the relationship between dependent variables, known as green technological innovation and sustainable Performance, the mediator Absorptive capacity, the independent variable Knowledge Management practices, and the moderating effect of Environmental awareness.

4.1. Sample Demographics and the Analysis of Missing Values

The study included demographics of respondents, that is, experience in the company and company size, through the use of descriptive analysis. It also examines the problems that are faced on the stage of data screening and various other techniques used to manage the missing values.

4.1.2 Identification and data entry of Missing values

Author Jolliffe (1988), a detailed analysis is necessary to find any mistakes that occur and the possibility of any missing values in the available dataset. Due to these reasons, the data screened through the use of the software known as SPSS version 20 is used to analyze missing values through each case and each item. At the start of the analysis, a total of 320 questionnaires were distributed in different SMEs that are located in Rawalpindi and Islamabad, but fortunately, only 280 questionnaires were returned. The 24 questionnaires were omitted from the analysis the reason was those questionnaires have more missing information relating to some construct or item that could not be used in the analysis. Thus, a final sample of 256 is finalized for the final analysis and to run the responses in the software. The entire response rate of respondents was good, as expected; the reason behind this was the other use of the self-administered questionnaire. But it is noticed that the response rate, as per the other research, is quite less; the reason behind this is the problem of the sample population.

To perform the analysis, descriptive statistics are used. It is a second step for identifying if there is any chance of the occurrence of outliers in the available data. Outliers are those extreme values that differ from most other data points in a dataset. They can have a big impact on your statistical analyses and skew the results of any hypothesis tests. Additionally, using descriptive statistics, it is also analyzed that if there is any abnormal variance exists in the data. In the present study, no outliers found through mean, standard deviation, and frequency distribution. The result is gathered, which indicates the accuracy of the data entry for the analysis. In the study, the missing data were immediately eliminated from the analysis after closely reviewing the questionnaires. The SPSS sheet did not contain any entries from any of the questionnaires that included missing values. As a result, there are no missing values in the data from this study, and the data is ready to perform the tests.

4.2 Correlation Analysis

The term "correlation" refers to a method that illustrates the link that exists between two or morevariables to quantify the level of correlation. Testing for simultaneous change between the two variables may be done in a manner that is both extremely beneficial and quite frequent. Therefore, the value of correlation might range anywhere from minus one to plus one. It is important to make use of bivariate correlations when assessing the collinearity of suggested variables.In correlation analysis, values with a negative sign indicate a negative link between the variables. Values with a positive sign indicate a positive relationship between the variables. Values with a zeroindicate that there is no association between the variables. According to the findings of this research,there is strong intercorrelation between all of the dependent and independent variables, and these correlations might be significant in both positive and negative directions.

Table 4.1: Correlation Coefficients: Knowledge Management Practices, SP, and Green Technological Innovation Model

Correlations

	GTI	SP	EA	KMP	AC
GTI	1				
SP	.719**	1			
EA	.438**	.410**	1		
KMP	.576**	.690**	.555**	1	
AC	.626**	.616**	.502**	.547**	1

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

This table presents the correlation matrix for this research, which includes both the dependent and independent variables. In addition to this, it illustrates the links between the variables that are dependent and those that are independent. It is recommended that the value of the independent variables be lower than 0.8 in the correlation matrix (Sekaran & Bougie, 2010). Therefore, the only thing that we will be looking at is whether the values of the independent variables are greater than 0.8 or 0.7. According to Sekaran and Bougie (2010), there is a problem with multicollinearity when the association between two independent variables is more than or equal to 0.8. On the other hand, there is no problem with multicollinearity when the value of the independent variables is less than 0.8. In such a situation, we shall not proceed with doing a test to check for multicollinearity between the variables that are considered independent.

4.3 Regression Analysis

Demonstrating the relation between dependent and independent variables may be done with the use of a model called linear regression. This analysis is used to assess the impact of the independent variable on the dependent variable. The optimum equation for linear regression

that best suits the quantifiable requirements, which are stated as BLUE (Best, linear, Unbiased equation).

4.3.1 Assumption of the Regression Equation

This study, using a regression model, makes a lot of assumptions. Before using either simple or multiple regression models, one may additionally ensure that all the assumptions have been satisfied. The following are the fundamental presumptions that a linear model must meet.

4.3.1.1 Assumption No. 1

The interval level of each variable included in the analysis must be measured. This questionnaire is designed with the use of Likert scales, which are known as an interval scale. Every scale has a total of five points. The Likert scale, which contains five points, is not regarded as an interval scale but an ordinal scale (Kelley & Maxwell, 2003). While the majority of the studies used the Likert scale, including the five-point scale as an interval scale. it is used to test research findings. In this, the Likert scale is used to analyze to verify the hypothesis and determine the variable ranges

4.3.1.2 Assumption No. 2

When performing an analysis using SEM, it is very important to verify that the normal assumption has been made. Kurtosis helps to examine the normality of a dataset, in addition to the skewness, and drawing a normal curve, both can help analyze the normality of the data. Both of them test high results indicate that the data did not follow the expected pattern (Qu, 2007). For both kurtosis and skewness, the range of acceptable values should be between minus two to plus two. Skewness and kurtosis values were used as preliminary indicators to assess the univariate normality of the data, which is a fundamental assumption in Structural Equation Modeling (SEM) using AMOS. The commonly cited threshold of ±2 was adopted based on recommendations from George (2011) and Byrne (2004), who suggest that values within this range indicate an acceptable approximation of normality for most behavioral science research. However, it is acknowledged that the cut-off criteria for normality assessment vary across the literature, with some researchers proposing more stringent thresholds (e.g., ±1.5 or ±1), especially in large samples, and others allowing wider ranges depending on sample size and analysis type.

While this study used ±2 as a practical guideline, additional methods were also considered to strengthen the robustness of normality Moreover, since SEM with maximum likelihood estimation (MLE) used in AMOS is relatively robust to mild deviations from normality,

particularly with a moderate to large sample size (n > 150), the adopted threshold was deemed appropriate for this analysis. Nonetheless, the limitation of relying solely on skewness and kurtosis thresholds is acknowledged, and future studies may benefit from applying multivariate normality tests such as Mardia's coefficient for further validation. The normalcy of the data is shown by the values that are displayed further down in the table. When the statistical value of all the data is divided by the standard error, the resulting range of values, from plus two to minus two, indicates that the data should be considered normal at every level. Therefore, every value is inside the acceptable range for kurtosis and skewness that has been given. To carry out the structural equation modeling (SEM) study, you are required to verify that the assumption of normality is correct.

Therefore, all values are located inside the kurtosis and skewness limits that have been given. After the measurement of these two tests, and before moving on to any investigation, it is necessary to test the data for additional fundamental presumptions, such as (a) verifying the normality of the data's distribution through variance, mean, kurtosis and skewness; (b) ensuring that there is no multicollinearity; if there is, it can be verified through the VIF and by creating correlation matrix; and (c) ensuring that the data is free of missing values. By the end of this chapter, the values of variance, means, kurtosis, and skewness shall all have been determined to confirm the fundamental requirements of normality and multicollinearity. Several studies show that there is cause for concern when vast amounts of data are being analyzed, since this allows for the possibility of non-normality. If the sample size is more than 200 or 300, then there should be a significant issue with deviation from the normal distribution (Ghasemi & Zahediasl, 2012). Therefore, it demonstrates that we are also able to make use of parametric approaches even when the data do not give a normal distribution over all of the supplied points. In addition, if the sample size of the research is large enough to incorporate hundreds of observations, then we can disregard the distribution of the data. Accordingly, taking into consideration what has been said so far, the statistics hand is normal. Therefore, there would be no use in the examination.

Below is the table of skewness and kurtosis to determine the normality of the data

Table 4.2 Skewness and Kurtosis

	N	Mini	Maxi	Mean		Std. Dev	Skewness		Kurtosis	
	Statistic	Statis	Statis	Statis	Std. Err	Statistic	Statis	Std. err	Statistic	Std. Error
GTI	256	2.20	5.00	4.011	.03829	.61256	-.786	.152	-.199	.303
SP	256	1.80	5.00	3.992	.03937	.62992	-.924	.152	.268	.303
EA	256	2.20	5.00	4.025	.04021	.64337	-.932	.152	.057	.303
KMP	256	2.38	5.00	4.043	.03357	.53711	-.853	.152	.658	.303
AC	256	2.00	5.00	4.086	.03852	.61637	-.931	.152	.421	.303
Valid N	256									

Although the kurtosis & skewness in the current study demonstrate that the data is normal. When the statistics value is divided by the standard error, the result must fall between +2 and -2. Therefore, as you can see in the accompanying table, all the replies fall within the range of +2 to 2, demonstrating the reliability of the data and the normality of their distribution. because the variables' variance from the means was smaller than 1.

4.3.1.3 Assumption No. 3

Figure 1: The normal P-P plot KMP with GTI

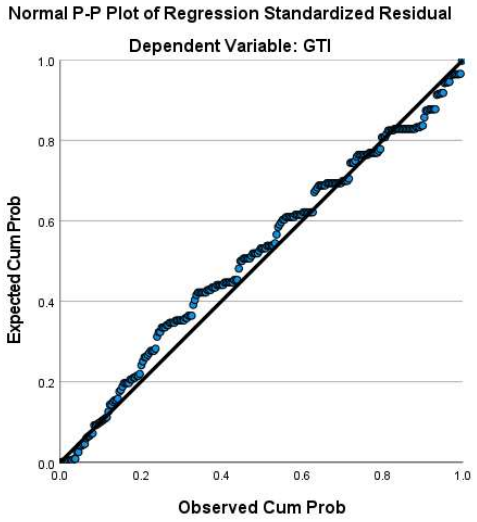
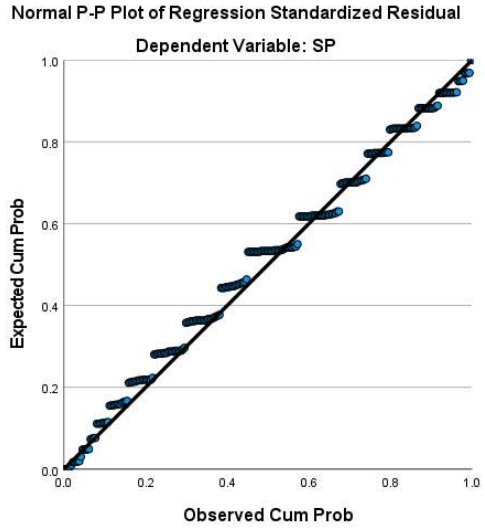


Figure 2:The normal P-P plot of **KMP** *with SP*



With only one independent variable, a simple linear regression model is used. This model estimates the relationship between the independent variable and the dependent variable using a straight line. The residuals from this model are then used to assess the normality assumption. The Normal P–P Plot of standardized residuals is a diagnostic tool used to assess the assumption of normality of residuals in linear regression. In the current analysis, the plot shows that the data points closely follow the 45-degree diagonal line, indicating that the residuals are approximately normally distributed. This pattern suggests that the model satisfies

the assumption of normality, which is critical for ensuring the validity of statistical inferences such as hypothesis testing, confidence intervals, and p-values in regression. Normal P-P plots are an analysis of whether the residuals or error conditions are normally distributed. So, just check whether there is a soft balance between the predicted value and the right value, and this number ensures that the normality assumption is met for regression.

4.3.1.4 Assumption No. 4

For the model, the value of Durbin Watson ranges from 1.5 to 2.5, and for R-squared, the value has to be between 0 and 1 irrespective of the circumstances (Sekaran & Bougie, 2010). The information presented in the table indicates that the value of Durbin Watson is 2.022 and 2.021. For the characteristics of this, using the mentioned number is most appropriate. On the other hand, the value of R-squared and the adjusted R-squared are both less than 1. It shows that both values lie between 0 and.1. It indicates the value is suited for the inquiry that is now being conducted. It means the relation among variables is not a problem, and the present model is suitable for examining autocorrelation. It also indicates that the autocorrelation is in good shape.

Table 4.3: Model Summary

Model	R	R Square	Adjus R Square	Std Error of the Estimate	Change statistics R	Df1	Df2	Sif F changes	Durbin Watson
1	.690[a]	.477	.475	.45662	.477	1	254	.000	2.022

a. predictors(constant) KMP

b. Dependent Variable: SP

Table 4.4 Model Summary

Model	R	R Square	Adjus R Square	Std Error of Est	Change statistics R	Df1	Df2	Sif F changes	Durbin Watson
1	.676[a]	.457	.455	.45209	.457	1	254	.000	2.021

a. Predictors: (Constant), KMP,

b. Dependent Variable: GTI

4.4 Demographics of the variable

Sample Demographics

In the demographics factor, the present study was conducted, which shows us that the study was analyzed using descriptive analysis, which including that what is the size of the company and how much experience employees have in the company. Table 9 provides the descriptive analysis of the data.

Table 4.5 Employees' Experience in the Company

		Frequency	Percent	Valid percent	Cumulative Percent
Valid	less than 2 Years	143	55.9	55.9	56.6
	02- 05 Years	100	39.1	39.1	58.1
	05-10 Years	11	4.3	4.3	75.3
	Total	256	100.0	100.0	

The table illustrates the distribution of employees based on their years of experience within the company, revealing that the majority (95.7%) have been with the organization for less than 5 years. Specifically, 0.8% of employees have less than 2 years of experience, 55.9% fall within the 2–5 years range, and only 4.3% have 5–10 years of tenure. This distribution suggests a workforce composed largely of newer employees, which may point to high turnover rates or a company still in its growth phase with ongoing recruitment. While the 39.1% of employees with 2–5 years of experience may indicate moderate retention and potentially effective onboarding processes, the low percentage of long-tenured staff (5–10 years) highlights possible issues with long-term employee retention, limited career development, or growth opportunities. These findings underscore the need for the company to examine its retention strategies and focus on fostering career advancement pathways to improve employee longevity and reduce turnover.

Table 4.6 Demographic of Employees

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	164	63.6	63.6	32.8
	Female	92	36.4	36.4	100.0

Due to the fact that men mostly hold positions of authority in Pakistan's administration, this is the situation. The fact that 65.6% of management roles in Pakistan's small and medium-sized enterprises are held by men demonstrates unequivocally that men mostly hold top-level jobs in the country.

4.5 KMO and Bartlett's Test of Sphericity

KMO is another important analysis. This test indicates to us how strongly there exists a partial correlation among the variables of the given analysis. It is a procedure of sampling adequacy through which we check the variable cases to perform the analysis. They are a statistical method that is usually used in the field of factor analysis that assess the appropriateness of applying this technique to a dataset. In some studies, KMO & Bartlett's test have very high importance if the researcher must accept the adequacy of the given sample. As the range of KMO of analysis is from 0 and 1, the index that we accepted is above 0.6. Moreover, this test of Sphericity indicates to the researcher how significant the study is. It can deliver the validity and reliability of the responses that are gathered through assessing the issues in the study. It should be noted that Bartlett's test of sphericity has to be less than 0.05. The table below reports the study findings for the suggested construct through KMO and Bartlett's test analysis.

Table 4.7 KMO and Bartlett's Test

KMO and Bartlett's Test	KMP	SP	GTI	AC	EA
KMO Measure of Sampling Adequacy	.898	.803	.803	.854	.810
Approx. Chi-Square	858.197	467.299	575.526	1881.36	422.778
Bartlett's Test and Sphericity	28	10	10	06	10
Sig.	.000	.000	.000	.000	.000

4.6 Structural Equation Modeling

SEM is considered the most used technique nowadays. It is a part of that multivariate analysis to perform hypothesis testing about the causal relations among variables. It enables the researchers to work on diverse models with the use of statistical analysis to perform the estimates with the help of the validity of the theories using empirical data. It enables analysis of diverse models in the study with the help of statistical analysis. It is used to assess multivariate causal relationships.(MacCallum & Austin, 2000) .Where the other techniques have failed to determine the relation among latent constructs, SEM can measure these relationships because it examines the direct as well as indirect effects of the model. It provides access to estimates that are valuable in identifying the measurement errors in tests of model fit. The most important purpose of structural equation modelling (SEM) is to provide hypotheses for the representation of models that are compatible with the variables that have been observed (Kline, 2023).

On the other hand, structural equation modelling (SEM) is used to conduct out analysis of the variables' behavior and investigation of the interactions between various components using eithera direct or indirect approach (Ghaleb & Yaslioglu, 2024). By making use of observed data, SEM is also helpful in assisting with the examination of the validity of the fundamental hypotheses. SEM is suitable for a large number of samples, which in general the sample size is generally defined by the evaluation method, the distributed features of the observed data, and the intricacy of the model, and should be greater than 200 (Kline, 1998). Because SEM is required to carry out confirmatory analysis, the SEM method is performed before the confirmation analysis is carried out.

4.6.1. Fit Indices

Fit indices (or model fit indices) are statistical measures used in Structural Equation Modeling (SEM), including when using software like AMOS, to evaluate how well your proposed model fits the actual data

The analysis of Fit indices is a statistical tool that is employed in the confirmatory factor analysis known as CFA and structural equation modeling known as SEM. It requires determining how well a model fits in the analysis of the observed data. This analysis is useful towards evaluating the suggested model fit, which shows us that the model is successful in incorporating the relation among other variables. Fit indices indicate how closely the observed data variances and their covariances indicate the following patterns in the dataset As per the observation of the model fit, it should be identified whether the gathered data covariance and variance are based on the model fit or not. Nonetheless, different researchers employ various estimations to ascertain a model fit. Many authors recommended values of the different analyses that are

- The Goodness of Fit Index (GFI)
- Tucker-Lewis Index (TLI)
- Comparative Fit index (CFI)
- Root square means error of approximation (RMSEA)

Goodness of Fit Index: GFI stands for Goodness of Fit Index and is used to calculate the minimum discrepancy function necessary to achieve a perfect fit model under maximum likelihood conditions (Jöreskog & Sörbom, 1984; Tanaka & Huba, 1985). The Goodness of fit Index (GFI) is a measure of how well the model fits the data, with values ranging from 0 to 1.

RMSEA: RMSEA is used to analyze the adjustment for model complexity. It shows how well the model would fit the population covariance matrix. RMSEA is one of the most widely recommended fit indices. It penalizes complexity, helping to avoid overfitting.(Browne & Cudeck, 1992).

CFI: CFI is another tool of fit indices. CFI is used to compare your model to a null model (where all variables are uncorrelated). It is not affected by sample size compared to GFI. Recommended in almost all SEM reporting guidelines.(Bentler, 1990).

TLI: TLI, also called the Non-Normed Fit Index (NNFI), it adjusts for model complexity. TLI rewards parsimony — models that achieve good fit with fewer parameters. A good balance between model fit and complexity.

After it has been shown that the model provides a satisfactory fit for the data, the next step is to estimate the values of the model's parameters. The Z statistic is defined as the ratio of the estimated value of each parameter to its standard error. The significant value ofthis statistic is 0.05, which is more than the value of 1.96, and the significant value of this statistic is 0.01, which is greater than the value of 2.56 (Hoyle, 1995).

Unstandardized parameter estimates entirely rely on the scaling information provided by variables; hence they are incomprehensible without their aid. In the model fitting process, standardized parameter estimation, a variation of unstandardized parameter estimation, uses informal parameter assessment rather than scaling. If an inadequate model fit is identified, then it is possible to adjust the model if themodifications appear to have a substantial impact. The process of correcting a specific and approximated model via either fixing the parameters that were previously free or releasing the parameters that were previously fixed is included in model modification. In this situation, the Language multipliers test, also known as LMT, is used to obtain data on the value of the chi-square change, that is, what happens when a fixed parameter is converted into a free one (Hoyle, 1995).

4.6.2 Measurement Model

In data analysis, measurement model fit and modification with confirmatory factor analysis is a crucial step. It helps the scholars to assess how well the relationship between the proposed model and the observed model matches in data collection. Running the measurement model and modification, identifying whether the items are loaded on their dimension or not, enables verifying the chance of correlation error term or residuals in the circumstance of common causes. At this point, the primary emphasis is on determining how well the model fits the data with the assistance of CFA. As you are aware, CFA is used to determine whether or not a single factor modelis valid, to determine the importance of a certain factor loading, and to determine whether or not thereis a connection between the variables. In addition to this, it is used in the analysis of convergent validity and the assessment of discriminant validity (DeCoster, 1998).

CFA provides sufficient detailsregarding the requirements of the model and the estimate to inspire confidence in the outcomes. (Hu & Bentler, 1999) It is recommended that we depend on those fit indices thathave diverse qualities of measurement, such as an incremental fit index

and a residual-based fit index. The cutoff values for several operations during the assessment of the model have been subject toconstant revision over time. The number 0.90 should be used as the cutoff for various incremental fit indices (Bentler & Bonett, 1980). On the other hand, the cutoff value for incremental fit indices should be 0.95, and 0.97 is regarded as a more acceptable number. When estimating the fit of the subsidiary measures, the cutoffvalue must first be removed from that scenario. Researchers focus their emphasis on additional aspectsof model fit to discover the global fit measures. These aspects include determining the standardized residual to determine whether or not certain variables are linked with one another (Bollen, 1989).

Another aspect of the model's validity that has to be considered is whether or not it can be modified. Researchers look at a wide variety of difficult models, but they are unable to adapt the models such that they provide a sufficient model fit. It is often said that post hoc adjustments were made to the model, which is fundamentally what was used for the modification indices. It is only carried out when the possible deviations can be rationalized both in theory and in practice (MacCallum, 1995). When the value of the T test is 2, the results of the T test will not be distributed based on the post hoc model change. However, when analyzing the outcomes of a research study, numerous model modifications need to be explicitly indicated. In addition, it is recommended that a letter be supplied with the text showing that each parameter in the model represents the a priori hypothesis. Thisis because letters tend to be more convincing than text alone. If this does nottake place, then each modification has to be well explained.

4.6.2 Confirmatory Factor Analysis

To authorize the building of the assembly in the research study, a Confirmatory Factor Analysis is performed. Examining both the seen and the unobserved aspects of the data is the primary objective of this research. Following an investigation of the observed factors, those variables are included in the comprehensive model, which is then prepared for more research. It also identifies the factor loading of the observed variables based on their constructions, and it gives the acceptable model fit for proposed hypotheses based on their acceptance or rejection. Both of these functions are carried out based on the results of the analysis. Because we hypothesize CFA first inside a component structure and then verify it empirically, as opposed to deriving it from the data as in exploratory factor analysis, it is distinct from exploratory factor analysisin this respect (Lei & Wu, 2007).The confirmatory factor analysis (CFA) is a statistical approach that mayverify the component structure of a collection of observable variables by the use of the variables themselves. When it comes to CFA, academics have extremely strong

opinions on the number of factors, the relationship between the factors, as well as the link between the variables and the measuredvariables.

Table 4.8 Model Fit Indices with Accepted Value

Measure Fit	RMSEA	CMIN/DF	CFI	TLI	IFI	GFI
Accepted Value	.80	≤ 2	≥ .90	≥ .90	≥ .90	≥ .90
Further Analysis Required	>.1	>2	< .90	< .90	< .90	< .90

The above values are taken from Byrne (2001,2010)

4.7 CFA of each Variable

4.7.1 Knowledge Management Practices

The knowledge management practices in this study are taken as an independent variable in the study. This variable comprises one dimension that contains a total of 8 items. Investigate the demonstrative vigor while looking at the measurement that was meant for the key want of CFA. There were eight factors whose entire loadings were stated, and each of them was diagonally more than 0.50. The results of the model fit are shown in Table 4.9, which may be seen below.

Figure 3:CFA for Knowledge Management Practices

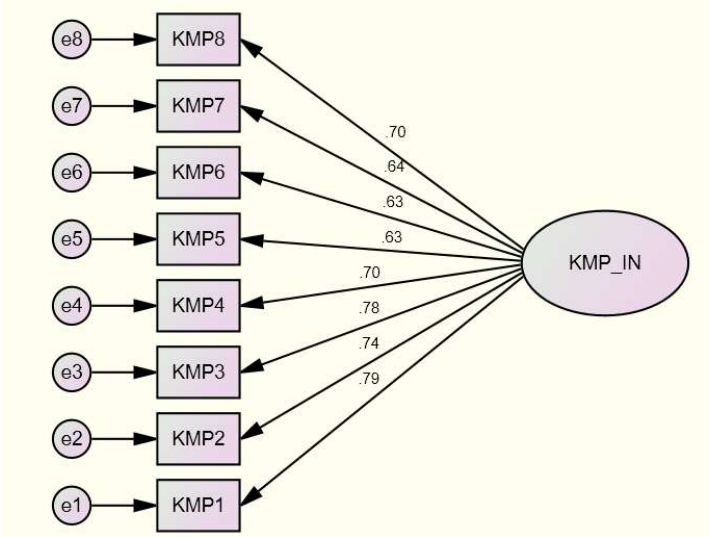


Table 4.9 CFA for KMP

Quest. Item	Item wordings	Final	
		Standardized Loading	**C.R**
KMP1	Our organization values employees' attitudes andopinions	.788	8.940
KMP2	Our organization notices and cares about changes in the market	.737	9.743
KMP3	Our organization gets information from marketsurveys	.782	8.940
KMP4	Information about the environment is shared openly and easily in our organization	.702	9.919
KMP5	People share useful information during their work	.632	10.437
KMP6	Our organization quickly responds to environmental-related concerns	.625	10.461
KMP7	My organization uses knowledge to change or improve its plans and goals	.643	10.440
KMP8	My organization has processes for using knowledge to solve new problems.	.704	9.948

	CMIN/DF (χ^2/do)	**RMSEA**	**GFI**	**TLI**	**CFI**
Model Fit	2.724	.082	.952	.943	.963

4.7.2 Green Technological Innovation

Green Technological innovation is the dependent variable in the analysis. Investigate the demonstrative vigour while looking at the measurement that was meant for the key want of CFA. There were five factors whose entire loadingswere stated, and each of them was diagonal 0. 50

Figure 3: CFA for Green Technological Innovation

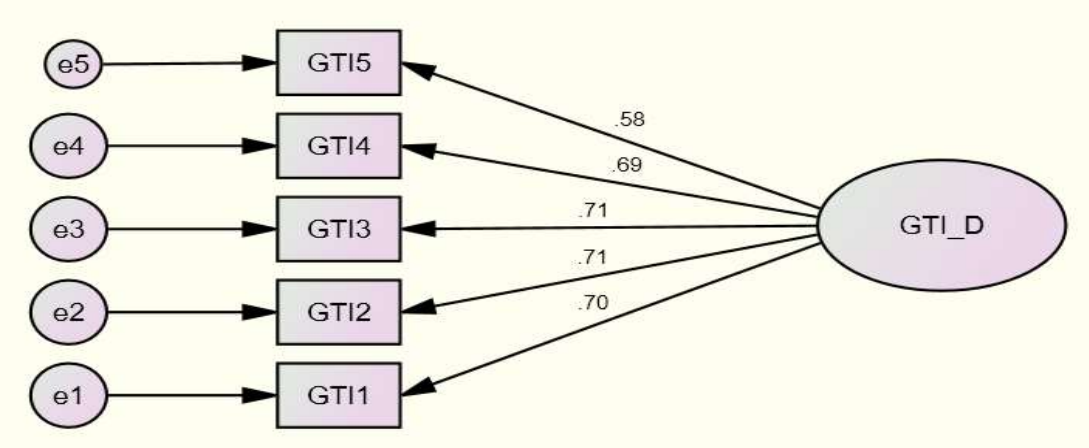


Table 4.10 CFA for Green Technological Innovation

Quest. Item	Item wordings	Final	
		Standardized Loading	**C.R**
GTI 1	Our organization continually improves its processes by adopting cleaner methods and green technologies to achieve cost savings.	.702	8.465
GTI 2	Our organization is in the process of recreating and redesigning our products to meet environmental needs.	.712	8.796
GTI 3	The organization adopts the recycling strategy	.718	6.390
GTI 4	The organization adopted eco-labeling activities for its stakeholders to make them conscious of the sustainable performance	.698	7.627
GTI 5	The research and development team of the organization makes it possible that the current technical advancement is included in the eco-initiative activities	.587	9.045

	CMIN/DF (χ^2/df)	**RMSEA**	**GFI**	**TLI**	**CFI**
Model Fit	2.939	0.079	.987	.966	.990

4.7.3 Sustainable Performance

Sustainable performance serves as a dependent variable. The CFA results show that all five items (SD1 to SD5) load significantly onto the latent construct SP_D (Sustainable Performance), with standardized loadings ranging from 0.65 to 0.73. These values exceed the acceptable threshold of 0.60, indicating that each item reliably reflects the construct. The model does not include correlated residuals, suggesting a unidimensional structure. The results of the model fit are shown in Table 4.11 which may be seen below.

***Figure 4: CFA for Sustainable* Performance**

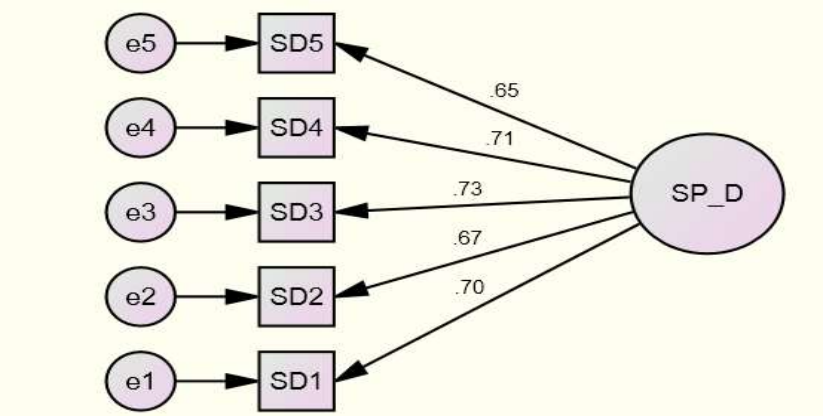


Table 4.11: CFA for Sustainable Performance

Items		Final	
		Standardized Loading	C.R
Sp1	Our organization's sustainability initiatives have led to measurable improvements in environmental performance.	.703	8.839
SP2	Our organization has increased our customer or stakeholder trust through our sustainability efforts	.676	8.917
SP3	Sustainability has improved our employees' morale and retention	.737	7.205
SP 4	Our sustainable development efforts are continuously evaluated and improved	.712	8.635
SP 5	Our operations today are more resilient because of sustainability-oriented decisions	.650	9.547

	CMIN/DF (χ^2/df)	RMSEA	GFI	TLI	CFI
Model Fit	2.460	.076	.986	.968	.987

4.7.4 Environmental Awareness

Environmental awareness is used as a moderator in the study. This variable comprises one dimension, which includes a total of 5 items. The factor loading is from 0.68 to 0.77. These values exceed the acceptable threshold of 0.60, indicating that each item reliably reflects the construct.

Figure 5: CFA for Environmental Awareness

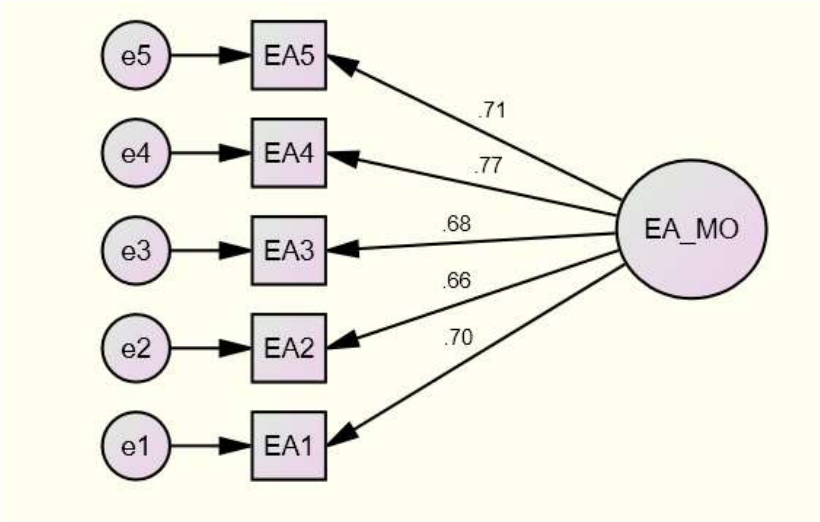


Table 4.12 Table for Environmental Awareness

Quest. Item		Final	
		Stand Loading	**C.R**
EA1	Our organization participates in external environmental initiatives or collaborations.	.707	8.414
EA2	The firm includes environmental concerns in our company's plans and strategies	.667	8.788
EA3	Our organization participates in external environmental initiatives or collaborations.	.687	8.408
EA 4	I am aware of the major environmental problems facing our planet today.	.779	8.175
EA 5	I feel a sense of personal obligation to take action to stop the disposal of toxic substances inthe air, water, and soil	.718	9.396

	CMIN	**RMSEA**	**GFI**	**TLI**	**CFI**
Model Fit	2.713	.078	.988	.953	.984

4.7.5 Absorptive Capacity

The absorptive capacity is a mediating variable in the present study. The factor loadings are from 0.68 to 0.77. These values exceed the acceptable threshold of 0.60, indicating that each item reliably reflects the construct. The model does not include correlated residuals, suggesting a unidimensional structure.

Figure 6 CFA for Absorptive Capacity

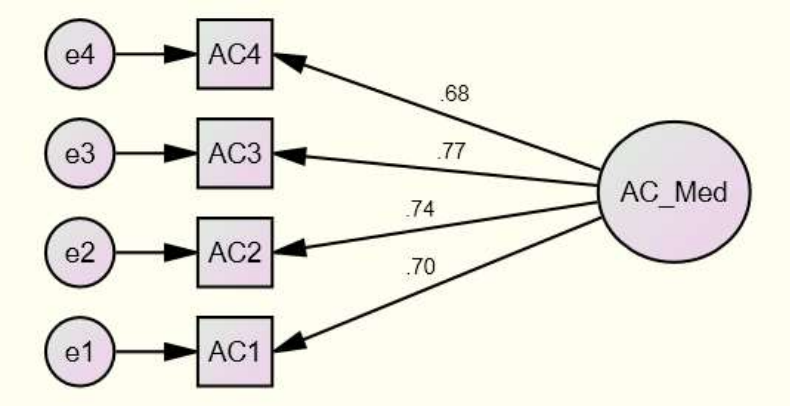


Table 4.13 Absorptive Capacity

Quest. Item		Final	
		Standardized Loading	**C.R**
AC1	My firm quickly analyses and interprets changing market demands	.707	8.615
AC2	My firm can successfully absorb new knowledge	.742	7.844
AC3	The firm has been effective in combining existing knowledge with newly acquired knowledge	.778	8.243
AC 4	Our firm regularly utilizes knowledge to develop new products or services	.684	8.639

	CMIN/DF	**RMSEA**	**GFI**	**TLI**	**CFI**
Model Fit	2.67	.065	.992	.977	.992

4.8 Overall Model Fit Measurement

The overall measurement model fit is analyzed by combining all the CFAs that are mentioned above. They are connected to the independent and dependent variables and the purpose behind this is to validate the appropriateness of the model that tells us the development of the dependent and the independent covariance of the arrangements. All the other items that are related and connected are the contradicting constructs, which offer adequate match from the

data and the measurement model. A measurement model tells us how accurately and reliably our survey questions or indicators measure the theoretical concepts we're interested in.

Figure 7 Overall Model Fit

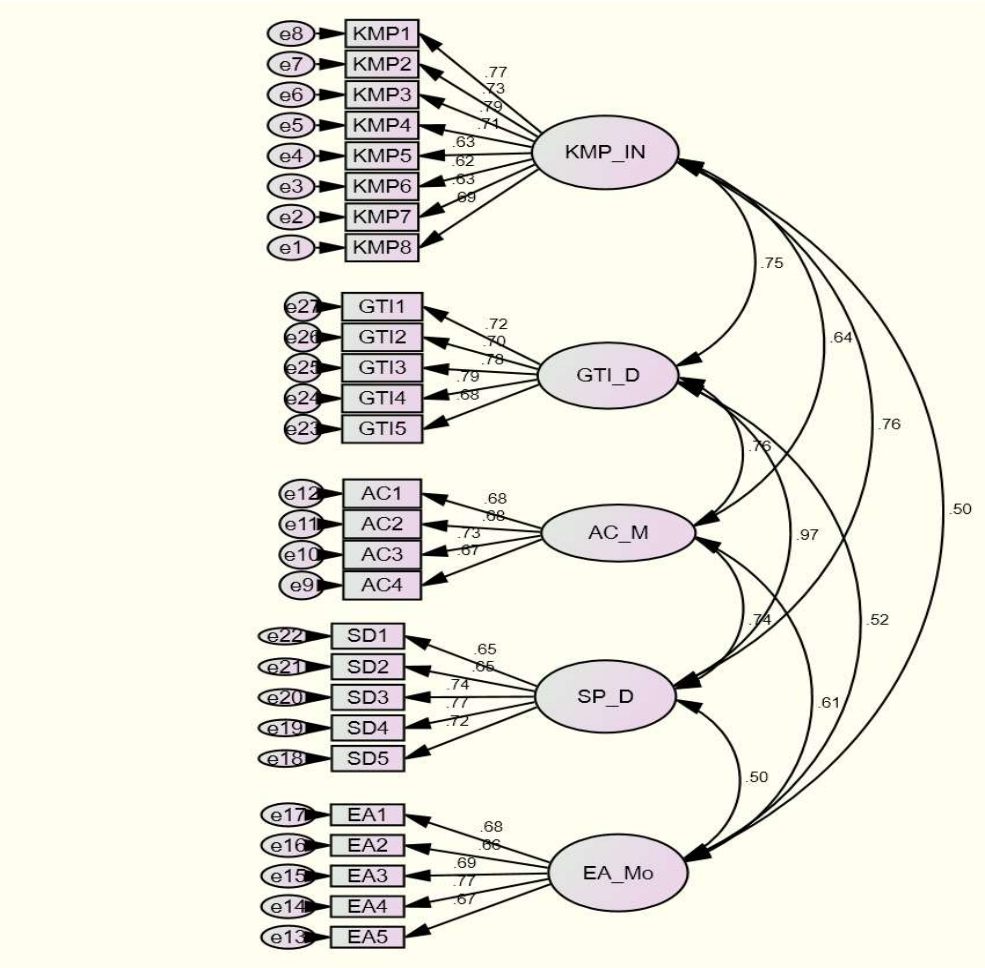


Table 4.14 Cut-off values of fit indices

	CMIN/DF	RMSEA	GFI	TLI	CFI
Model Fit	1.757	.054	.981	.920	.929

4.9 Construct Validity

Construct validity indicates us that how well a test measures the concept it was designed to evaluate. It offers a significance checker for specified research.It offered a crucial foundation for the theory and research methodology that emerged from it to be used practically.When it c omes to survey instruments, the issues of construct validity and content should be priorities. Construct validity is a vital component that will help in selecting item in the given set is provide a true representative of the theoretical latent construct for which they are considered. (Byrne, 2009). When common variance doesn't create a problem, then the researcher's focus should be on the area of divergent and convergent validity, as per the author (Zhu, 2000) acceptance and rejection of the construct validity depend on both coefficients. Divergent validity, also called discriminatory validity. it helps identify towards the extent of one independent variable, one independent variable which changes with the effect of another variable. Measuring towards the possible effect on the dependent variables, here the validity of convergent validity shows us the proportion of variance on the other factors. It provides a connection to other latent variables (Byrne, 2009).while the average variance extracted provides the estimation towards the convergent validity through analyzing the detecting measurement convergence. As per the author (Lee, 2007), the value of AVE should be > 0.5 which Examine the outcome to analyze whether convergent validity exists or not. For discriminant validity, the value of MSV should be less than the value of AVE, the observed which indicates that there are no significant difficulties with the data. Further, (Zhu, 2000) stated that the discriminant validity exists if the value of correlation among variables is less than 8.

In this analysis, we processed correlation values and standardized regression weights to assess the validity of the model. The results are analyzed in Appendix 7. As per the findings, two of the four constructs have the values of AVE that are higher than 0.5 in the scenario of convergent validity, that is, 5. The figure for the knowledge management method is more than 0.5 in the current study.

Table 4.15 Validity of the Construct

	CR	AVE	MSV	ASV	KMP	GTI	SP	AC	EA
KMP	0.962	0.681	0.416	0.321	0.699				
GTI	0.960	0.866	0.421	0.201	0.305	0.617			
SP	0.964	0.672	0.321	0.399	0.351	0.731	0.525		
AC	0.942	0.939	0.521	0.254	0.482	0.409	0.687	0.736	
EA	0.976	0.800	0.502	0.298	0.443	0.581	0.520	0.283	0.758

** p<0.1 (sign at two tail 1)

The correlation Pearson is conducted through AVE and the square root of AVE.

4.10 Hypothesis Analysis

Hypothesis I: ***Knowledge Management positively and significantly impacts the Green Technological Innovation***

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The standardized approximation of the GTI–KMP connection yields the beta value of 0.392 with the P value being 0.00 and the critical value being 5.433. It reveals the important association between the Knowledge Management practices and Green Technological Innovation. A high level of Knowledge management practices in the organization can be helpful for them to incorporate green technological innovation.GTI shows proactive commitment to sustainability, attracting ethical investors and partners. Applying green technological innovation in the organization helps them to achieve their competitive advantage over their competitors. KMP from different stakeholders and external markets strongly correlates with innovativeness. Previous research also shows that there is a positive and significant relationship between green technological innovation and knowledge management practices. A study published in the Journal of Cleaner Production examined KM practices in Pakistani manufacturing and service firms. It found that KM processes significantly impact green innovation and CSD activities. Specifically, knowledge creation and acquisition were linked to environmental and economic sustainability, though their impact on social sustainability was less pronounced (Abbas & Sağsan, 2019). So, based on our results and hypothesis, it is observed that there is a positive

relationship between knowledge management practices and green technological innovation.

Hence, H1 is backed by prior research that knowledge management practices have a large and favorable influence on Green technological innovation. This is displayed below in Table 4.16.

Hypothesis II: ***Knowledge Management Practices and Sustainable Performance***

The analysis shows a strong and statistically significant relationship between knowledge management and sustainable performance. A beta value of 0.459 means that improvements in knowledge management are associated with noticeable increases in sustainable performance outcomes. The p-value of 0.00 confirms that this relationship is highly significant and not due to random variation, and the critical value of 6.179 provides additional evidence of the robustness of this result. Overall, the findings highlight the crucial role that effective knowledge management plays in achieving long-term environmental, social, and economic sustainability goals. "Numerous studies have established a positive relationship between knowledge management (KM) practices and sustainable performance across various sectors and regions. These studies highlight that effective KM practices such as knowledge acquisition, sharing, and responsiveness significantly contribute to environmental, economic, and social sustainability. A study published in the Journal of Knowledge Management examined multinational manufacturing corporations in Pakistan. It found that KM processes (acquisition, dissemination, and responsiveness) positively influence green innovation, which in turn enhances corporate sustainable performance across environmental, economic, and social dimensions. (Shahzad, Qu, Ur Rehman, et al., 2020). Based on the statistical results, we accept the hypothesis that Knowledge Management (KM) has a significant positive impact on Sustainable Performance (SP).

Hence, from the results of the analyses and hypothesis, we concluded that H2 knowledge management practices have a positive impact on sustainable performance. This is displayed in Table 4.16

Table 4.16 Summary to analyze the Results of the mentioned hypothesis

Relation Between Variables	Beta Value	P Value	Critical Value	Final Decision
β_1 (GI←KMP)	.392	0.00	5.433	Supported
β_2 (SP ← KMP)	.459	0.00	6.179	Supported

Hypothesis III & IV: ***Absorptive Capacity significantly and partially mediates the relationship between KMP and Green Innovation, and KMP and Sustainable Performance***

The value of beta in the various effects may be determined by using a standardized approximation of the KMP-AC-GTI and KMP-AC-SP connection. The table presented below shows the value of beta for KMP-AC-GTI, with the total effect being 1.765, while the value of P is .001, which shows there is a significant relationship. The table also shows the direct effect of KMP on GTI, which is 0.392, while the value of p is .004, which is also significant, and the indirect effect of KMP on GTI in the presence of AC, that is the mediator variable, is 0.470, which is calculated by multiplying the path from (KMP to AC) and (AC to GTI). The P value is .001. As a result of KMP on GTI is significant, which indicates there is a partial mediation among variables. The table also shows us the relationship of KMP on SP in the presence of mediator AC. The total effect of KMP on SP and AC is 1.773, while the p-value is .001. While in direct effect of KMP on SP is .459, the p-value is .002, which is significant. The indirect effect of KMP on SP in the presence of AC is 0.431, while the p-value is 0.001, which shows there is a significant relationship between KMP on SP in the presence of AC.

According to several studies, the dissemination of green information directly stimulates green innovation. (Wong 2013). Companies can achieve genuine success with green innovation if they can absorb the information and use it in a better manner (Wu 2013). Because of the rapidly changing environment, organizations see it is important for them to get the information and then absorb it properly to get better results. According to Jianga, Shaoa, et al. (2018), the efficiency of an organization's knowledge management (KM) systems has a significant impact on its capacity to engage in green innovation and develop new products, processes, and knowledge. This is the conclusion drawn from a study that looked at the relationship between KM systems and green technological innovation and sustainable performance. Therefore,

Hypotheses 3 and 4 demonstrate that the KMP and Green technological Innovation and KMP and sustainable performance have a link that is partly mediated by absorptive capacity, which also has a substantial impact on the relationship. knowledge Management Practices (KMP) enhance Absorptive Capacity (AC) by equipping employees and organizations with the skills and structures needed to identify, assimilate, and apply new external knowledge. This enhanced absorptive capacity becomes a critical mechanism through which organizations can successfully implement Green Technological Innovations (GTI) and improve Sustainable Performance (SP).

In this framework, AC acts as a mediator, transmitting the positive effects of KMP toward both GTI and SP. For example, organizations with strong KM systems are more likely to understand and integrate external green technologies or sustainability trends, which in turn contribute to their environmental, economic, and social performance outcomes. However, the analysis also reveals that KMP has a direct and significant impact on both GTI and SP, even after accounting for the role of AC. This indicates that not all effects of KMP operate through AC. Some components of knowledge management such as internal best practices, employee learning-by-doing, or organizational knowledge repositories, may directly influence innovation and sustainability outcomes without the need for intermediate processing through absorptive capacity. Therefore, the mediation is identified as partial, since the indirect effects through AC are significant, but the direct effects of KMP on GTI and SP remain significant as well. This underscores the multifaceted nature of KM's influence on organizational sustainability and innovation, operating through both mediated and direct pathways.

Figure 8 Mediation Analysis

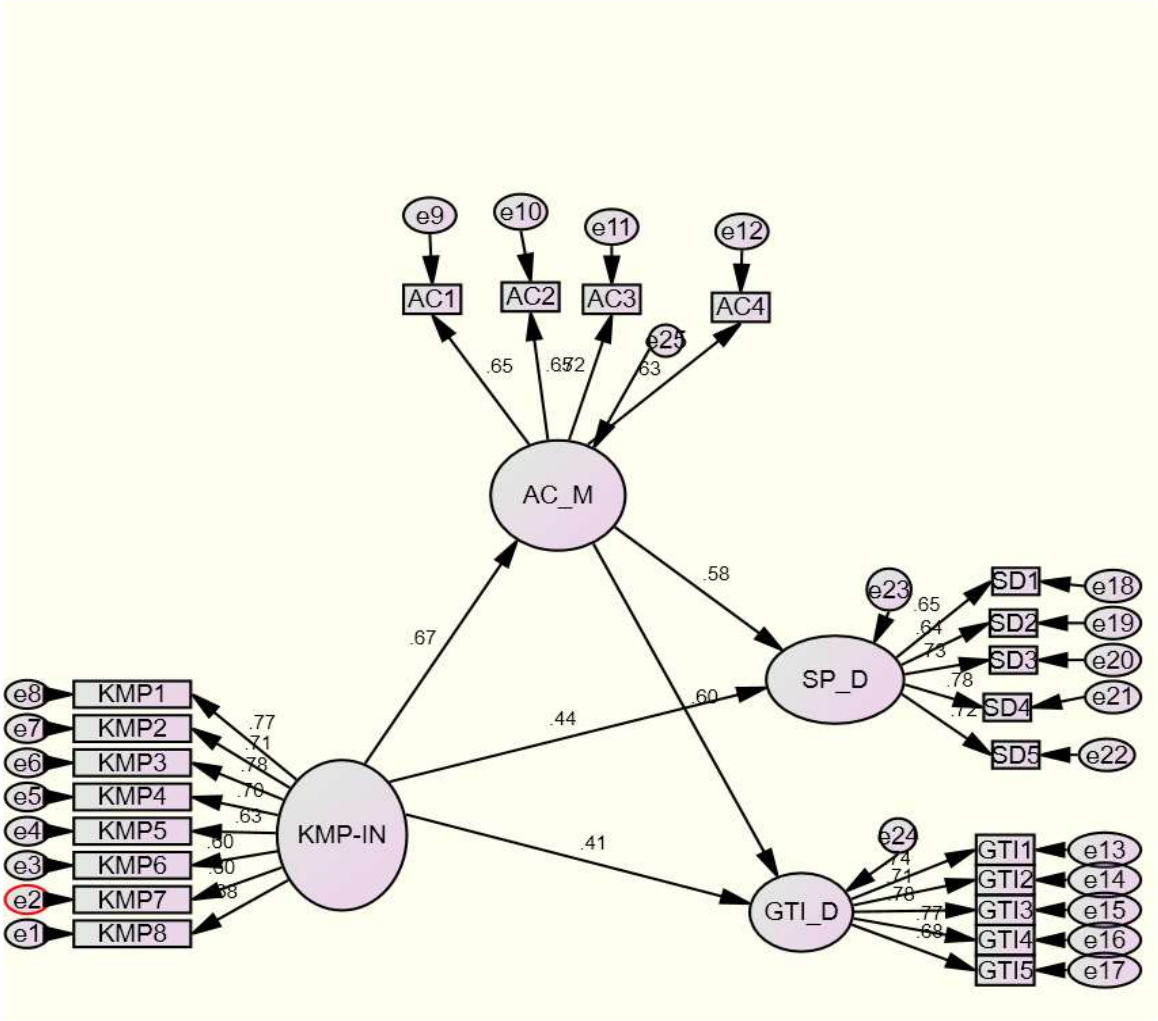

Table 4.17 Mediation Analysis KMP-AC-GTI

Variables	Total Effects (C)	Direct Effects (C')	Indirect Effects (ab)	Results	Mediation Level
KMP-AC-GTI	β= 1.765 p = .001	β= 0.392 p = .004	β= 0.470 p = .000	Significant	Partial

Table 4.18 Mediation Analysis KMP-AC-SP

Variables	Total Effects (C)	Direct Effects (C')	Indirect Effects (ab)	Results	Mediation Level
KMP-AC-SP	β= 1.773 p = .001	β= 0 .459 p = .002	β= 0.431 p = .000	Significant	Partial

Hypothesis V: ***Environmental awareness strengthens the relationship between KMP and Absorptive Capacity***

The interaction effect between knowledge management practices and environmental awareness on absorptive capacity was found to be positive and statistically significant (β = 0.128, S.E = 0.030, CR = 2.719, p < 0.01). This indicates that environmental awareness partially moderates the relationship, such that organizations with higher environmental awareness benefit more from KMP in developing absorptive capacity. The pervious study the relationship between environmental factors, knowledge management, absorptive capacity, and innovation capacity. The findings indicated that environmental factors positively influence knowledge transfer and absorptive capacity, thereby enhancing innovation capacity (da Silva Neto & La Falce, 2024). So based on the results and previous hypothesis, we accept our last hypothesis that environmental awareness strengthens the relationship between Knowledge management practices and absorptive capacity

Figure 9 Moderating Role of EA

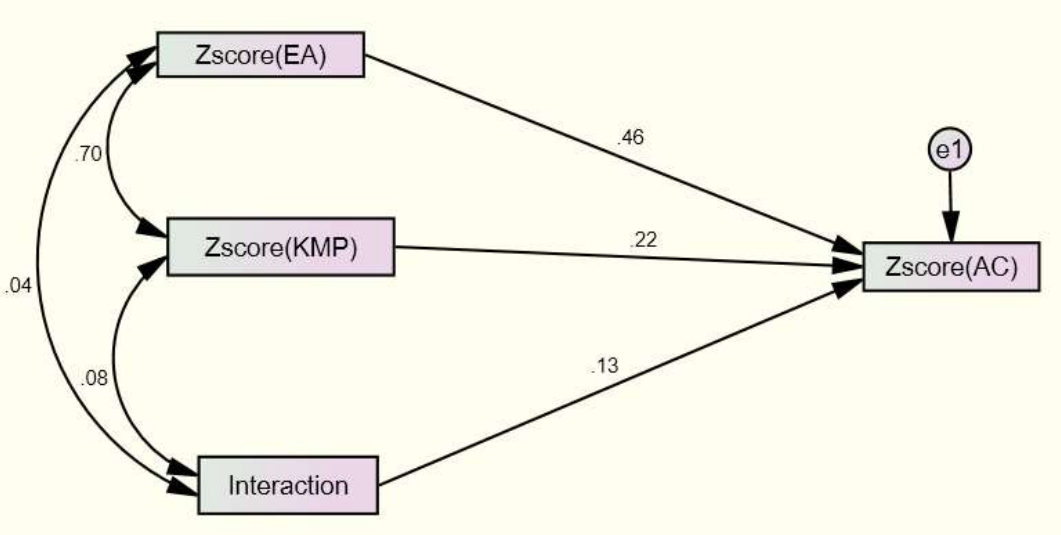

Table 4.19 Moderation Analysis KMP*EA-AC

Variables	Estimates	S.E	CR	P-Value	Result	Moderation level
KMP-EA-AC	0.128	0.30	2.719	***	Significant	Partial

*****P ≤0.05**

Table 22 presents the results of the moderation analysis examining the interaction between Knowledge Management Practices (KMP) and Environmental Awareness (EA) on Absorptive Capacity (AC). The interaction term (KMP*EA) has a positive beta value of 0.128, with a standard error of 0.030 and a critical ratio (CR) of 2.719, indicating statistical significance at the 0.01 level ($p < 0.01$). These results suggest that Environmental Awareness significantly and partially moderates the relationship between KMP and AC. In other words, higher levels of environmental awareness enhance the positive impact of knowledge management practices on a firm's ability to absorb and apply external knowledge.

Table 4.18: Status of the Relationships/Hypotheses in the Final SEM Model

RELATIONSHIP/HYPOTHESIS	Status in the Final SEM Model
Knowledge Management Practices and Green Technological Innovation	Remained
Knowledge management practices and sustainable performance	Remained
Absorptive capacity mediates the relationship between knowledge management practice and green technological innovation	Remained
Absorptive capacity mediates the relationship between Knowledge Management Process and Sustainable Performance	Remained
Moderating role of environmental awareness on KMP and Absorptive Capacity	Remained

CHAPTER NO 5

CONCLUSION, IMPLICATIONS OF RESEARCH, AND FUTURE DIRECTIONS

5.1 Overview

In last chapter includes the overall conclusion of the study. The main purpose of conducting this study is to analyze the relationship among the variables, i-e, Knowledge Management practice impact towards Green technological innovation and Sustainable performance with the effect of mediating variable Absorptive capacity and moderating variable of environmental awareness. Although several studies have already been conducted in the present literature that identify the predictors of the dependent variable. Mostly, it is observed that these predictors have a significance influence on green technological innovation and sustainable performance but still there is a gap, the reason is that no any study found that had not only used and discussed the concept of "knowledge management practices" through the mixture of variables that are analyzed in the present study. Furthermore, the proposed study is less studied in developing countries This last chapter consists of the conclusion. The study includes academic and managerial implications. The present study contained some limitations. Furthermore, the chapter suggests future research that can be beneficial in creating an opportunity for future studies.

5.2 Discussion

Hypothesis I: Knowledge Management (KM) practices have a significant and positive impact on Green Technological Innovation (GTI). By enabling the systematic acquisition, sharing, responsiveness of knowledge, KM practices enhance an organization's capacity to develop and implement environmentally sustainable technologies. These practices foster collaboration, support continuous learning, and facilitate the integration of green knowledge across all levels of the organization. Empirical studies consistently show that firms with strong KM frameworks are better equipped to respond to environmental challenges with innovative green solutions. Moreover, KM supports the creation of a culture that values sustainability, encourages the exploration of eco-friendly alternatives, and strengthens the innovation process (Polas et al., 2023). Thus, for organizations seeking to achieve both competitive advantage and environmental responsibility, investing in effective KM practices is a strategic imperative for

driving green technological advancement. So, from the previous study and this study results we can say that KMP enhances the green technological innovation.

Hypothesis II: Knowledge Management (KM) practices positively influence the sustainable performance of organizations by enhancing their ability to make informed, innovative, and strategic decisions that balance economic, environmental, and social goals (Jeong et al., 2020). Through the effective acquisition, sharing, and responsiveness of knowledge, organizations can improve operational efficiency, support green innovation, reduce environmental impact, and strengthen stakeholder relationships. Numerous studies confirm that KM is a critical enabler of sustainable performance, helping firms adapt to dynamic market conditions, comply with environmental regulations, and pursue long-term growth (Saifulina et al., 2023). By embedding KM into organizational processes and culture, companies are better positioned to achieve sustainability targets and create value not just for shareholders, but for society and the environment as a whole. Therefore, leveraging KM is essential for any organization committed to sustainable development. So, based on previous research and results, we accept our second hypothesis.

Hypothesis III & IV: Absorptive capacity (AC) plays a crucial mediating role in the relationship between Knowledge Management Practices (KMP) and Green Technological Innovation (GTI). While KM practices enable organizations to acquire, share, and manage knowledge, it is through absorptive capacity that this knowledge is effectively assimilated, transformed, and applied to foster green innovation (Abdulmuhsin et al., 2024). Organizations with strong AC are better equipped to recognize the value of external environmental knowledge, integrate it with internal capabilities, and use it to develop innovative, eco-friendly technologies. firms have strong KM systems but weak absorptive capacity, knowledge often remains unused or misaligned with strategic goals (Dabić et al., 2019). On the other hand, when absorptive capacity is high, firms are more capable of translating knowledge into actionable strategies that improve resource efficiency, reduce environmental impact, enhance stakeholder engagement, and support long-term sustainable development. In conclusion, absorptive capacity serves as a vital link that enables organizations to unlock the full value of knowledge management for sustainability. Strengthening this capacity ensures that knowledge is not just acquired, but also transformed into practical, innovative, and sustainable organizational practices (Pacheco et al., 2018). Previous research also highlighted that AC can have a relationship with KMP and SP, and GTI. So, we accept our III and IV hypotheses

Hypothesis V: Environmental awareness (EA) plays a critical moderating role in the relationship between Knowledge Management Practices (KMP) and Absorptive Capacity (AC). While KMP, such as knowledge acquisition, sharing, responsiveness, are foundational to organizational learning and innovation, the degree to which these practices translate into enhanced absorptive capacity greatly depends on an organization's awareness and prioritization of environmental issues. Environmental awareness refers to the extent to which individuals and organizations recognize the significance of environmental challenges and the need for sustainable action. When environmental awareness is high, organizations are more likely to actively seek and utilize environmental knowledge, collaborate with external stakeholders, and prioritize eco-innovation. This heightened sensitivity to environmental concerns amplifies the effectiveness of KMP, allowing firms to more effectively internalize and transform knowledge relevant to sustainability and green innovation.

In organizations with strong environmental awareness, knowledge is not only managed efficiently but also directed purposefully toward solving environmental problems and improving sustainable performance. Such firms are more open to adopting best practices in green technology, regulatory compliance, and circular economy models (Abbas & Sağsan, 2019). Conversely, in organizations with low environmental awareness, even well-developed KM systems may fall short in enabling absorptive capacity, as the relevance of environmental knowledge may be undervalued or ignored (Shah et al., 2023). Empirical literature supports this moderating effect, indicating that environmental awareness enhances the influence of KMP on absorptive capacity by shaping organizational motivation, attention, and resource allocation. In essence, EA acts as a catalyst, sharpening the organization's focus on acquiring and applying knowledge that is not just innovative but also aligned with environmental priorities.

Environmental awareness significantly strengthens the link between Knowledge Management Practices and Absorptive Capacity (Rustam et al., 2020). It ensures that the knowledge being managed is not only retained and shared but is also environmentally relevant and purposefully used. For organizations aiming to build dynamic capabilities and foster green innovation, cultivating environmental awareness across all levels is essential. It transforms traditional KM processes into powerful tools for sustainability, ensuring that absorptive capacity is developed in alignment with global environmental imperatives. So based on previous research and results, we accept our fifth hypothesis.

5.3 Conclusion

The results of SEM also indicate that all the hypotheses are accepted based on the results. The conceptual framework presented in this study is novel in several ways. First, while prior research has often examined Knowledge Management Practices (KMP) and Sustainable Performance (SP) separately or in direct relationships, this study introduces Green Technological Innovation (GTI) as a distinct dependent variable, linking it directly to KMP in the context of environmentally oriented innovation. Second, the framework incorporates Absorptive Capacity (AC) as a mediating variable, offering a deeper understanding of the internal capabilities through which knowledge management translates into green innovation. Few previous studies have tested this mechanism, especially within the context of manufacturing SMEs in developing economies like Pakistan. Furthermore, the inclusion of Environmental Awareness (EA) as a moderator provides an original contribution by examining the contextual conditions under which KMP is more likely to lead to GTI and SP through AC. This interaction effect reflects the increasing importance of environmental consciousness in shaping innovation strategies, a factor that has been underexplored in current literature. Methodologically, the use of Structural Equation Modeling (SEM) with AMOS, combined with moderated mediation analysis, provides a rigorous approach to testing complex relationships among latent variables. This integrated framework, grounded in the Resource-Based View (RBV) and Knowledge-Based Theory, is not only theoretically rich but also empirically unique in its application to the Pakistani SME sector, which has received limited attention in green innovation research. Together, these aspects contribute to the theoretical originality and methodological robustness of the study.

In the context of Pakistani SMEs, where environmental regulation and sustainability infrastructure are still developing, these findings are particularly relevant. They highlight the strategic importance of fostering environmental consciousness and building absorptive capacity to fully leverage knowledge for green innovation and long-term sustainable growth. This study fills several critical gaps in the existing literature. First, it explores the direct influence of Knowledge Management Practices (KMP) on Green Technological Innovation (GTI), contributing to the underdeveloped understanding of how knowledge processes within SMEs can drive green innovation outcomes. While previous studies have discussed the theoretical link between KMP and innovation, empirical validation in the context of GTI, specifically within SMEs in Pakistan, remains limited, addressing Gap 1.

Second, the study incorporates Absorptive Capacity as a mediating variable and Environmental Awareness as a moderator to provide a deeper understanding of the mechanisms and conditions under which KMP translates into GTI. By doing so, the study moves beyond simple direct relationships and offers a comprehensive model that explains how and under what circumstances KMP can enhance GTI, thus filling Gap 2, where indirect and conditional effects have rarely been explored.

Third, by focusing on manufacturing SMEs rather than large firms, the research responds to Gap 3, which highlights the lack of studies investigating GTI adoption and its performance implications in resource-constrained, developing economy contexts. The study contributes novel insights into the barriers and enablers of GTI among SMEs in Pakistan, a sector often overlooked despite its significant role in national economic and environmental sustainability.

In sum, this research enriches the current body of knowledge by presenting a holistic view of how internal knowledge capabilities and contextual awareness foster green technological innovation within SMEs, offering both theoretical and practical implications for sustainability and innovation management. It highlights the importance of building knowledge-sharing processes and absorptive capabilities to successfully implement green technologies. Moreover, by showing the moderating role of environmental awareness, the study suggests that fostering a culture of sustainability can significantly enhance the effectiveness of KMP in driving green innovation. These findings can guide capacity-building programs, policy incentives, and sustainability training targeted at SMEs aiming to transition toward more environmentally responsible operations.

5.3 Research Implications

This study has added some remarkable contributions towards the managerial academic as well as organizational perspectives. These implications are as follows

5.3.1 Academic Implications

The connection among knowledge management practices, green technological innovation, and sustainable performance contributed to the development of the theoretical frameworks and models in fields such as knowledge management, innovation studies, and sustainability science. Scholars explore the fundamental mechanisms, processes, and factors that influence how knowledge management practices impact green innovation and sustainability outcomes. Green technologies reduce carbon emissions. A study by the World Bank found that the global adoption of green technologies could prevent 5.5 million deaths per year due to air pollution.

That's a huge health benefit that could be gained from incorporating green technology. Green technologies are also more sustainable than conventional ones, so they can help prevent resource depletion and pollution. Through a literature review that there are fewer studies present on green technological innovation and sustainable performance in Pakistan SMEs. This study also enriches the existing theoretical models

Enrichment of Existing Theoretical Models

Academic research into KMP's impact on GTI and SP contributes significantly to the evolution of several foundational theories:

- **Resource-Based View (RBV)**: Reinforces the idea that knowledge is a strategic intangible resource that can lead to sustainable competitive advantage through innovation.
- **Knowledge-Based View (KBV)**: Confirms that the firm's ability to create, store, and apply knowledge is central to its innovation and sustainability capacity.

Implication: Future academic work can expand these theories by explicitly integrating green and sustainability dimensions into knowledge-focused organizational models.

The intersection of KM, innovation, and sustainability requires an interdisciplinary approach combining insights from strategic management, environmental science, operations, and innovation studies**.**

Implication: Scholars are encouraged to develop integrative frameworks that combine KM theory with sustainability science and innovation theory to capture the complexity of KMP's impact on GTI and SP.

There is an academic need to refine or develop constructs and scales that better capture the links between KMP, GTI, and SP, especially across sectors and cultural contexts.

Implication: This calls for methodological innovation in how researchers conceptualize and measure:

- Environmental knowledge absorption
- Eco-innovation outcomes
- Triple Bottom Line performance

5.3.2 Managerial Implications

The present study provides insightful recommendations and managerial implications that managers and management should put into practice. The formulated hypothesis is either declared to be accepted or rejected by the quantitative portion of SEM. As a result, it offered

insight into which constructions had a significant impact on green technological innovation and sustainable performance

The managerial implications of the present study are discussed below

- This research highlighted that adopting green technologies and sustainable performance of the firm is important for today's businesses. Managers need to integrate green technological innovation and sustainable performance objectives into the organization's strategic planning process. This involves aligning business goals with environmental sustainability targets, identifying opportunities for green innovation, and setting clear targets and performance indicators to track progress.
- Managers of the organization must allocate resources, including financial capital, human capital, and technological infrastructure, to support green technological innovation initiatives and sustainability programs. This may involve prioritizing investments towards the research and development of green technologies, upgrading infrastructure to improve energy efficiency, and training employees on sustainable practices.
- Managers should prioritize the advancement of environmentally sustainable products and services that meet stakeholders' needs while minimizing environmental impact. This may involve redesigning products to use fewer resources, incorporating recycled materials, extending product lifecycles through repair and reuse programs, and obtaining eco-label certifications.
- Managers must have focused on a culture in which continuous improvement and learning are implemented that would drive ongoing innovation and performance improvement in sustainability. This involves regularly reviewing and updating sustainability strategies, learning from successes and failures, and adapting to evolving environmental and market conditions.

5.4 Limitation of the Study

The present study has some limitations that are discussed as under

- The present study is conducted with very less constructs compared to other studies. It is the possibility that the study contains several exogenous variables that would be ignored during the research
- The information is only gathered from organizations that are located in Rawalpindi and Islamabad only. The analysis is only being done on SME's This study can also be conducted

by taking the data from other major cities of Pakistan or some other countries and have to be target to other sectors like pharmaceutical sector textile and other.

- In the study there exist a cross-country analysis that can be performed by examining green technological innovation and sustainable performance with new independent variables.
- The length of the questionnaire was less in questions, so by increasing the length and number of questions, it would provide significant results maybe, the result may be different.
- Additionally, since the number of items has decreased, using the same variables and the newly constructed construct for any other sample could produce more accurate results. Butler (1991) asserts that different situations get different results from the same scales. Despite lacking some of the previously indicated characteristics, this study endeavor still makes an important and worthwhile contribution to the present body of knowledge.

5.5 Future Directions

Even though the present research is conducted carefully but still directed towards more areas other than the present area to be discussed through the use of more advanced research tools. The present study identified the following suggestions for future researchers that will help them when they research the given topic.

- Future research in the domain of knowledge management (KM) and green innovation should contemplate several crucial possibilities. By conducting a more comprehensive examination of certain knowledge management (KM) practices, such as knowledge production, acquisition, and more nuanced comprehension of their distinct effects on green innovation and sustainable performance may be attained. This will empower organizations to discern the most impactful KM methods.
- Future studies may consider integrating other internal factors, such as dynamic capabilities, organizational learning, or innovation culture, as mediators or moderators to further explain how KMP translates into green outcomes.
- Researchers could examine the role of regulatory pressure, market competition, or stakeholder engagement as contextual variables that might strengthen or weaken the KMP–GTI relationship.
- Longitudinal studies are essential for monitoring the enduring impacts of knowledge management (KM) on green innovation and sustainable performance, offering a dynamic perspective on the evolving nature of these associations across time.

- The inclusion of cross-cultural research will provide valuable insights into the impact of cultural elements. Simultaneously, the examination of information transfer and training approaches will facilitate the adoption of knowledge management (KM) and green innovation practices among workers
- The model that is used in the present study can be enhanced by introducing or adopting more mediating and moderating variables like green human resource, and by implementing more complication to the proposed model to get the different results.
- It is directed that comparative study should be conducted to the same conceptual model by taking data through the different population like from different sector like pharmaceutical industry and from different management like low level management; the analysis can be conducted towards the cross-national on cross-country basis that will different direction.
- In future it is advised that more sampling technique will be used that will make to increase the generalizability towards the more findings.
- Future research could explore the influence of green leadership, employee environmental behavior, or green HRM practices as factors that contribute to or hinder the adoption of GTI within organizations.

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Questionnaire Survey

Dear Respondent,

I am a student of MSBA at NUML Islamabad. Currently, I am pursuing my research on "Impact of KMP on Green technological innovation and sustainable performance in SMEs in Pakistan". In this context, a questionnaire has been developed to solicit your responses given your experience. I assure you that the information you provide will be kept confidential and will be used only for academic purposes. Respondents should be rated on a five-point Likert scale.

Instructions

- Please put a circle around the appropriate answer according to the scale given below.

1) How old is the company?

i) < 2 years ii) 2- 5 years iii) 5-10 years iv) > 10 years

2) What is the size of your company? (number of employees)

i) < 30 ii)30-50 iii) 50 -70 iv) > 70

	Variables	SDA	DA	N	A	SA
GTI	**Green Technological Innovation** Upadhyay, Kumar, & Sahoo (2022)					
1	Our organization keeps improving its processes by using cleaner methods or green technologies to save resources and reduce costs.	1	2	3	4	5
2	Our organization is actively involved in redesigning and improving products or services to comply with existing environmental or regulatory requirements.	1	2	3	4	5
3	Our organization is adopting the recycling strategy.	1	2	3	4	5
4	Our organization actively uses eco-labeling to help our clients understand our environmentally friendly practices.	1	2	3	4	5
5	The Research & Development team at our organization ensures that the current technical advancement is included in the development of new eco-initiatives.	1	2	3	4	5

SP	**Sustainable Performance** Bansal (2005)					
1	Our organization's sustainability initiatives have led to measurable improvements in environmental performance.	1	2	3	4	5
2	Our organization has increased our customer or stakeholder trust through our sustainability efforts.	1	2	3	4	5
3	Sustainability has improved our employees' morale and retention	1	2	3	4	5
4	Our sustainable development efforts are continuously evaluated and improved.	1	2	3	4	5
5	Our work is stronger and more stable today because we make decisions that focus on sustainability.	1	2	3	4	5
EA	**Environmental Awareness** Mostafa, (2007) Haron et al., (2005)					
1	Our organization is fully aware of the environmental impact of its operations.	1	2	3	4	5
2	The organization includes environmental concerns in our company's plans and strategies.	1	2	3	4	5
3	Our organization participates in external environmental initiatives or collaborations.	1	2	3	4	5
4	We are aware of the major environmental problems facing our planet today.	1	2	3	4	5
5	We feel a sense of personal obligation to take action to stop the disposal of toxic substances inthe air, water, and soil.	1	2	3	4	5
AC	**Absorptive Capacity** Flatten et al., (2011)					
1	Our firm quickly analyzes and interprets changing market demands	1	2	3	4	5
2	Our firm can successfully absorb new knowledge.	1	2	3	4	5
3	Our firm has been effective in combining existing knowledge with newly acquired knowledge.	1	2	3	4	5
4	Our firm regularly utilizes knowledge to develop new products or services.	1	2	3	4	5
KMP	**KMP**					

	Darroch & McNaughton (2003)					
1	Our organization values employees' attitudes and opinions.	1	2	3	4	5
2	Our organization is sensitive to information about changes in the marketplace.	1	2	3	4	5
3	Our organization gets information from market surveys	1	2	3	4	5
4	Information about the environment is shared openly and easily in our organization	1	2	3	4	5
5	People share useful information during their work.	1	2	3	4	5
6	Our organization quickly responds to environmental-related concerns	1	2	3	4	5
7	My organization uses knowledge to change or improve its plans and goals	1	2	3	4	5
8	My organization has processes for using knowledge to solve new problems.	1	2	3	4	5