Interplay of Emerging Industrial Technologies, Ambidexterity, and Sustainability: A Case Study of Textile Sector in Pakistan

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DEDICATION

I dedicate this endeavor to my beloved parents and my cherished family, especially my elder brother *M. Imran*, whose unwavering support and encouragement have been my guiding light through every step of this journey.

To my mentor, *Brig (R) Dr. Masood Raza*, whose guidance, wisdom, expertise, and unwavering belief in my potential have been instrumental in my growth, I owe an immeasurable debt of gratitude. Your wisdom has illuminated my way, and your mentorship has empowered me to strive for greatness.

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ABSTRACT

The global market increasingly demands personalized products and sustainable manufacturing practices, coupled with a digital transformation disrupting the manufacturing industry. Particularly, the manufacturing sector of developing economies encounters significant sustainability challenges across economic, environmental, and social fronts while adopting emerging industrial technologies (EIT). Artificial Intelligence (AI), Internet of Things (IoT), Autonomous Robots (AuR), and Mobile Technologies (MT) are the significant EIT that are transforming the shape of industrial process for optimal growth and efficiency. However, this technological transformation may impact the organizational sustainability due to EITs higher capital investment, lack of skilled personnel to operate EIT and EIT dependency on extensive energy consumption. In addition, ambidextrous practices enable industries to navigate disruptive technological shifts. This study aims to quantitatively investigate the impact of EIT on the sustainability of manufacturing industry with the mediation of Organizational Ambidexterity (OA). The textile industry is considered as a case study and the quantitative data from 192 textile professionals was collected using a survey questionnaire and analyzed using partial least square structural equation modelling (PLS- SEM). The findings reveal a differential influence of EIT on the organizational sustainability dimensions – significant impact in the case of AI, complementary mediation of OA with AuR, competitive mediation of OA for IoT, and fully mediated by OA for MT. The study enriches the dynamic capabilities framework, highlighting OA as essential for effective technological integration to achieve sustainability, contributing directly to SDGs 8, 9, and 12. For practitioners and policymakers, this research offers a strategic roadmap for leveraging EIT aligned with organizational sustainability objectives, advocating for the development of ambidextrous capabilities to navigate implementation hurdles effectively.

Keywords: *Textile Industry, Emerging Industrial Technologies, Organizational Sustainability, Organizational Ambidexterity, PLS-SEM Analysis*

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LIST OF ABBREVIATIONS

EIT	Emerging Industrial Technologies
OA	Organizational Ambidexterity
OS	Organizational Sustainability
IoT	Internet of Things
AI	Artificial Intelligence
MT	Mobile Technologies
AuR	Autonomous Robots

CHAPTER 1: INTRODUCTION

In the past three decades, there has been a remarkable evolution in Information Technology (IT) systems, leading to profound impacts on various aspects of everyday life. A significant transformation has occurred with the transition from traditional computers to intelligent devices that leverage cloud computing infrastructure services (Kagermann et al., 2013). These advancements have not only facilitated extensive connectivity between humans and machines within a cyber-physical system framework, utilizing information from diverse sources but have also enabled direct communication between machines. This integration of networks within the realm of production and operations is commonly referred to as the fourth industrial revolution (Tjahjono et al., 2017), and various Emerging Industrial Technologies (EIT) act as a stepping stone for this industrial revolution. The significance and prominence of adopting EIT have increased within enterprises and industrial sectors (Luthra & Mangla, 2018). The profound impact of these technologies is demonstrated through the established interconnectedness, data sharing, and autonomous communication between machines and humans, facilitating decision-making processes independent of human intervention (Aoun et al., 2021). However, realizing the full potential of EIT requires thorough and comprehensive efforts, including end-to-end integration across all business operations (Virmani et al., 2023). Nonetheless, it is crucial to approach and assess these technologies with a greater level of scrutiny and consideration, particularly in terms of their implications for sustainability (Bai & Sarkis, 2020).

The manufacturing sector in developing economies, like Pakistan, encounter challenges, notably the increasing trend of highly customized product demands globally. Customers are now seeking products that are tailored to their specific needs and preferences, requiring manufacturers to adapt and customize their production processes accordingly (Herrmann et al., 2014a). This shift towards personalization requires manufacturers to incorporate a high degree of flexibility and agility in production systems to accommodate diverse product variations (Hu et al., 2011). Product customization not only entails smaller batch sizes and frequent product changeovers, which can result in increased setup times, higher production costs, and reduced economies of scale (Hu et al., 2008; Z. Jin et al., 2023) but also requires closer collaboration and communication between manufacturers and customers. This demands effective coordination, information sharing, and feedback mechanisms throughout the production process to ensure that customer requirements are accurately translated into the final product (E. Porter & E. Heppelmann, 2019).

Pakistan's industrial sector, crucial in both economic contribution and employment, faces significant technological and innovation challenges. It contributes to approximately 18.8% of the gross value added, highlighting its significant economic importance (Pakistan Economic Survey, 2023). It employs a considerable portion of the workforce, with approximately 23.9% of employees engaged in industrial activities (Pakistan Economic Survey, 2023). The struggle to adopt and integrate EIT disrupts the ability of firms to enhance productivity and remain globally competitive (United Nations Industrial Development Organization., 2020). Notably, some emerging and developing nations are undergoing a transition, shifting from being prominent performers in industrial production capabilities to gaining entry into the league of leading firms with advanced technological and digital capabilities (Miah & Omar, 2012).

Emerging Industrial Technologies (EIT) encompass a range of innovative and sophisticated technologies that are reshaping diverse industries, facilitating improvements in productivity, efficiency, and automation. These technologies are commonly in their nascent stages of development or implementation and have the potential to disrupt conventional industrial practices (Winston & Strawn, n.d.). Their evolution is driven by advancements in fields like Artificial Intelligence (AI), Autonomous Robots (AuR), Internet of Things (IoT), Cloud Computing (CC), Big Data Analytics (BDA), and Mobile Technologies.

To comprehend the interconnection between emerging industrial technologies and Industry 4.0, it is imperative to grasp the concept of Industry 4.0 which refers to the integration of digital technologies within industrial operations, leading to the establishment of "smart factories" or "smart manufacturing" (Kamarul Bahrin et al., 2016; Ojra, 2019). The primary objective of Industry 4.0 is to foster the development of extensively interconnected and autonomous systems that harness the potential of data and advanced technologies to enhance efficiency, productivity, and decision-making processes. Emerging Industrial Technologies (EIT) play a pivotal role in enabling the vision of Industry 4.0. These technologies serve as the foundation for the digital transformation of various industries, allowing for the collection, analysis, and utilization of data to optimize operational processes, enable predictive maintenance, improve product quality, and enhance overall performance. These technologies function as the building blocks for the interconnected systems and intelligent automation that characterize Industry 4.0 (J. Lee et al., 2015; Monostori, 2014). However, in scholarly literature, the terms "Emerging Industrial Technologies" and "Industry 4.0 Technologies" have been utilized interchangeably. To ensure simplicity and maintain alignment with the research focus, this study adopts the same practice, thereby remaining consistent with the prevailing terminology in the literature.

The global landscape of Advanced Digital technologies reveals a significant concentration of their creation and diffusion, with limited progress observed in most emerging economies. A mere 10 economies, classified as frontrunners, dominate this domain, accounting for 90 percent of all global patents and 70 percent of related exports. In contrast, 40 economies designated as followers exhibit active involvement in these technologies, albeit with comparatively lower levels of intensity. The remaining regions of the world can be categorized as latecomers, exhibiting minimal activity, or as laggards, displaying a complete absence of engagement in the global creation and utilization of such technologies (Andreoni, 2020). Within these economies, the firms have been categorized based on their digital capabilities into four distinct groups: Digital Leaders, Highly Innovative firms, Product Innovative firms, and non-innovative firms. These classifications enable a comprehensive understanding of the varying degrees of digital maturity and innovation within the business landscape. The description of the beforementioned term is given in Table 1.1.

Table 1.1: Firm Class & its Description

Firm Class	Description
Digital Leader	Digital leading firms are organizations that prioritize digitalization, demonstrating excellence in product and process innovation, automation, and research and development (R&D) expenditures. They possess distinct digital characteristics, such as a significant presence of computer users, software development or procurement, dedicated IT personnel, engagement of computer consultants, and extensive use of the internet for all business activities. These firms stand out in their commitment to leveraging digital technologies, driving innovation, and maximizing their competitive advantage in the digital landscape (Andreoni, 2020; Araujo et al., 2021; Oberer & Erkollar, 2018).
Highly Innovative Firms	Highly innovative firms exhibit notable traits associated with innovation, including engagement in product and process innovation, substantial investments in research and development (R&D), and a certain level of digitalization. These firms possess the necessary technological capabilities required to effectively adopt and leverage advanced technologies, making them favorable candidates for embracing new technological advancements (Jekunen, 2014; Schneider & Veugelers, 2010).
Product Innovative Firms	Product innovators are characterized by their distinct focus on innovation within the product domain. These firms demonstrate a remarkable commitment to introducing novel and technologically advanced products to the market. By prioritizing product innovation, they continually seek to meet the evolving needs and preferences of customers. Additionally, product innovators allocate significant resources to research and development (R&D) activities,

	aiming to develop cutting-edge solutions and maintain a competitive edge. Their emphasis on product R&D investments signifies a forward-looking approach, enabling them to remain at the forefront of technological advancements and leverage emerging opportunities. Through their sustained commitment to product innovation, these firms position themselves as leaders in driving technological progress and addressing market demands (Chakrabarti, 1974; Johne & Snelson, 1988; Slater et al., 2014).
Non-Innovative Firms	Non-innovative firms demonstrate a lack of emphasis or engagement in innovation activities. These firms typically exhibit limited or no involvement in product innovation, process improvement, research and development (R&D) investments, and digitalization efforts. Non-innovators often rely on existing products and traditional business practices without actively seeking to introduce new or improved offerings to the market. Consequently, these firms may struggle to adapt to evolving customer demands, technological advancements, and changing market dynamics. Their limited focus on innovation can hinder their competitiveness and growth potential in an increasingly dynamic and competitive business environment (An Exploratory Study Comparing Characteristics Of Innovators And Non-Innovators At A Large University. - ProQuest; Purchase Sequence Responses: Innovators vs. Non-Innovators; Freel, 2000).

In such developing economies, digital leading firms, representing the pinnacle of technological players, constitute a meager percentage ranging from 0.1 percent to 3.0 percent of the total firms (refer to Table 1.2). Consequently, only a small number of firms in each country belong to this exclusive category. In India, digital leaders account for 1.69 percent, in Bangladesh 0.70 percent, and 0.00 percent in Pakistan. Notably, some emerging and developing nations are undergoing a transition, shifting from being prominent performers in industrial production capabilities to entering the league of leading firms with advanced technological and digital capabilities (Miah & Omar, 2012). Within the considered countries, there exists a notable presence of highly innovative firms, constituting a significant share of the overall business landscape. Specifically, in India, these firms account for 17 percent, followed by 16 percent in Bangladesh, 11 percent in Kenya, and 2.07 percent in Pakistan. Highly innovative firms often exhibit ambidexterity in their organizational approach. They actively pursue both exploratory and exploitative activities, allowing them to simultaneously explore new opportunities and technologies while optimizing their existing products or processes.

Product Innovators account for 50 percent in India, 4 percent in Bangladesh, 36 percent in Malawi, 32 percent in Namibia, and 23 percent in Pakistan. Product innovators, by their nature, engage in exploratory activities to develop and introduce new and technologically advanced products to the market. This involves a level of ambidexterity, as they need to balance exploration for innovative ideas with the exploitation of existing capabilities to bring those ideas to fruition. Conversely, the proportion of non-innovators varies from 31 percent in India, 37 percent in Bangladesh, 40 percent in Malawi, 52 percent in Namibia to 75 percent in Pakistan. Overall, it is worth noting that the minority of potentially high-performing firms possess robust capabilities, characterized by their status as digital leaders and highly innovative entities.

Table 1.2: Firm Categories Share in Fifteen under-development Countries (United Nations Industrial Development Organization., 2020)

Country	Digital Leaders	Highly Innovative	Product Innovators	Non-Innovators
Malawi	2.99	20.90	35.82	40.30
Uganda	2.88	9.13	44.71	43.27
India	1.69	16.81	50.33	31.17
South Sudan	1.22	6.10	63.41	29.27

Sudan	1.06	5.32	32.98	60.46
Nigeria	0.75	9.95	27.36	61.94
Kenya	0.71	11.39	33.45	54.45
Bangladesh	0.70	15.91	46.32	37.08
Congo	0.55	10.38	30.60	58.47
Nepal	0.43	2.13	14.47	82.98
Ghana	0.35	7.80	18.79	73.05
Pakistan	0.00	2.07	22.63	75.30
Namibia	0.00	15.87	31.75	52.38
Tanzania	0.00	0.74	17.65	81.62
Zambia	0.00	15.30	45.15	39.55
Note: only the manufacturing sector is considered				

This technological lag is interconnected with pressing environmental sustainability issues. Conventional manufacturing systems exhibit significant environmental imbalances, leading to heightened resource consumption, climate change, ecological degradation, and increased pollution (Tseng et al., 2018). According to statistical data from (Shahid et al., 2018), the industrial sector significantly contributes to air pollution, thereby posing environmental and health challenges. (Shahid et al., 2018) reveals that, with a 23.2% contribution, the industrial sector ranks as the first-largest source of particulate matter (PM10) and the third-largest source of nitrogen oxides (NOx) in Pakistan. Moreover, industrial facilities emit substantial amounts of environmentally hazardous heavy metals, accounting for approximately 19.91% of lead emissions (Hussain et al., 2018) and an alarming level of mercury emissions (Umar et al., 2022). The detrimental effects of industrial air pollution on the environment and human health have been estimated to cost US$ 47.8 billion (5.88% of GDP) in 2022 in Pakistan (Rafique et al., 2022). The presented data provides valuable insights into the significant contribution of industrial sources to overall emissions. As evidenced by the findings from a survey conducted in 2019 by the Air Quality Life Index (AQLI) (Michael Greenstone & Fan, 2019), none of the major three Pakistani key cities examined in the study met the annual air quality standards for particulate matter as set by the WHO. In some instances, the levels of air pollution surpassed the WHO set standard by twofold, underscoring the substantial energy demands of the Pakistani industrial sector. These issues not only have negative consequences for the environment but also pose long-term risks to the sustainability of the manufacturing sector itself.

In addition, traditional manufacturing systems are also linked with social challenges including poverty and inequality. These systems have been associated with various social issues such as poverty, inequality, inadequate income, societal disharmony, and lack of unity (Bai & Sarkis, 2020). Considering these concerns, EIT emerges as a potential solution, promising to address social sustainability challenges, thereby indicating a path toward a more sustainable and technologically advanced industrial future (Morrar et al., 2017).

Furthermore, the industrial sector has long been recognized as a crucial player in the pursuit of sustainable development. This is evident in significant documents such as the Brundtland Report of 1987 (World Commission on Environment and Development, 1987), which extensively discusses the delicate balance between environmental preservation and economic gains. Moreover, ongoing discussions surrounding the UN Sustainable Development Goals, particularly Goal 12 focus on sustainable consumption and production patterns, further emphasize the industry's role in sustainability efforts (United Nations. (n.d.), n.d.). From a sustainability science perspective, it is vital to closely monitor the ongoing transformations within the industry. It is worth noting that the impact and nature of changes brought about by industrial digitalization may vary across countries, contingent on their existing industrial structures. Countries with advanced automation in their manufacturing sectors may experience different effects compared to those with predominantly manual labor-based manufacturing like Pakistan. As a result, policymakers should anticipate the potential international heterogeneity in impacts arising from the diverse consequences of digitizing the manufacturing sector (Beier et al., 2017).

In Pakistan, the industrial sector contributes to approximately 18.8% of the gross value added, highlighting its significant economic importance (Pakistan Economic Survey, 2023). Furthermore, it employs a considerable portion of the workforce, with approximately 23.9% of employees engaged in industrial activities (Pakistan Economic Survey, 2023). The industrial sector's significance extends to energy consumption, accounting for about 28% of the total final energy consumption in Pakistan (Pakistan Economic Survey, 2020). However, it is crucial to note that this prominence in energy usage also results in the industrial sector being one of the major contributors to greenhouse gas emissions, responsible for approximately 25% of the country's total emissions (USAID, 2016).

The specific relationship between EIT in achieving OS in the manufacturing industry in general and the textile industry in particular has not been extensively explored. EIT encompasses a range of innovative and sophisticated technologies that are reshaping diverse industries and facilitating productivity, efficiency, and automation improvements. These technologies are commonly in their nascent stages of development or implementation and have the potential to disrupt conventional industrial practices (Monostori, 2014). The development of these technologies is driven by advancements in several key areas: Artificial Intelligence (AI), Autonomous Robots (AuR), Internet of Things (IoT), Cloud Computing (CC), Big Data Analytics (BDA), and Mobile Technologies (MT). This development is shaping the future of industries, including the textile sector, by introducing novel, efficient methods of operation. The selection of AI, IoT, AuR, and MT as the focal EIT for this study was strategic. These technologies represent the forefront of industrial innovation, each offering unique capabilities to transform manufacturing processes. AI and IoT provide advanced data analytics and connectivity, enhancing decision-making and operational efficiency. AuR introduces automation for increased precision and productivity, while MT offers mobility and real-time communication. Collectively, these technologies embody the diverse aspects of digital transformation crucial for advancing sustainability in the textile sector.

To implement EIT to optimize the OS in the manufacturing sector, there is a requirement to create a balance between existing and disruptive systems, economics, environmental concerns, and social challenges. Therefore, organizational ambidexterity (OA) supports maintaining this balance. OA refers to an organization's ability to balance and effectively manage both exploration and exploitation activities (Fernández-Pérez de la Lastra et al., 2022). Exploration involves seeking new opportunities, experimenting with innovative approaches, and adapting to changing environments. Exploitation, on the other hand, includes maximizing existing resources, capabilities, and processes to improve efficiency and optimize performance (Aftab et al., 2022).

There are existing studies portrayed the impact of digitalization on organizational sustainability (Dalenogare et al., 2018a; Garcia-Muiña et al., 2018; Ghobakhloo, 2020; Nascimento et al., 2019). A recent study by (Chaudhuri et al., 2024) aims to examine how Industry 4.0 technologies influence organizational data-driven culture and its subsequent impact on innovation and sustainability performance. The study reported that the adoption of Industry 4.0 technologies positively affects social, competitive, and financial performance, mediated by a data-driven culture, and improved innovative capabilities. In addition, a study suggested that technological sustainability should be the fourth dimension of sustainability apart from social, economic, and environmental (Vacchi et al., 2021). A study explored that eco-efficiency, occupational health and safety, and energy efficiency are the major challenges to industrial sustainability (Neri et al., 2018). The implementation of IoT has been studied by (Beier et al., 2018) to improve the environmental sustainability of the manufacturing industry. The sustainability of technological processes such as Industry 4.0 and waste treatment technologies has been examined to optimize industrial sustainability (Bai et al., 2020a; Jamwal et al., 2021; Kamali et al., 2019). Thus, the problem statement articulates as follows:

"Amidst the escalating demand for highly customized and personalized products, increasing pressure to adopt environmentally sustainable practices, and digital

transformation pervading the industry, the manufacturing sector of developing economies face economic, environmental, and social sustainability challenges. This study aims to investigate the potential impact of specific Emerging Industrial Technologies – AI, IoT, AuR, MT – on achieving organizational sustainability across these dimensions and provide insights into the role that organizational ambidexterity plays in navigating these challenges effectively."

The degree of impact EITs have on the achieving OS needs to be ascertained. Hence, the research question this study aims to answer is as follows:

"RQ1: Is there a positive impact of EIT on OS?

RQ2: Does OA mediate the hypothetical relationship between EIT and OS?"

In line with this question, this research aims to address the following distinct objectives:

- Investigate the relationship between OA and the adoption and implementation of EIT within the textile sector of developing economies.

- Evaluate the influence of OA as a mediator on the interrelationship between EIT and the holistic sustainability performance of manufacturing organizations.

- Offer analysis-based insights to the textile sector regarding the efficient development and effective management of OA as they embark on the adoption and integration of EIT, aiming to promote sustainable operations. This way the research endeavor will aid in formulating policies and strategies that promote the widespread adoption of emerging industrial trends, enabling these economies to harness the potential benefits offered by technological advancements.

- Serve as a foundation for subsequent research that will delve into individual technologies and explore additional mediating and moderating variables, such as Digital Maturity, Organizational Culture, transformational leadership, and innovative performance. By leveraging the findings and insights derived from this study, future researchers can concentrate on developing frameworks, such as

Digital Maturity Assessment and Readiness Assessment, etc., and offer guidelines for formulating customized digital transformation roadmaps specifically tailored to developing economies like Pakistan.

The comprehensive analysis of the existing literature on industrial technologies and organizational sustainability still lacks a conceptual research framework that strengthens the relationship between EITs and OS. Considering major EITs such as AI, IoT, AR, and MT and examining their impact on OS is still a gap in the literature along with the mediating impact of OA in a developing country. Therefore, this study aims to bridge this gap by estimating this hypothetical relationship with the influence of OA in managing technological trade-offs. This central inquiry guides the study, contributing to the understanding of digitalization's potential in industrial manufacturing for optimizing sustainable development goals (SDG) 9 which is industry, innovation, and infrastructure.

The paper begins with a comprehensive analysis of the current state of research, providing a concise overview of existing findings about EIT, organizational ambidexterity, and organizational sustainability in section 2. It further examines how OS is anticipated to be influenced by the projected digitalization trends. Subsequently, the methods employed in designing and conducting the survey are stated in section 3, followed by the presentation and comparative analysis of the survey results in section 4. The paper continues to discuss the most notable findings derived from the survey in section 5. In conclusion, a summary of the key findings is provided, along with an outlook for potential avenues for future research in this domain.

CHAPTER 2: LITERATURE REVIEW

To maintain the scholarly integrity and depth of this study, it is crucial to engage thoroughly with the current scholarly discourse (Corallo et al., 2020). In line with this aim, an exhaustive review of relevant literature was conducted to affirm both the pertinence and originality of the present research. The ensuing segments of this paper present the results of this review, systematically arranged into separate sub-sections as delineated below: Emerging Industrial Technologies (EIT), Sustainability and its Dimensions, EIT Acceptance: Global Prospect, Importance of EIT for Developing Economies, Convergence of EIT and OS, Organizational Ambidexterity, Research Gap, and Research Model and Hypothesis Formulation.

2.1 Emerging Industrial Technologies

Emerging Industrial Technologies (EIT) represent a diverse array of cutting-edge and innovative technologies that are pivotal in transforming numerous industry sectors, promoting advancements in productivity, efficiency, and the scope of automation. These technologies are generally at nascent stages of evolution or adoption, harboring the capability to radically alter traditional industrial methodologies (Matt et al., 2015). Their development is propelled by breakthroughs in domains such as Artificial Intelligence (AI), Autonomous Robots (AuR), Internet of Things (IoT), Cloud Computing (CC), Big Data Analytics (BDA), and Mobile Technologies (Valero et al., 2022). EIT's significant influence is evident in the way it fosters connections and interactions among computers and machines, paving the way for self-governing decision-making processes that operate independently of human input (Aoun et al., 2021). Nevertheless, the effective deployment of EIT requires thorough and comprehensive strategies, encompassing complete business integration (Virmani et al., 2023).

The integration of EIT within business models significantly boosts productivity and competitive edge (Lu et al., 2019; Rymaszewska et al., 2017), attributed to the strategic application of insights derived from the vertical amalgamation of disciplines, notably Cyber-Physical Systems (CPS). Within the ambit of EIT, CPS functions as a pivotal communication framework, enabling the seamless fusion of the cyber domain (IT: Information Technology) with the physical sphere (OT: Operations Technology), thus transcending the isolated layers that once functioned independently. CPS plays a crucial role in enabling comprehensive interactions (Alcácer & Cruz-Machado, 2019) among diverse elements, processes, applications, and technologies, thereby cultivating a degree of interconnectivity that was unattainable in the previous industrial era (Apilioğulları, 2022).

A critical aspect of Emerging Industrial Technologies lies in the concept of Digital Transformation. This process, emblematic of the industry four point zero (A. Z. Khan & Bokhari, 2018), involves the strategic use of EIT to fundamentally reshape and revitalize business models, thus ensuring an organization's proactive response to market demands. Organizations employing a "ground-up" strategy integrate nascent technologies and methodically restructure their operations, products, and services (Dezi et al., 2018). Digital transformation is marked by a dynamic path, defined by specific goals that differ based on the industry context (Apilioğulları, 2022; Pellicelli, 2023). However, achieving this path requires a parallel emphasis on change management, addressing organizational inertia, and ensuring a seamless shift to digital operations (Gilchrist, 2016; Pellicelli, 2023).

(Tan & Wang, 2010) delineated key attributes vital for the deployment of Emerging Industrial Technologies, emphasizing aspects like reliability, scalability, modularity, Quality of Service (QoS), integration, interoperability, networking, and security. Furthermore, the critical need for ubiquitous data exchange, monitoring, and self-organizing capabilities, along with security and privacy considerations, was underscored to augment supply chain efficiency within the framework of Emerging Industrial Technologies (Miorandi et al., 2012; Xu, 2012). (Monostori, 2014) undertook a study to pinpoint essential communication features in an EIT setting, focusing particularly on the establishment of secure and reliability connections between WSN devices and other components. (Beigne et al., 2015; de Camargo Fiorini & Jabbour, 2017) highlighted the importance of adaptability as a fundamental aspect for the efficient handling of reprogrammable devices and components in Emerging Industrial Technologies, aiming to expand the platform's functionalities. Within this context, visual computing technology emerges as a critical facilitator, addressing various elements such as automated and adaptable production lines.

2.2 Sustainability and its Dimensions

While the concept of sustainability is increasingly scrutinized as a standalone, comprehensive notion, its applicability endures, especially when paired with specific qualifiers like "economic/financial," "ecological," "social," "environmental," or "organizational". Various experts have endeavored to contextualize this term within the confines of their disciplines (Hansmann et al., 2012; Morelli, 2016.). Nonetheless, the future of sustainability is often conceptualized as necessitating a balance or a synergistic harmony among social, environmental, and economic factors. This approach, commonly articulated as the "people, planet, and profit" framework (Hansmann et al., 2012), highlights the synergy among these elements and stresses the importance of their strategic alignment and prioritization to secure the sustainable and desirable operation of societal systems (Elkington, 1994; Savelyeva & Douglas, 2017).

Presently, a multitude of corporations in the industrial sector have adopted sustainability frameworks to evaluate their performance across social, financial, and environmental realms. This method, known as the Triple Bottom Line (3BL), has its roots traced back to 1994 (Elkington, 1994), marking the year when John Elkington first introduced this concept and its associated terminology.

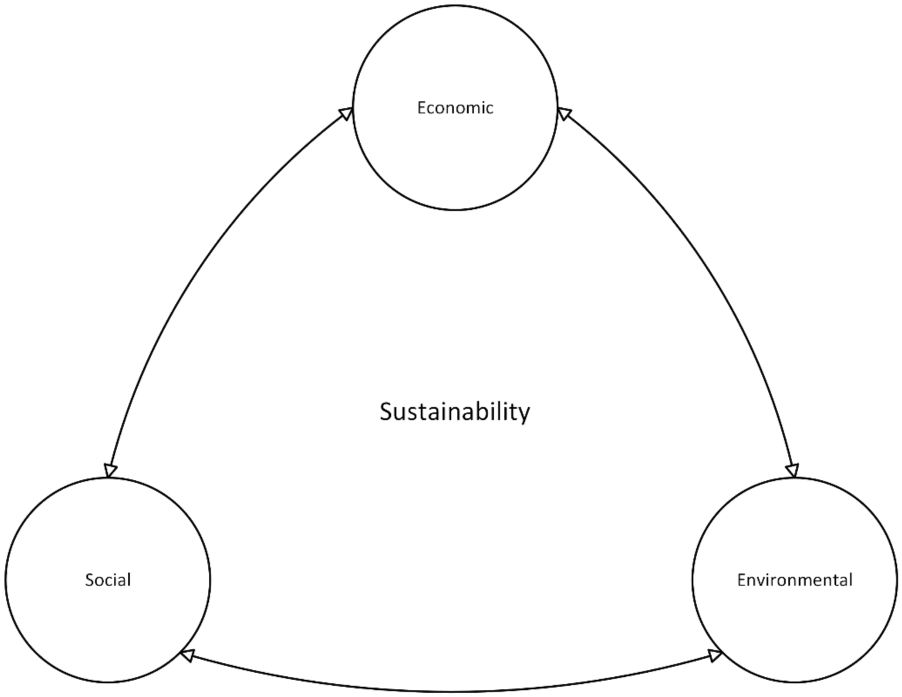

Figure 2.1: Dimensions of sustainability

Table 2.1 provides an exhaustive overview of the principal economic, ecological, and social dimensions of the IIoT, as delineated in current scholarly literature.

Table 2.1: Dimensions of sustainability dealt with in literature (Kiel et al., 2017)

Sustainability (TBL) Dimensions	Relevant aspects of each dimension	Literature Representative of each dimension
Economic	• Complete Visibility of Costs • Enhanced Transparency, Customization, Flexibility, and Quality Improvement	(Amshoff et al., 2015; Arnold et al., 2016; Dalenogare et al., 2018; Bai et al., 2020; Hofmann & Rüsch, 2017; Oesterreich & Peukert et al., 2015;

	• Reduction in Time-to-Market • Development of Innovative Business Models • Substantial Financial Commitments • Variability in Profit Margins	Teuteberg, 2016; Schuhmacher & Hummel, 2016; Zhou et al., 2017; Stock & Seliger, 2016)
Social	• Advancement in Employee Learning and Development, Equitable Compensation, Improved Worker Motivation • Ambiguous Effects on Job Creation or Reduction • Decrease in Monotonous Tasks, Boost in Creative Activities • Inevitable Change in Organizational Structure • Influence of Organizational Culture, Internal	(Ferreira et al., 2023; Garcia-Muiña et al., 2018; Müller, 2019; Herrmann et al., 2014a; Imran et al., 2018; Stock & Seliger, 2016; Virmani et al., 2023; Tesch et al., 2017)

	Politics, and Network Infrastructure on IIoT Adoption	
Environmental/Ecological	• Transparency in Greenhouse Gas Emissions • Optimized Utilization of Resources and Energy • Minimization of Waste • Streamlining of Logistics Processes • Reduction in Incorrect Deliveries and Defective Products	(Braccini & Margherita, 2018; de Sousa Jabbour et al., 2018;; Morelli, n.d.; Piyathanavong et al., 2019; Herrmann et al., 2014a; Stock & Seliger, 2016; Sarkis & Zhu, 2017)

2.3 EIT Acceptance: Global Prospect

Analysis of history spanning the last two centuries illustrates the significant role of manufacturing in the ascent of global powers. During the 19th century, England's robust manufacturing sector positioned it as a global leader, a status subsequently assumed by the United States, Germany, Japan, and the USSR in the 20th century. Manufacturing has consistently served as a primary catalyst for national development, prosperity, and wealth accumulation (Herrmann et al., 2014b). The inception of Industry 4.0 traces back to a German government initiative designed to bolster the long-term competitiveness of the manufacturing industry (Gilchrist, 2016; Müller et al., 2018). This paradigm shift in technology aims to enhance the efficiency and efficacy of industrial processes, encompassing production systems, material utilization, distribution networks, and product management (Lin et al., 2018). (Lobova et al., 2019) investigated the effective implementation of Industry 4.0 across diverse nations, with a particular focus on the United States, the United Kingdom, Germany, and Japan. Their study furnishes empirical proof that these countries, notwithstanding the relatively recent emergence of Industry 4.0, have amassed significant practical expertise in its adoption. Developed nations have taken proactive measures in shaping the trajectory of Industry 4.0, leveraging their resources and societal frameworks. A thorough examination of predictive data, with a specific emphasis on the USA, the UK, Germany, and Japan, underscores the pivotal role of Industry 4.0 in fostering a knowledge-driven economy.

However, (Veile et al., 2020) have underscored critical considerations for the implementation of Industry 4.0, which encompass acquiring specialized knowledge and expertise, ensuring the availability of financial resources, effectively integrating employees into the process, and fostering a flexible corporate culture. Their study further identifies comprehensive planning, collaboration with external partners, efficient management of data interfaces, interdisciplinary communication, establishment of adaptable organizational structures, and ensuring data security as pivotal factors for the success of Industry 4.0 initiatives. In contrast, the United States has been actively exploring various dimensions of Industry 4.0, spanning research and development (R&D), technology adoption, and talent management. (Bosman et al., 2020) suggest that smaller-scale manufacturers, particularly those with fewer than 20 employees and limited financial resources (sales under $10 million), prioritize the adoption of digital technologies on the factory floor to enhance productivity, quality, and safety. Meanwhile, larger manufacturers with more employees (20 or more) and greater financial resources (sales of $10m or more) prioritize technologies that support enterprise operations.

The implementation of Industry 4.0 in developing nations remains limited. (Luthra & Mangla, 2018) identified that organizational challenges are the most prominent in these regions, followed by technological, strategic, legal, and ethical issues. These insights are crucial for practitioners, policymakers, regulatory bodies, and managers, as they offer valuable guidance on tackling the hurdles in adopting Industry 4.0 for supply chain sustainability. In Pakistan, the absence of a well-defined understanding and definition of Industry 4.0 presents a barrier to its efficient integration into business operations. Despite the evident necessity, the Pakistani government has yet to initiate targeted Industry 4.0 programs aimed at promoting renewable energy, enhancing internal production processes, facilitating technology-driven organizational transformations, or fostering workforce development through training and educational initiatives. Conversely, China is actively advancing Industry 4.0 initiatives to bolster its existing industries and fortify its global manufacturing standing. However, research by (Stoycheva et al., 2018) reveals that private and large companies are more inclined to adopt Industry 4.0 strategies independently, with government subsidies playing a less significant role in these decisions. The adoption of Industry 4.0 positively impacts firms' financial performance, innovation, and stock returns, but not necessarily supply chain efficiency. It also improves a firm's information transparency. An analysis by (H. W. Lee, 2019) examined secondary data from a survey encompassing 27 industrial sectors and 2225 companies in Brazil, investigating the correlation between the adoption of Industry 4.0 technologies and the anticipated benefits in product enhancement, operational efficiency, and potential drawbacks. Contrary to prevailing assumptions, Lee's regression analysis suggests that while certain Industry 4.0 technologies are perceived as advantageous for industrial performance, others fail to meet these expectations. Similarly, (Dalenogare et al., 2018a) propose that fostering organizational justice and implementing work-life balance initiatives can enhance organizational performance by reinforcing its groundwork. However, they caution that the implementation of diversity programs aimed at upholding democratic principles may have adverse short-term effects on organizational performance.

2.4 Importance of EIT for Developing Economies

The significance of Small and Medium-sized Enterprises (SMEs) in driving industrial growth within a nation cannot be overstated (Faraz Mubarak et al., 2019). In Pakistan, SMEs are classified based on criteria such as the number of employees (up to 250), paid-up capital (up to 25 million Rs.), and annual sales (up to 250 million Rs.) (Qureshi & Herani, 2011). Comprising approximately 90% of all enterprises in Pakistan, SMEs play a vital role by employing 80% of the non-agricultural workforce and contributing nearly 40% to the country's annual GDP. However, unlike larger formal sector enterprises, SMEs frequently encounter challenges related to financial and other resource constraints. In addressing these challenges, it's essential to establish a support system for SMEs, aiding them in areas like technological advancements, marketing, financial aid, and training in human resources (SMEDA, 2019). Despite their economic significance, Pakistani SMEs face several issues that considerably impede their efficiency. These hurdles encompass a deficient business information infrastructure, a lack of strategic planning, and an insufficiency in human capital to address contemporary business requirements (Wielgos et al., 2021; Faraz Mubarak et al., 2019). To address these shortcomings and enhance the status of SMEs, the integration of advanced digital technologies from the Emerging Industrial Technologies (EIT) spectrum into their operational frameworks is imperative (Shahbaz et al., 2018; Dar et al., 2017).

The textile sector in Pakistan plays a crucial role as a key manufacturing industry, accounting for 57 percent of the nation's exports and providing employment to a large segment of the workforce. Despite being the eighth largest exporter of textiles in the world, Pakistan has been facing a significant and prolonged downturn in its textile exports, resulting in a marked reduction in overall export figures to their lowest in six years (A. Khan & Khan, 2010). This downturn in exports has adversely affected Pakistan's Gross Domestic Product (GDP). Several factors contribute to this decline, including inadequate investment in research and development, lack of modernization in facilities, and rising manufacturing costs. As a result, Pakistan's textile industry is experiencing not only a decrease in exports but also a diminishing market share internationally (S. Ali, 2021).

Alongside the production sector's struggles, the services sector in Pakistan is grappling with its own set of challenges in achieving expected performance levels (Shamsi, 2015). Notably, the logistics industry in the country is facing numerous difficulties, largely due to insufficient technological advancements. The instability of Pakistan's e-commerce market exacerbates challenges for the logistics sector (Shamsi, 2015). Moreover, Pakistan's logistics industry trails behind neighboring countries such as China, India, and Malaysia in terms of development and efficiency (Hameed et al., 2017).

The apparel sector in Pakistan is a significant contributor to the country's textile exports, accounting for approximately 20% of them (A. Javed & Atif, 2019). As a vital source of foreign exchange earnings, this industry is central to Pakistan's economic landscape (A. Javed & Atif, 2019). However, despite its critical role, the clothing industry has been facing a slowdown in growth, as highlighted in the World Trade Organization (WTO) 2019 report (World Bank, 2019). This downturn is reflected in the reduction of textile and apparel exports, which saw a 15% drop in June 2019 compared to the same month in the previous year (PBS, 2020). When benchmarked against other developing countries, such as Bangladesh and Vietnam, Pakistan's apparel industry's share in global exports is modest, representing only 1.10% (A. M. Javed et al., 2020). This comparison underscores the challenges faced by Pakistan in maintaining and enhancing its position in the global apparel market.

The studies conducted by (Imran et al., 2018), (S. A. R. Khan et al., 2021) contribute valuable insights into the impact of various technological advancements on different sectors in Pakistan. (Imran et al., 2018) focused on assessing the influence of critical Industry 4.0 elements on the production and service sectors, particularly in the textile and logistics industries. Similarly, (S. A. R. Khan et al., 2021) explored the effects of blockchain technology on circular economy practices and eco-environmental performance, shedding light on the interconnectedness of technology adoption and sustainability initiatives. Furthermore, (Kazmi & Abbas, 2021) delved into the impact of Industry 4.0 technologies on job sustainability and worker performance in developing areas, emphasizing the importance of soft skills development and training in enhancing adaptability. Lastly, (Malik & Imran, 2022) unveiled the positive effect of Emerging Industrial Technologies (EIT) on firm performance, highlighting the mediating role of factors like employee involvement and mass customization capabilities. These studies collectively contribute to understanding the implications of technological advancements and innovation on various aspects of business and industry in Pakistan.

The study conducted by (Iqbal & Rahim, 2021) delves into the ethical dilemmas associated with Emerging Industrial Technologies (EIT), with a particular focus on issues such as unemployment and the transition to a knowledge-based economy. Their research provides a comprehensive review of Pakistan's stance on the digital economy, the challenges posed by unemployment, and the country's efforts to embrace digital transformation amidst the ongoing industrial revolution. Similarly, (Faraz Mubarak et al., 2019) investigated the impact of various Industrial revolutionary technologies on the performance of Small and Medium-sized Enterprises (SMEs) in Pakistan, highlighting the significant enhancements in business performance attributable to big data, cyber-physical systems, and interoperability. Furthermore, (Umar et al., 2022) demonstrated the mediating role of Green Supply Chain Management (GSCM) practices in the relationship between digitalization and both economic and environmental performance, underscoring the positive influence of Industry 4.0 technologies on GSCM practices. Additionally, (Kalam et al., 2019) explored the potential of Industry 4.0 in Pakistan's Oil and Gas sector, developing an Artificial Neural Network (ANN) model to estimate gas rates using various input parameters. Moreover, (Butt et al., 2020) aimed to identify factors motivating the integration and implementation of Industrial Revolution (IR) 4.0 in Pakistan's education system, highlighting the lack of a systematic framework for Education 4.0 despite motivated educators and existing policies. Their findings underscored the country's need for a structured plan or framework to integrate IR 4.0 effectively, which would significantly advance the progression of Education 4.0 in Pakistan.

The study conducted by (Tariq, 2022) explores the impact of emerging technologies on sustainable production and services within Pakistan's petroleum and coal sector. It emphasizes the pivotal role of various industrial revolution technologies, including cloud computing, big data, cyber-physical systems (CPS), and the Internet of Things, in enhancing performance and facilitating more efficient production and service delivery. The research also underscores the importance of effective team management and the cultivation of shared values to successfully address the challenges posed by the fourth industrial revolution. Similarly, (K. Ali & Kausar, 2022) delve into the relationship between innovation and organizational sustainability in Pakistan's manufacturing sector. The study investigates the mediating role of continuous improvement and the moderating effect of Industry 4.0 in this relationship. Their findings reveal a direct and significant link between innovation and organizational sustainability, with continuous improvement mediating the impact of innovation on sustainability. Furthermore, Industry 4.0 emerges as a moderator in these relationships, influencing the dynamics between innovation, continuous improvement, and sustainability.

2.5 Convergence of EIT and OS

Manufacturing organizations, responding to the fluctuating demands of the market and tight profit margins, are increasingly finding it necessary to reevaluate their process frameworks (Lindner et al., 2019). In this pursuit, business managers are progressively focused on incorporating innovative technologies into their supply chain operations to boost efficiency and achieve sustainability (Madan Shankar et al., 2017). Moreover, the creation of sustainable products has emerged as a crucial factor for remaining competitive in the international arena. In this scenario, it has become essential for companies to adopt a comprehensive approach that encompasses not only economic factors but also environmental and social dimensions of manufacturing (Gbededo et al., 2018). As a result, there is a growing trend among organizations to investigate and adopt emerging technologies that align with their sustainability goals.

The potential of Emerging Industry 4.0 technologies closely aligns with the sustainability objectives of organizations. Industry 4.0 facilitates the integration of intelligent devices and systems into digital manufacturing and business operations (Martin et al., 2000a; Seuring & Müller, 2008). This convergence of technology enhances product customization, improves production efficiency, fosters resource conservation, reduces waste, and enhances workplace safety. Key technologies encompassed within Industry 4.0, such as Artificial Intelligence (AI), Autonomous Robots, Augmented Reality (AR), Additive Manufacturing (AM), Circular Economy (CE), Cybersecurity (CS), Internet of Things (IoT), Big Data Analytics (BDA), Cloud Computing (CC), and both Vertical and Horizontal Integration, play crucial roles in supporting diverse sectors including manufacturing, services, and healthcare (Whittle et al., 2019). These technologies not only advance operational capabilities but also play a significant role in driving sustainable practices across industries.

The current body of research highlights the critical role of Emerging Industrial Technologies (EIT) in the context of the circular economy, a key element in sustainability studies. Recent empirical research, such as those conducted by (S. Kamble et al., 2020; Li et al., 2020), provides evidence supporting the positive influence of Industry 4.0 technologies on promoting sustainable development. (Bag et al., 2021) assert that the integration of Industry 4.0 technologies facilitates automation and digitalization, which are pivotal for gaining a competitive edge. The authors further identify crucial sustainability and circular economy principles, including "Refusing, Rethinking, Reducing, Reusing, Repairing, Refurbishing, Remanufacturing, Repurposing, Recycling, and Recovering." These principles can be effectively realized through the adoption of Industry 4.0 technologies. Additionally, (Rajput & Singh, 2019) explore the potential of digital transformation in enhancing the efficiency of sustainable supply chains. It focuses on how digitalization enables transparent and real-time monitoring of products, which is a crucial aspect of sustainable supply chain management. This body of research collectively underscores the synergy between Industry 4.0 technologies and sustainable development goals, particularly in the realm of circular economies.

(de Camargo Fiorini & Jabbour, 2017) highlighted the importance of self-configuration and self-optimization in the sustainability of supply chains, noting how these elements enhance efficiency and dynamism. To support the shift from a linear to a circular economy within supply chains, (Blunck & Werthmann, 2017) advocated for integrating value networks through Industry 4.0 technologies to achieve transparency. (García-Moreno & López-Ruiz, 2023; Govindan & Hasanagic, 2018) concentrated on integrating industrial systems to optimize resource utilization and promote waste reuse, resulting in both economic and environmental benefits. (Lu et al., 2019; Xu, 2012) discussed the potential of cloud manufacturing in facilitating on-demand manufacturing services via internet connectivity and its role in enhancing cloud-based cyber-physical production systems. (Cardin, 2019) highlighted that the adoption of Cyber-physical production systems (CPPS) signifies a significant shift in manufacturing processes. This transformation offers various advantages, including optimized production processes, resource-efficient production methods, and an emphasis on human-centered production. (Lu et al., 2019) proposed an energy-efficient manufacturing architecture within an open CPPS, allowing for self-configuration of manufacturing activities and improved operational efficiency. This study underscored the interconnectedness of CPPS with various elements in the manufacturing process and its influence on customized closed-loop supply chains. (Liu et al., 2019) investigated the role of human-robot collaboration in promoting sustainable manufacturing practices. They emphasized that EIT, characterized by the digital transformation of manufacturing, facilitates the exchange of heterogeneous data between physical and virtual environments, thereby enhancing the efficiency and sustainability of manufacturing processes.

Differing from the studies mentioned earlier, (Tortorella et al., 2018) devised a sustainable business strategy that integrated digital technologies to enhance waste recycling and foster innovation in product development. This strategy yielded significant reductions in resource usage and optimization of natural resources. (S. S. Kamble et al., 2018) proposed a comprehensive framework for sustainable Industry 4.0, highlighting the crucial role of emerging technologies in facilitating efficient human-machine collaboration and seamless integration of shop-floor equipment. Such integration leads to enhanced financial efficiency, improved workplace safety, and better environmental protection. (Ghobakhloo & Fathi, 2021) explored the potential benefits of EIT in terms of social and environmental sustainability. This study investigated various aspects such as the reduction of energy consumption, the diminution of carbon footprints, and advancements in social welfare, highlighting the broad-reaching implications of EIT in fostering sustainable practices. Additionally, (Martin et al., 2000b; Moktadir et al., 2018) underscored the importance of raising awareness and providing accessible information about green design and disposal systems. This approach is crucial for facilitating sustainable manufacturing practices. By educating and informing stakeholders about these practices, companies can make more environmentally responsible choices, contributing to overall sustainability in the manufacturing sector.

The study by (Bai et al., 2020b) uncovered significant variations in the impact of Industry 4.0 emerging technologies on sustainability, with the influence differing based on the specific technology and sustainability aspect in focus. This finding indicates that the relationship between Industry 4.0 technologies and sustainability is complex and multi-faceted. Supporting this notion, (Dalenogare et al., 2018a) found that while the adoption of various EIT may differ among manufacturing industries, their implementation consistently leads to increased productivity. This enhancement is achieved through product innovation, improved production efficiency, and operational cost reduction. This underscores the potential of Industry 4.0 technologies to drive significant improvements in the manufacturing sector.

2.6 Organizational Ambidexterity

Organizational Ambidexterity (OA) refers to an organization's ability to balance and effectively manage both exploration and exploitation activities (Fernández-Pérez de la Lastra et al., 2022). Exploration involves seeking new opportunities, experimenting with innovative approaches, and adapting to changing environments. Exploitation, on the other hand, entails maximizing existing resources, capabilities, and processes to improve efficiency and optimize performance (Aftab et al., 2022).

The relationship between EIT and OA lies in their mutual influence. EIT can provide opportunities for organizations to explore and adopt new technologies, fostering innovation and enabling organizations to adapt to changing market dynamics (Benzidia et al., 2021). Conversely, OA plays a vital role in facilitating the successful adoption and integration of EIT. Organizations that possess high levels of ambidexterity are more likely to effectively explore and exploit emerging technologies (Aftab et al., 2022), leveraging them to achieve sustainable competitive advantages. Numerous empirical studies have consistently demonstrated a positive association between capabilities in Big Data Analytics (BDA) and various dimensions of organizational ambidexterity, including supply chain ambidexterity (Wamba et al., 2020), human ambidexterity (Dezi et al., 2018), ambidextrous business process management, and ambidexterity and agility (Simeoni et al., 2020). Multiple studies have argued in favor of the importance of achieving a harmonious balance between exploitation and exploration innovation for sustaining organizational performance (Gomes et al., 2020; Katou et al., 2021; Simeoni et al., 2020). Simeoni et al. (2019) proposed that the ambidextrous capability of balancing paradoxical yet complementary tasks holds significant potential for aligning economic profitability and social-environmental sustainability objectives. Building on a case study, (Aftab et al., 2022)contended that ambidexterity plays a crucial role in preventing organizations from falling into the trap of polarized development that prioritizes either sustainability or profitability. Researchers further emphasized that such a strategy could be counterproductive and vulnerable to adverse circumstances over the long term. This argument is supported by the findings of (Gomes et al., 2020), who substantiated that embracing and reconciling divergences and tensions between exploration and exploitation could lead to enhanced sustainable manufacturing outcomes.

OA can play a significant role in promoting organizational sustainability. Through ambidextrous practices, organizations can effectively manage the exploration and exploitation of EIT. This enables them to adapt to disruptive technological changes, foster innovation, and maintain a balance between short-term efficiency and long-term adaptation, resulting in improved organizational performance and sustainability (Aftab et al., 2022; Gomes et al., 2020; Katou et al., 2021; Simeoni et al., 2020).

2.7 Research Gap

After an extensive review of the current literature on organizational sustainability and organizational ambidexterity in the context of EIT, the subsequent research gaps were identified.

- While several studies (Koplin et al., 2007; Beekaroo et al., 2019) have documented successful instances of technology adoption in developed countries, there remains a noticeable gap in research concerning the achievement of sustainability in manufacturing organizations in developing countries, such as Pakistan.

- Research conducted on Pakistan's manufacturing industry, including works by (K. Ali & Kausar, 2022; Kalam et al., 2019; Faraz Mubarak et al., 2019; S. A. R. Khan et al., 2021; Umar et al., 2022; Tariq, 2022) lacks a comprehensive approach to exploring the capabilities of EIT (I4.0) in achieving sustainability. Additionally, these studies have limited their focus to only one or two specific manufacturing sectors. Future research needs to encompass system integrators, solutions providers, and Industry 4.0 experts, who are crucial in facilitating transformation.

The challenges and statistics stated in Chapter 1 also necessitate the need for research within the context of developing economies, aiming to provide industry experts and government stakeholders with a comprehensive understanding of the impact and interrelationships between Emerging Technological Innovations (ETI), Organizational Ambidexterity (OA), and Organizational Sustainability (OS). Such research endeavors will aid in formulating policies and strategies that promote the widespread adoption of emerging industrial trends, enabling these economies to harness the potential benefits offered by technological advancements.

2.8 Research Model and Hypothesis Formulation

2.8.1 Emerging Industrial Technologies

The emergence of Emerging Industrial Technologies (EIT) is underpinned by a core set of technological advancements, including Artificial Intelligence, Internet of Things, Autonomous Robots, Simulation, Augmented Reality, Additive Manufacturing, Cloud Computing, Cybersecurity, Big Data and Analytics, as well as Vertical and Horizontal Integration. While the sustainability implications of cloud computing, simulation, and big data analytics have been extensively discussed in existing literature (Xu, 2012; Shdifat et al., 2022; J. Lee et al., 2014), this research focuses on four EIT advancements that have received limited exploration in previous studies.

2.8.1.1 Artificial Intelligence (AI)

The Internet of Things (IoT) generates massive volumes of data, which can be harnessed to enhance production efficiency and enable intelligent automation. Artificial Intelligence (AI) and Machine Learning techniques offer valuable opportunities to extract insights from this Big Data, uncover hidden patterns, and develop predictive mechanisms for achieving the objectives of smart manufacturing (Shaikh et al., 2021). Various learning approaches, including supervised, unsupervised, semi-supervised, and reinforcement learning, can be effectively employed at different stages of the manufacturing process (Ghahramani et al., 2020). However, challenges such as non-representative data, insufficient contextual data, garbage data, denormalized data, increased model training times, and real-time model updating can impede the effectiveness of AI-based approaches for automated and intelligent manufacturing. Based on the preceding explanation, the authors posit the following hypothesis.

- H1a: Artificial Intelligence (AI) positively impacts Organizational Sustainability (OS)
- H5: Artificial Intelligence (AI) positively impacts Organizational Ambidexterity (OA)

2.8.1.2 Internet of Things (IoT)

The Internet of Things (IoT) stands as a cornerstone within the domain of Emerging Industrial Technologies (EIT), facilitating the connectivity and communication of physical devices and objects via the Internet. This technology integrates sensors, actuators, and networked systems to enable real-time data collection, analysis, and sharing. IoT plays a pivotal role in enhancing monitoring, automation, and optimization of manufacturing processes, leading to enhanced operational efficiency, resource utilization, and overall productivity (J. Jin et al., 2014). Furthermore, IoT facilitates the seamless integration of various components within the production ecosystem, promoting interoperability and collaboration among machines, systems, and human operators. Research across various domains has explored IoT applications, including predictive maintenance, supply chain management, and energy management, demonstrating its positive effects on cost reduction, quality enhancement, and environmental sustainability in manufacturing (Tan & Wang, 2010; Gilchrist, 2016; Miorandi et al., 2012). Given these insights, the authors put forth the following hypothesis."

- H2a: Internet of Things (IoT) positively impacts Organizational Sustainability (OS)

- H6: Internet of Things (IoT) positively impacts Organizational Ambidexterity (OA)

2.8.1.3 Autonomous Robots (AuR)

Advanced industrial robots equipped with intelligent capabilities are specifically engineered to carry out tasks with a strong emphasis on versatility, safety, flexibility, and collaboration (Umar et al., 2022; Noor Hasnan & Yusoff, 2018). As technological advancements continue, robots are anticipated to seamlessly interact with one another and operate in close proximity to humans, with a paramount focus on safety protocols. Furthermore, these next-generation robots are expected to exhibit enhanced capabilities while maintaining cost-effectiveness in comparison to current manufacturing robots. This evolution in robotics has the potential to bring about a transformative impact across various industries. It will empower robots to learn from their human counterparts and execute a broader spectrum of tasks with heightened efficiency and adaptability (Kamarul Bahrin et al., 2016). Given the insights presented above, the authors propose the following hypothesis.

- H3a: Autonomous Robots (AuR) positively impact Organizational Sustainability (OS)

- H7: Autonomous Robots (AuR) positively impact Organizational Ambidexterity (OA)

2.8.1.4 Mobile Technologies (MT)

MT in manufacturing consists of the utilization of portable electronic devices and wireless communication technologies to enhance operational efficiency and facilitate real-time data exchange within manufacturing processes. These technologies include smartphones, tablets, wearables, and other mobile devices equipped with relevant applications and connectivity capabilities.

The integration of MT into manufacturing operations offers several advantages. Firstly, these technologies enable the real-time monitoring and control of manufacturing processes, empowering workers and supervisors to access critical information and make informed decisions while on the move (Morkos et al., 2012). Mobile devices provide access to real-time data sourced from sensors, equipment, and production systems, enabling prompt responses to anomalies or issues that may arise. Secondly, MT promotes mobility and flexibility within the manufacturing environment. Workers can traverse the production floor freely while remaining connected to pertinent systems and information (G. Zhou & Jiang, 2005). This enhanced flexibility facilitates collaboration, expedites communication and coordination among team members, and fosters the exchange of expertise and knowledge. Moreover, MT can enhance inventory management and logistics efficiency in manufacturing. Mobile devices can be employed for inventory tracking, barcode scanning, and real-time updates on material availability and movements (Barata et al., 2020). These capabilities facilitate accurate inventory control, diminish errors, and streamline supply chain operations. Lastly, MT can support training and skill development in manufacturing settings. Mobile devices serve as conduits for delivering training modules, instructional videos, and interactive guides, allowing workers to conveniently access learning materials and enrich their knowledge and competencies while on the job (Morkos et al., 2012).

- H4a: Mobile Technologies (MT) positively impacts Organizational Sustainability (OS)

- H8: Mobile Technologies (MT) positively impact Organizational Ambidexterity (OA)

2.8.2 Organizational Ambidexterity (OA)

Organizational Agility (OA) encompasses the capacity of firms to effectively leverage their existing market competencies while simultaneously exploring new opportunities and pursuing radical innovations (Ed-Dafali et al., 2023a; Raisch et al., 2009). Achieving a balance between exploiting existing competencies and exploring new ones involves making explicit and implicit choices based on strategic priorities and resource constraints. These choices become deeply ingrained within the organizational culture, norms, and decision-making processes (Tortorella et al., 2018). Scholars widely argue that firms must concurrently focus on both exploitative and explorative innovations to attain and sustain a competitive advantage in both current and future markets (Ghantous & Alnawas, 2020).

Exploitative innovations are characterized by incremental changes as firms modify their products, services, and business processes to align with the prevailing customer requirements. The primary objective of exploitative innovations is to enhance the efficiency of existing services (Raisch et al., 2009), typically exhibiting a lower degree of novelty and requiring relatively fewer resources, business risk, and investment. On the other hand, exploratory innovations are characterized by their revolutionary or adaptive nature (Cao et al., 2009). These innovations entail extensive market research and the cultivation of sensing capabilities to identify novel opportunities for generating new ideas, services, and business processes (Patel et al., 2012; Tortorella et al., 2018). The aim is to drive significant transformations in existing business operations and offerings by developing innovations that cater to emerging customer demands (Tortorella et al., 2018).

The concept of OA encompasses two fundamental attributes: alignment and adaptability (Andriopoulos & Lewis, 2009). These attributes are focused on instigating changes within business processes to effectively address both current and future customer needs, demands, and preferences (Belhadi et al., 2022). Businesses that aspire to outperform their competitors must embrace both exploitative and explorative innovations, recognizing that these two approaches are complementary rather than mutually exclusive in driving organizational success (Ed-Dafali et al., 2023b). The hypotheses formulated for this study are as follows:

- H1b: Organizational Ambidexterity mediates the relationship between AI and Organizational Sustainability
- H2b: Organizational Ambidexterity mediates the relationship between IoT and Organizational Sustainability
- H3b: Organizational Ambidexterity mediates the relationship between AuR and Organizational Sustainability
- H4b: Organizational Ambidexterity mediates the relationship between MT and Organizational Sustainability
- H9: Ambidexterity (OA) positively impacts Organizational Sustainability (OS)

The conceptual framework (refer to Fig. 1) employed in this study encompasses four prominent Emerging Industrial Technologies, along with the mediating variable of organizational agility (OA), which is utilized to ascertain the influence on organizational sustainability.

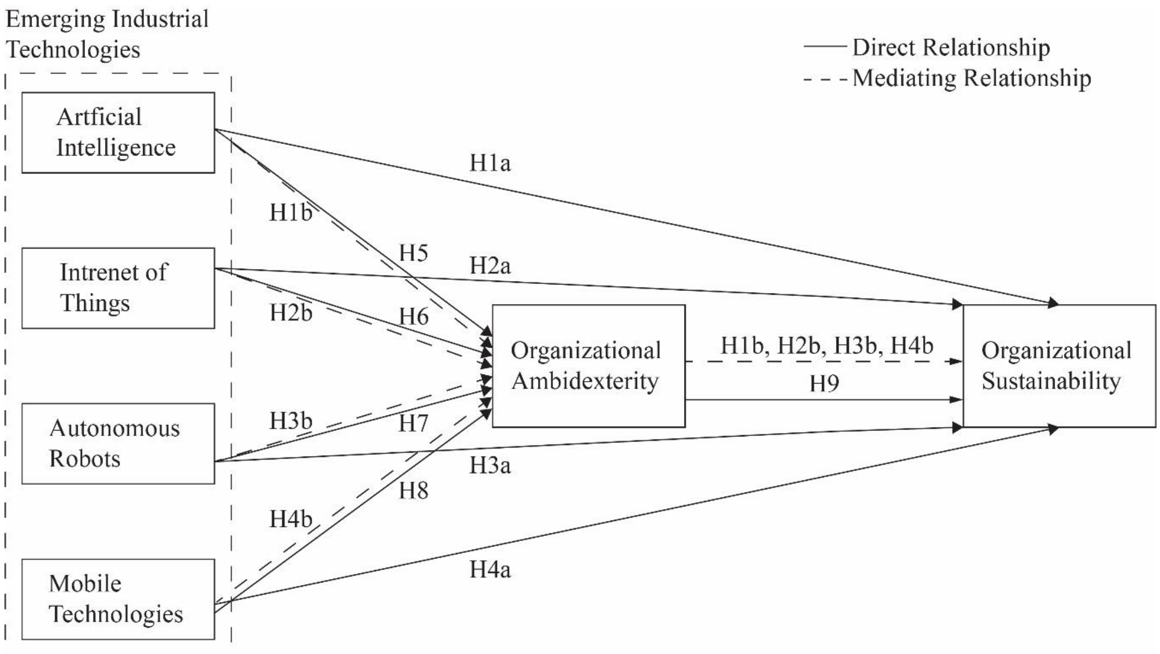

Figure 2.1: Research Framework

CHAPTER 3: RESEARCH METHODOLOGY

Research methodology refers to the systematic approach used to address a research problem. It involves studying the various steps undertaken by a researcher during their investigation, including the rationale behind their choices. Understanding research methods and the selected methodology is crucial for researchers as it guides their study design and decision-making process. By familiarizing themselves with different research techniques and methodologies, researchers can enhance the rigor and validity of their research outcomes (C.R. Kothari, 2004).

3.1 Research Paradigm

A research paradigm encompasses various elements, including epistemology, ontology, technique, and approach, which guide the research process. Within a specific paradigm, researchers have the flexibility to choose from multiple methodologies. These methodologies serve as systematic approaches to conducting research and aid researchers in conducting rigorous investigations. The research field recognizes three main research paradigms: quantitative, qualitative, and mixed methods. Figure 2 illustrates these paradigms.

For this thesis, the chosen research paradigm is quantitative, indicating a preference for numerical data analysis. The research design employed is non-experimental, and the study relies on survey-based data collection methods.

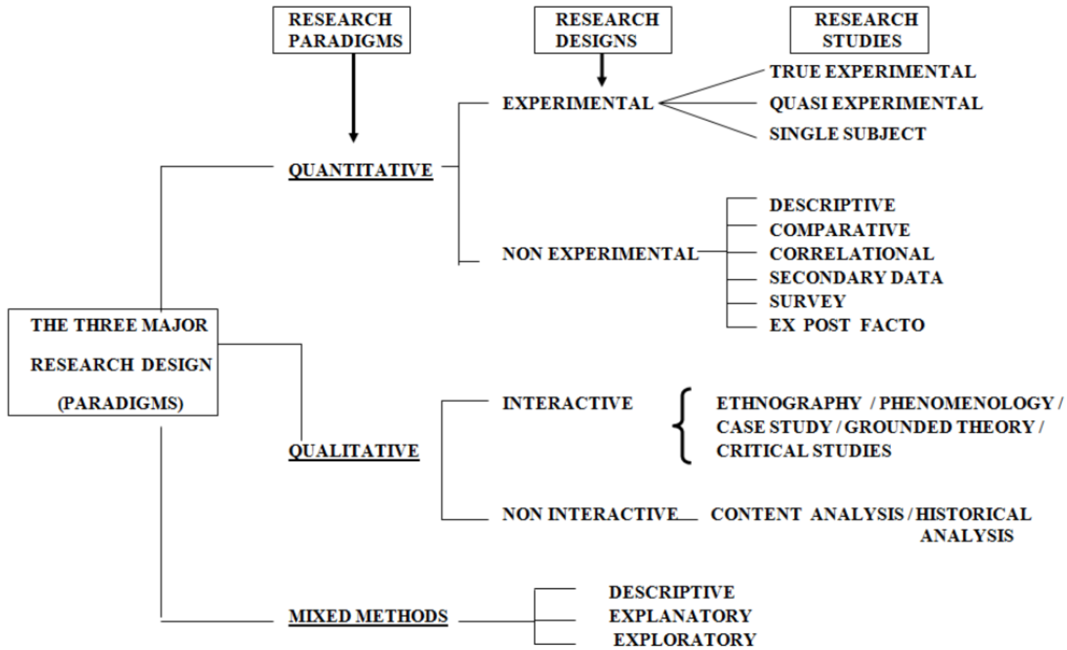

Figure 3.12: Research Paradigm, Research Design, and Research Studies (Khaldi, 2017)

The targeted population for this study consisted of middle and senior managers working in Pakistani textile factories and included the system integrators and service providers to the textile industry. The textile sector in Pakistan contributes approximately 18.8% of the gross value added and employs a considerable portion of the workforce, with approximately 23.9% of employees engaged in industrial activities.

3.2 Sampling Size and Data Collection

Roscoe (1975) proposed a guideline for determining an appropriate sample size, recommending a range of more than 30 to less than 500 respondents (as cited in Sekaran and Bougie, 2012). Conversely, Comrey and Lee (1992) argued that a sample size exceeding 200 is sufficient. This view is supported by Haque et al. (2017), who suggest that a sample size over 200 is acceptable for drawing reliable conclusions in social science research.

Web-based surveys have emerged as a prevailing method for data collection, surpassing traditional approaches such as mail and face-to-face interviews. With the exponential growth of Internet users worldwide, reaching 100 million by 1998, researchers have increasingly adopted Internet tools, including email and web-based surveys, for their research endeavors. Furthermore, the recent global pandemic has further accelerated the shift towards web-based surveys. The table presented below provides a succinct overview of the benefits associated with utilizing web-based surveys compared to other data collection techniques.

Table 3.13: Advantages of web-based survey (Mertler, C., 2002)

High response rate	Web-based surveys exhibit a higher response rate and offer a more expedient means of gathering data compared to traditional methods.
Paperless approach	Web-based surveys are significantly more efficient as they eliminate the need to track down and distribute physical paper copies of questionnaires. There is no waiting period involved in sending and receiving the surveys, leading to a streamlined data collection process.
Electronic records	Web-based surveys offer a notable advantage in terms of efficiency by eliminating the logistical challenges associated with tracking and distributing physical paper copies of questionnaires. The absence of a waiting period for sending and receiving surveys enhances the speed and efficiency of the data collection process, resulting in a streamlined and expedited research endeavor.
Resource efficient	Web-based surveys offer the advantage of cost savings, as they eliminate the need for printing and postage expenses associated with traditional paper surveys.

According to the recommended sampling procedure for questionnaire administration outlined by (D.A. Dillman, 2007), an online survey was developed using Google Forms and distributed to the target audience through cold messaging on various platforms, emails, and industry contacts. Before distribution, a promise of confidentiality was given to ensure data security. As an incentive for participation, respondents were offered access to a summary of the research findings. A total of 203 responses were received, resulting in a response rate of 18.32%, and only 192 were usable. One notable challenge faced during data collection was the respondents' limited understanding of EIT, leading some to refrain from participating in the survey. This lack of familiarity with EIT concepts among potential respondents could have influenced the response rate, as they expressed concerns about unknowingly introducing biases into the research. However, their interest in the study's outcomes suggests a growing awareness and curiosity about the role of EIT in the textile sector, underscoring the relevance and timeliness of this research in contributing to the broader industry dialogue. (John T. Roscoe. Holt, 1975) proposed a guideline for determining an appropriate sample size, recommending a range of more than 30 to less than 500 respondents (as cited in (Sekaran, 2013)). Thus, 192 responses considered for this study were appropriate and sufficient. The data was collected from May 2023 to August 2023.

The sampling technique employed in this study was a combination of purposive sampling and convenience sampling. A set of filters was applied on LinkedIn, including region (Pakistan), industry (textile), and keywords (e.g., "Managers," "C-suite," "Digital Transformation," and "Digitalization"), to purposefully select participants who possessed the desired expertise and knowledge. This ensured that the sample comprised managers and C-suite executives in the manufacturing industry who were knowledgeable about digital transformation and EIT. Furthermore, convenience sampling was utilized to take advantage of the available pool of individuals on LinkedIn who met the predetermined criteria. Therefore, the sampling technique adopted for this study can be characterized as a combination of purposive sampling, which allowed for the targeted selection of participants based on specific criteria, and convenience sampling, which leveraged the accessibility of individuals through the LinkedIn platform.

In this study, a Likert scale ranging from "strongly agree" to "strongly disagree" was utilized for measurement. The assessment of Emerging Industrial Technologies (EIT) incorporated a 22-item scale, adapted from (Chiarini, 2021; Dubey et al., 2020; Li et al., 2020), focusing on AI, IoT, Autonomous Robots, and Mobile Technologies. Organizational Ambidexterity (OA) was evaluated using a six-item scale based on the work of (Belhadi et al., 2022; Ed-Dafali et al., 2023). Additionally, Organizational Sustainability (OS) was measured through a six-item scale derived from (Chiarini, 2021; S. Kamble et al., 2020). Table 3.1 presents a gender distribution with a majority of male respondents (83%) compared to females (17%). In terms of job roles, Managers form the largest group (38%). The experience profile presents a dominance of mid-career professionals (58% with 5-10 years of experience), indicating a blend of seasoned insight and current operational knowledge. The organizational age data shows a strong representation of well-established companies (80% over 10 years old), suggesting that the findings are grounded in mature business practices. Employee numbers skew towards larger organizations (65% with over 300 employees), emphasizing perspectives from scalable operations.

Table 3.2: Demographics of the survey respondents

Gender	Frequency	Percentage
Male	160	83%
Female	32	17%
Designation		
Executives	56	29%
Sr. Manager	28	15%
Manager	72	38%
Automation Engineer	36	19%

Respondent Experience (Years)		
<5	112	19%
5 – 10	36	58%
>10	44	23%
Age of Organization (Years)		
<5	20	10%
5 – 10	20	10%
>10	152	80%
Number of Employees		
<100	52	27%
100 – 300	16	8%
>300	124	65%
Nature of Business		
Textile/Apparel	148	77%
Solution Providers	44	23%

In this research, the Structural Equation Modeling (SEM) technique was applied using SmartPLS-4. Initially, instrument reliability and validity were assessed. Subsequently, SEM analyses were conducted to examine the hypothesized relationships. PLS path modeling, known for its efficacy in depicting complex cause-effect relationships in management research (Gudergan et al., 2008), was particularly applicable to this study.

PLS-SEM is capable of handling intricate models, characterized by numerous constructs, indicators, and structural links (J. Hair, M. Hult, M. Ringle, 2014). Its suitability for early-stage theoretical exploration and its capability to analyze constructs in complex structural models were key considerations, especially given the limited research on the relationship between EIT and OA. PLS-SEM's flexibility with smaller sample sizes and its ability to operate independently of data distribution assumptions further justified its selection (J. Hair, M. Hult, M. Ringle, 2014). The sample size criterion in PLS-SEM is that the sample size should be 10 times the number of paths directed at a single construct (J. Hair, M. Hult, M. Ringle, 2014). This criterion was adequately met in this study with 192 respondents against nine paths pointing at the most complex construct.

CHAPTER 4: ANALYSIS AND RESULTS

4.1 Measurement Model Analysis

The measurement model was analyzed to confirm the reliability and validity of the constructs (referenced in Table 4.1). Initially, factor loadings for all model items surpassed the minimum acceptable threshold of 0.50, aligning with (Hair, 2010). Although the preferred factor loadings of above 0.7 are suggested by (Esposito Vinzi et al., 2010), lower loadings are common in social science research. The implications of removing items with weaker loadings were carefully considered, focusing on the impact on composite reliability, content, and convergent validity. It held to the guideline by (J. Hair, M. Hult, M. Ringle, 2014) to only consider the removal of items with loadings between 0.40 and 0.70 if it enhances composite reliability or average variance extracted (AVE). In this case, the removal of one specific item (MT4, with a loading of 0.589) was assumed unnecessary as the construct's reliability and AVE were already above recommended levels. Furthermore, confidence interval evaluations of the loadings did not justify the exclusion of any items from further analysis.

Reliability was evaluated using Cronbach's alpha, rho_a, and composite reliability, statistics for both were well above the recommended threshold of 0.700, (J. Hair, M. Hult, M. Ringle, 2014). The rho_a values, were between Cronbach's alpha and composite reliability values (Sarstedt et al., 2017), and also surpassed 0.70, indicating robust reliability (Henseler et al., 2016). Convergent validity was established as the AVE exceeded 0.500. Discriminant validity, assessed through the Fornell & Larcker criterion and the Heterotrait–Monotrait ratio of correlations (Henseler et al., 2016), was established, with values below the conservative threshold of 0.85 (refer to Table 4.2 for details).

Table 4.1: Reliability and Validity Analysis Results

Construct(s)	Item(s)	Loadings	Cronbach's alpha	rho_a	Composite Reliability	Average Variance Extracted (AVE)

AI	AI1	0.836	0.845	0.865	0.885	0.565
	AI2	0.766				
	AI3	0.755				
	AI4	0.649				
	AI5	0.675				
	AI6	0.809				
AuR	AuR1	0.643	0.816	0.826	0.867	0.523
	AuR2	0.724				
	AuR3	0.836				
	AuR4	0.634				
	AuR5	0.75				
	AuR6	0.731				
IoT	IoT1	0.81	0.816	0.862	0.867	0.568
	IoT2	0.728				
	IoT3	0.653				
	IoT4	0.805				
	IoT5	0.76				
MT	MT1	0.725	0.726	0.773	0.826	0.547
	MT2	0.797				
	MT3	0.824				

	MT4	0.589				
OA	OA1	0.803	0.894	0.898	0.915	0.574
	OA2	0.784				
	OA3	0.808				
	OA4	0.741				
	OA5	0.717				
	OA6	0.751				
	OA7	0.713				
	OA8	0.741				
OS	OS1	0.604	0.840	0.868	0.881	0.555
	OS2	0.786				
	OS3	0.802				
	OS4	0.798				
	OS5	0.762				
	OS6	0.696				

Abbreviations: AI, Artificial Intelligence; AuR, Autonomous Robots; IoT, Internet of Things; MT, Mobile Technologies; OA, Organizational Ambidexterity; OS, Organizational Sustainability

Table 4.2: Fornell–Larcker criterion & Heterotrait–Monotrait ratio (HTMT) of correlation

Construct(s)	AI	AuR	IoT	MT	OA	OS
AI	*0.752*	0.592	0.824	0.410	0.541	0.388
AuR	0.520	*0.723*	0.474	0.481	0.750	0.609
IoT	0.696	0.439	*0.754*	0.487	0.548	0.263
MT	0.335	0.376	0.391	*0.739*	0.710	0.343
OA	0.489	0.658	0.502	0.590	*0.758*	0.638
OS	0.333	0.534	0.210	0.312	0.591	*0.745*

Notes: Italicized diagonal values represent the square roots of the Average Variance Extracted (AVE). Below these, the values are correlations between constructs; above are the Heterotrait-Monotrait (HTMT) ratios of correlation.

4.2 Structural Model Analysis

In assessing the structural model, R^2, Q^2, and path significance is evaluated. The model's adequacy is measured by R^2 values for the dependent variables, with a benchmark of 0.1 (Falk, 2014) all of which surpassed this threshold in the results (Table 3). Predictive relevance is confirmed through Q^2 values above 0, indicating significant predictive ability for the constructs. The model fit is examined using the standardized root mean square residual (0.121), which is slightly above the recommended value of 0.10. However, this discrepancy is considered less critical in PLS-SEM, as the role of observed correlations versus model-implied correlations differs from that in covariance-based SEM (J. Hair, M. Hult, M. Ringle, 2014).

In the further evaluation of model fit, the study tested hypotheses to determine the significance of the proposed relationships. Hypothesis 1a (H1a) postulated a significant influence of Artificial Intelligence (AI) on Organizational Sustainability (OS). Results affirm this hypothesis, with AI demonstrating a notable effect on OS ($\beta = .127$, $t = 1.850$, $p = .032$), thereby supporting H1a. Similarly, Hypothesis 2a (H2a) and Hypothesis 3a (H3a) postulated a significant influence of the Internet of Things (IoT) and Autonomous Robots (AuR) on Organizational Sustainability (OS) respectively. Results affirm this hypothesis, with IoT demonstrating a significant effect on OS ($\beta = -0.225$, $t = 3.812$, $p < 0.001$) and AuR also demonstrating a significant effect on OS ($\beta = 0.255$, $t = 3.220$, $p = 0.001$). This wasn't the case with Hypothesis 4a (H4a) which states that there is a significant effect of Mobile Technologies (MT) on OS. Results show that there is no significant impact of MT on OS ($\beta = -0.028$, $t = 0.390$, $p = 0.348$).

Further, the influence of AI, IoT, AuR, and MT on Organizational Ambidexterity (OA) was investigated. The analysis yielded robust evidence that IoT, AuR, and MT have significant effects on OA: IoT ($\beta = 0.138$, $t = 2.505$, $p = .006$), AuR ($\beta = .440$, $t = 5.333$, $p < .001$), and MT ($\beta = .355$, $t = 4.574$, $p < .001$). These results affirm Hypotheses 6, 7, and 8. However, AI did not exhibit a statistically significant effect ($\beta = 0.045$, $t = 0.782$, $p = 0.217$) on OA.

Furthermore, the study explored the effect of OA on OS. The findings indicated a significant effect of OA ($\beta = 0.491$, $t = 7.383$, $p < 0.001$) on OS. Consequently, Hypotheses 9 received empirical support.

Additionally, the robustness of these findings was further affirmed through a bootstrapping procedure with 10,000 resamples, leading to the generation of 95% confidence intervals, as delineated in Table 4.3. The deviation of these intervals from zero indicates significant relationships. The results of the hypotheses testing, including these relationships and their statistical validations, are comprehensively summarized in Table 4.3.

Table 4.3: Direct relationship analysis

	Path Coefficient	**Standard deviation (STDEV)**	**t statistics**	**p values**

H1a: AI -> OS	0.127	0.068	1.850	0.032
H2a: IoT -> OS	-0.225	0.059	3.812	0.000
H3a: AuR -> OS	0.255	0.079	3.220	0.001
H4a: MT -> OS	-0.028	0.073	0.390	0.348
H5: AI -> OA	0.045	0.058	0.782	0.217
H6: IoT -> OA	0.138	0.055	2.505	0.006
H7: AuR -> OA	0.440	0.083	5.333	0.000
H8: MT -> OA	0.355	0.078	4.574	0.000
H9: OA -> OS	0.491	0.067	7.383	0.000
R^2: OA = 0.747	Q^2: OA = 0.561			
R^2: OS = 0.545	Q^2: OS = 0.280			

4.3 Mediation Analysis

The mediation analysis sought to examine the role of Organizational Ambidexterity (OA) as a mediator between Emerging Industrial Technologies (EIT) and Organizational Sustainability (OS). The specific indirect effects of EIT on OS, as mediated by OA, produced varied outcomes (See Table 4.4).

The role of OA as a mediator between Artificial Intelligence (AI) and OS was not statistically significant ($\beta = 0.022$, $t = 0.786$, $p = 0.216$), indicating that H1b is not supported. Conversely, the mediating influence of OA on the IoT-OS relationship was substantiated ($\beta = 0.068$, $t = 2.304$, $p = 0.011$), thereby affirming H1b.

Conversely, the relationship between Autonomous Robots (AuR) and OS is partially mediated by OA, as evidenced by the significant indirect effect ($B = 0.216$, $t = 4.559$, $p <$

0.001), validating H2b. This complementary mediation suggests that while AuR directly contributes to OS, OA enhances this relationship, reinforcing the positive impact of AuR on OS. The relationship between the Internet of Things (IoT) and OS presents a competitive partial mediation by OA, validating H3b. Although the indirect effect is positive (B = 0.068, t = 2.304, p = 0.011), the total effect of IoT on OS is negative (B = -0.157, t = 2.236, p = 0.013), indicating that while OA does transmit some of the IoT's positive effects to OS, it also competes with direct negative consequences that IoT may have on OS.

A particularly important finding is the full mediation of OA in the relationship between Mobile Technologies (MT) and OS, validating H4b. The significant indirect effect (B = 0.175, t = 3.607, p < 0.001) in the absence of a significant direct effect (B = -0.028, t = 0.39, p = 0.348) suggests that OA completely accounts for the influence that MT exerts on OS.

The results from the analysis reveal varying roles of OA in shaping the impact of EIT on OS. OA does not mediate the AI-OS relationship, suggesting AI's impact on sustainability is direct and uninfluenced by OA. In the case of AuR, OA acts as a complementary mediator, implying that while AuR directly fosters sustainability, OA amplifies this effect. For IoT, competitive partial mediation is observed, indicating that the direct negative impact of IoT on sustainability is somewhat mitigated by the positive influence through OA. Most notably, the relationship between MT and OS is fully mediated by OA, meaning the effect of MT on sustainability is entirely channeled through the organization's ambidextrous capabilities, indicating the critical role of adaptability and balance in leveraging technology for sustainable outcomes.

Table 4.4: Specific indirect effects

	Path Coefficient	**Standard deviation (STDEV)**	**t statistics**	**p values**	**5%**	**95 %**
AI -> OA -> OS	0.022	0.028	0.786	0.216	-0.025	0.067

AuR -> OA -> OS	0.216	0.047	4.559	0.000	0.142	0.297
IoT -> OA -> OS	0.068	0.029	2.304	0.011	0.024	0.119
MT -> OA -> OS	0.175	0.048	3.607	0.000	0.099	0.258

Table 4.5: Total effects

	Original sample (O)	Standard deviation (STDEV)	t statistics	p values	5%	95%
AI -> OS	0.149	0.067	2.208	0.014	0.037	0.259
AuR -> OS	0.471	0.075	6.267	0.000	0.35	0.596
IoT -> OS	-0.157	0.070	2.236	0.013	-0.263	-0.034
MT -> OS	0.146	0.069	2.116	0.017	0.029	0.255

4.4 Explanatory Power

The R^2 statistics explain the variance in the endogenous variables that can be explained by the exogenous variables. In essence, it reflects the extent to which changes in the dependent variable(s) are identifiable from the independent variable(s) (Shmueli & Koppius, 2011). These values act as a scale of the model's explanatory power, representing its in-sample predictive capability (Rigdon, 2012). The R^2-statistics range from 0 to 1, with higher values denoting increased explanatory power. (Cohen, 1998) provides benchmarks for evaluating R^2-statistics outcomes as substantial (0.26), moderate (0.13), and weak

(0.02). However, the thresholds for acceptable R-squared values are dependent upon the specific research context. For instance, within certain fields such as finance, an R^2-statistics as low as 0.10 may be considered satisfactory, especially in complex prediction tasks like forecasting stock returns (e.g., (Raithel et al., 2012). The present analysis demonstrates that the R^2 statistics for Organizational Ambidexterity (OA) and Organizational Sustainability (OS) are 0.747 and 0.545 respectively (Table 4.3), indicating that both constructs have substantial explanatory power within the model.

To further differentiate the explanatory value of each exogenous variable within the model, the effect size (f2) is calculated, which quantifies the change in R2 statistics when an exogenous construct is omitted. This measure assesses the magnitude of an independent variable's influence on the dependent variable, providing insight into the strength of the relationship between the latent variables. Conventionally, an f2 value of 0.35 is considered high, 0.15 medium, and 0.02 low at the structural level. The f2 values in this analysis range from 0.003 (negligible) to 0.624 (high), indicating varying degrees of influence by the exogenous constructs on the endogenous variables. Lastly, the model's Q^2 values of 0.561 for OA and 0.280 for OS (Table 4.3) state the model's predictive relevance, as values greater than zero signify the model's capability to predict the endogenous constructs effectively.

CHAPTER 5: CONCLUSION, LIMITATIONS, AND FUTURE RESEARCH

While existing literature has underlined the pivotal role of various EITs in enhancing OS within the dynamic landscape of global markets, empirical studies exploring the mediation role of OA in leveraging EIT for OS remain scarce. This study investigates the direct impact of EIT – such as AI, IoT, and AuR – on OS, alongside examining OA's mediation effect. In response to the first research question (RQ1), findings reveal that EIT indeed has a positive impact on OS. Through quantitative analysis, varying degrees of influence from different EITs have been observed, with some technologies demonstrating direct effects on sustainability, while others benefitted from the mediation of OA. This positive correlation highlights EIT's pivotal role in modernizing operational processes, contributing to the environmental, economic, and social sustainability of the textile sector and by extension the whole manufacturing industry. Moving on to the second research question (RQ2), the study provides evidence supporting the mediating role of OA between EIT and OS. Findings reveal that organizations adept at balancing innovative explorations with the exploitation of existing technologies are better positioned to realize the full spectrum of EIT benefits on OS. By addressing these research questions, our study contributes to a deeper understanding of the dynamics between EIT, OA, and OS in the textile sector, providing valuable insights for both academia and industry practitioners. This also highlights the strategic importance of fostering OA to capitalize on EIT, thereby offering significant theoretical and managerial implications for sustainable organizational practices.

In the context of Pakistan's textile sector, the study's results shed light on the intricate dynamics between Emerging Industrial Technologies (EIT) and Organizational Sustainability (OS), with the mediating role of Organizational Ambidexterity (OA). OA plays a significant role in promoting organizational sustainability. Through ambidextrous practices, organizations can effectively manage the exploration and exploitation of EIT. This enables organizations to adapt to disruptive technological changes, foster innovation, and maintain a balance between short-term efficiency and long-term adaptation, resulting in improved organizational performance and sustainability (Aftab et al., 2022; Gomes et al., 2020; Katou et al., 2021; Simeoni et al., 2020).

The analysis concludes a direct impact of AI on OS in Pakistan's textile sector without the mediating role of OA. This direct impact may be attributed to AI's potential to optimize production processes, reduce waste, and enhance product quality, thereby contributing directly to OS without the need for ambidextrous organizational structures. This might reflect a sectoral maturity in AI applications where the technology itself has become a standard rather than a competitive differentiator. Currently, the sector is at the point of a technological shift, with AI adoption in its nascent stage – ranging from some firms undertaking feasibility studies to piloting the digitization of operations, primarily in apparel manufacturers (Noor et al., 2022). This implies that the full potential of AI to drive sustainability is yet to be harnessed. The direct impact may also be indicative of the future trajectory rather than the present situation of the sector. Therefore, the current impact of AI on OS is likely limited and dependent upon how swiftly and effectively the sector can navigate the transition from traditional methods to a more technologically advanced framework, which underscores the sector's need for developing ambidextrous capabilities (Imran et al., 2018).

The complementary partial mediation observed in the relationship between AuR and OS highlights a scenario where technological advancement works synergistically with organizational strategy. AuR improves efficiency and reduces human error, contributing to sustainable outcomes. However, the essence of OA—characterized by its capacity to leverage existing capabilities while concurrently exploring innovative avenues—is critical in maximizing the potential of AuR. This flexibility is crucial in an industry like Pakistan's textiles, marked by fluctuating demands and a pressing need for customization. The application of OA in this context aligns with the principles of reconfigurable manufacturing systems, advocating for a swift and adaptable reconfiguration of manufacturing processes. By embedding OA into the fabric of AuR deployment, Pakistani textile firms not only embrace technological innovation but also cultivate an organizational culture that is agile, responsive, and sustainable. This integration positions these firms to effectively respond to dynamic market trends and customer demands, creating a manufacturing ecosystem that is technologically progressive, adaptable, and sustainably oriented.

The competitive partial mediation of OA in the IoT-OS relationship is indicative of a more complex scenario. While IoT offers substantial benefits through real-time monitoring and data analytics for sustainable practices (Happonen et al., n.d.), its direct relationship with OS is negative. This contradiction might arise from challenges such as the high cost of technology implementation, data security concerns, or a lack of skilled personnel to manage IoT systems (Manglani et al., 2019). The positive mediation by OA suggests that the textile sector's ability to adapt and reconfigure organizational resources is mitigating some of these challenges, thus salvaging the potential positive impact of IoT on sustainability.

Remarkably, the full mediation by OA in the relationship between MT and OS implies that Mobile Technologies alone do not directly influence sustainability. Instead, their effect is entirely channeled through OA. This could be because MT, while its integration offers opportunities to enhance productivity, flexibility, and decision-making in the manufacturing environment, ultimately contributing to improved operational performance and competitiveness (Patil et al., 2021), requires a responsive and adaptive organizational culture to translate these benefits into sustainable outcomes such as enabling users to access information, communicate, and perform various tasks while on the go. MT provides real-time access to critical data, enabling employees to monitor production status, inventory levels, and equipment performance remotely. Mobile apps and platforms facilitate collaboration among teams, allowing seamless information sharing and coordination. In conclusion, for the Pakistani textile sector, this may reflect the need for a strategic pivot towards integrating mobile solutions within an ambidextrous framework to achieve sustainability targets.

The relationship between EIT and OA lies in their mutual influence. EIT can provide opportunities for organizations to explore and adopt new technologies, fostering innovation and enabling organizations to adapt to changing market dynamics (Benzidia et al., 2021). Conversely, OA plays a vital role in facilitating the successful adoption and integration of

EIT. Organizations that possess high levels of ambidexterity are more likely to effectively explore and exploit emerging technologies (Aftab et al., 2022), leveraging them to achieve sustainable competitive advantages.

Overall, the discussion anchored in the study's analytical results underscores the varying roles of OA in mediating the impact of EIT on OS. It highlights the subtle interplay between technology and organizational capability, suggesting that the road to enhancing OS in Pakistan's textile sector is not uniform across different technologies. Instead, it requires a tailored roadmap that considers specific attributes – such as strategic planning and vision, financial resources, employees' engagement in the implementation process, technology and need assessment, infrastructure development, skill development, and cultural change management (Veile et al., 2020) – and implementation contexts of each technological innovation. Somewhat similar findings from (Lee, 2019) also demonstrated that certain Industrial technologies are perceived as advantageous for enhancing industrial performance, product improvement, and operational efficiency while some emerging technologies do not align with above expectations, challenge conventional wisdom.

In conclusion, this study offers an insightful exploration into the integration of EIT into the textile sector of developing economies like Pakistan, underscoring the pivotal role of OA in facilitating this transition. The findings of this study reveal a subtle interplay between technological advancements and organizational strategies, with OA emerging as a critical mediator in harnessing the full potential of technologies such as Autonomous Robots, the Internet of Things, and Mobile Technologies for enhancing OS.

The results of the analysis demonstrate that while some technologies like AI exhibit a direct impact on OS, others, notably AuR and MT, benefit significantly from the mediating influence of OA, indicating a complementary relationship. In contrast, the impact of IoT on OS, modulated by OA, presents a competitive dynamic, highlighting the complexities involved in adopting new technologies. The study reveals the full mediation role of OA in the relationship between MT and OS, illustrating the profound impact organizational agility and adaptability can have in a technologically evolving landscape.

The study's findings thus answer the central research question, demonstrating the integral role of both EIT and OA in advancing sustainable practices in the textile sector.

As the textile sector of developing economies continues to navigate through the challenges and opportunities presented by EIT, this study underscores the importance of developing strategic ambidextrous capabilities. Such capabilities are not merely beneficial but essential for leveraging technological advancements effectively. These capabilities enable organizations to remain agile, responsive, and sustainable in an increasingly competitive and technology-driven global market.

Ultimately, this study contributes to the broader discussion on technology adoption in traditional industries, providing valuable insights for policymakers, industry leaders, and researchers. It highlights the need for a holistic approach that encompasses not just technological upgrades but also organizational and cultural shifts towards greater flexibility and innovation-driven mindsets. The path ahead for Pakistan's textile sector, as illuminated by this research, is one that seamlessly weaves technology with strategic organizational practices, setting the stage for sustainable and competitive growth in the era of digital transformation.

This study contributes significantly to the understanding of technology adoption in traditional industries like Pakistan's textile sector. It highlights the pivotal role of OA in facilitating the integration of EITs like AI, IoT, and Autonomous Robots. By demonstrating OA's mediating effect between EIT and OS, the research enriches existing theories on technology adoption and organizational agility. The study also broadens the discourse on sustainability in technology integration, offering insights into the synergistic potential of these elements for industry transformation, particularly in emerging markets.

From a practical standpoint, the findings of this study serve as a strategic guide for industry practitioners and policymakers. It underscores the importance of fostering an organizational culture that is adaptable and responsive to technological advancements for achieving sustainable growth. This research provides a blueprint for balancing technological innovation with operational flexibility, which is essential for maintaining competitiveness in the global market. Additionally, it suggests that policy frameworks supporting both technological and organizational development are crucial for successful technology adoption in traditional sectors like textiles.

While insightful, this study has some limitations. This study focuses on a specific industry within a unique national context which limits the generalizability of its findings to other sectors or regions. Since based on a cross-sectional design, the study captures a snapshot in time, potentially overlooking long-term trends and the dynamic nature of technological adoption and organizational change. The reliance on self-reported data could introduce biases, affecting the accuracy of insights into EIT adoption and OA's role. Additionally, the focus on certain technologies like AI, IoT, and Autonomous Robots might exclude other relevant emerging technologies. Also, the quantitative approach of the study may not fully encapsulate qualitative factors such as organizational culture or leadership, which are critical in understanding the broader impact of technology integration. Lastly, the rapid evolution of technology presents a challenge, as findings could quickly become outdated with the emergence of new technologies or methodologies post-study. These limitations highlight the need for a careful interpretation of the results and suggest pathways for future research to build upon this foundational work.

Future research built upon findings from this study should consider broadening the scope both industrially and geographically to enhance generalizability. Longitudinal studies would be valuable to understand the long-term effects of EIT and the evolving role of OA. Incorporating qualitative methods can bring out deeper insights into organizational culture and implementation challenges while expanding the range of technologies studied would keep the findings relevant. An interdisciplinary approach, considering external factors like government policies and global trends would provide a more comprehensive understanding. Such future research directions would not only address the current study's limitations but also enrich the understanding of the complex dynamics between technology, organizational strategy, and sustainability in the evolving global textile industry.

5.1 Theoretical Implications

Despite the growing interest of scholars and practitioners in the domain of EIT, with a predominant focus on MNCs, this research advances the understanding of EIT within the context of Pakistan's textile sector – an area that has been underexplored in the academic discourse. The study broadens the theoretical landscape by intricately mapping the mediating influence of OA in harnessing EIT for enhancing OS. Various studies (Aftab et al., 2022; Gomes et al., 2020; Katou et al., 2021; Simeoni et al., 2020) have shed light on how organizations can utilize ambidextrous practices to effectively manage the exploration and exploitation of Digital capabilities. By dissecting the differential mediation effects across various technologies – direct in the case of AI, complementary with AuR, competitive for IoT, and fully mediated by OA for MT – this study provides a granular understanding of how technological adoption impacts organizational sustainability. These findings extend the dynamic capabilities framework by illustrating the critical role of OA not merely as a facilitator but as a strategic imperative that modulates the efficacy of technological integration to achieve OS.

Furthermore, this research challenges the prevailing notion within the technology management domain that the direct application of EIT uniformly contributes to OS. Instead, it posits that the value derived from EIT is contingent upon the organization's ambidextrous capabilities, emphasizing the need for a strategic alignment between technological investments and organizational practices. As evident from the analysis, the direct impact of AI on OS can be attributed to its ability to optimize production processes, reduce waste, and enhance product quality. The complementary partial mediation between AuR and OS highlights how AuR improves efficiency and reduces errors, but the essence of OA is critical in maximizing AuR's potential. Integrating OA into AuR deployment positions firms to embrace innovation, maintain agility, and respond effectively to market trends and customer demands, fostering a sustainable manufacturing ecosystem. The competitive partial mediation of OA in the IoT-OS relationship reflects complexity. IoT offers benefits in real-time monitoring and data analytics for sustainability (Happonen et al., 2020), but its direct impact on OS is negative, possibly due to challenges like high implementation costs, data security concerns, and a lack of skilled personnel (Manglani et al., 2019). OA's full mediation in the MT – OS relationship suggests that MT alone doesn't directly influence sustainability. MT, while enhancing productivity and flexibility, requires a responsive and adaptive organizational culture to translate benefits into sustainable outcomes (Patil et al., 2021) by providing real-time access to critical data, enabling remote monitoring, and fostering collaboration. This nuanced perspective contributes to a more sophisticated understanding of the interplay between EIT and OS, suggesting that the path to sustainability is not technocentric but requires a balanced approach that incorporates technological, organizational, and strategic fronts.

Finally, the study's insights into the non-linear and technology-specific mediation roles of OA underscore the importance of considering organizational context and capabilities in the deployment of technologies. This contribution is pivotal for the ongoing discourse on sustainable technological adoption, providing a theoretical foundation for future research to explore the conditions under which technological innovations can most effectively contribute to organizational sustainability.

5.2 Practical Implications

From a practical standpoint, the findings of this study serve as a strategic guide for industry practitioners and policymakers in various ways. First, decision-makers should strategically assess and invest in EIT that aligns with their organizational goals. While AI is found to have a direct impact on OS, other technologies like AuR, IoT, and MT benefit from the mediation of OA. This implies the need for a balanced approach to technology adoption, recognizing the unique contributions of each technology. Second, the development of ambidextrous capabilities within organizations is crucial, necessitating a culture of innovation and adaptability. Third, as the sector transitions toward embracing technological advancements, organizations should anticipate challenges and adapt accordingly. This includes addressing issues such as the cost of technology implementation, data security concerns, and the need for skilled personnel to manage EIT. OA plays a critical role in mitigating these challenges, allowing firms to harness the positive potential of EIT.

In summary, this research provides a blueprint for balancing technological innovation with operational flexibility, which is essential for maintaining competitiveness in the global market. By strategically investing in EIT that aligns with organizational goals, developing OA, and proactively addressing challenges associated with technology adoption, firms can enhance their OS and thrive in a rapidly changing industry.

Collaboration with solution providers for manufacturing can further facilitate this technological transition and contribute to sustainable growth.

5.3 Limitations and Future Directions

While insightful, this study has some limitations. This study focuses on a specific industry within a unique national context which may limit the generalizability of its findings to other sectors or regions. Since based on a cross-sectional design, the study captures a snapshot in time, potentially overlooking long-term trends and the dynamic nature of technological adoption and organizational change. The reliance on self-reported data could introduce biases, affecting the accuracy of insights into EIT adoption and OA's role. Additionally, the focus on certain technologies like AI, IoT, AuR, and MT might exclude other relevant emerging technologies. Also, the quantitative approach of the study may not fully encapsulate qualitative factors such as organizational culture or leadership, which are critical in understanding the broader impact of technology integration. Lastly, the rapid evolution of technology presents a challenge, as findings could quickly become outdated with the emergence of new technologies or methodologies post-study. These limitations highlight the need for a careful interpretation of the results and suggest pathways for future research to build upon this foundational work.

This study encourages future research to expand by focusing on in-depth and technology-specific investigations, such as feasibility and techno-economic assessment of each EIT. This approach, complemented by broadening the geographical and industrial scope, can enhance the study's applicability.

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APPENDIX A

ID______

QUESTIONNAIRE SURVEY

Part A: Personal Information:

Gender: ☐ Male ☐ Female ☐ Prefer not to say

Designation: ☐ Executive ☐ Sr. Manager ☐ Middle Manager ☐ Other (Please specify)

Organization's Name (optional but recommended): ____

Nature of Business:

- Textile, Apparel
- Pharmaceuticals
- Steel
- Others (please specify): ____________________________

Experience (years): ☐ less than 5 years ☐ 5-10 years ☐ More than 10 years

Age of Company (years): ☐ less than 5 years ☐ 5-10 years ☐ More than 10 years

Number of employees: ☐ less than 100 ☐ 100 - 300 ☐ More than 300

Informed Consent:

Do you allow us to share (anonymously) this feedback publicly for publication purposes?

☐ Yes ☐ No

Signature: ___________________________________

Part B

Please select your response against each statement and tick (✓) appropriate.

Emerging Industrial Technologies

Internet of Things (IoT): The Internet of Things (IoT) is a network of interconnected devices, sensors, and machines that can communicate and exchange data with each other over the internet. IoT enables the integration and automation of various processes, allowing real-time monitoring, analysis, and control of equipment and production systems.

1. **IoT** can contribute in **organizational sustainability** by providing **lower lead times** for customers and **lower overall costs**.

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

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2. **IoT** supports **organizational sustainability** in improving the **production capacity**.

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

---

3. **IoT** provides **linkage of all the devices** to the internet which helps in production processes required for **organizational sustainability**.

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

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4. **IoT** provides **better communication** between devices eventually leading to **organizational sustainability**.

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

5. **IoT** has an impact in **organizational sustainability** as it provides a connection between customers and company and increases the **customer satisfaction level**.

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

Artificial Intelligence (AI): Artificial Intelligence (AI) focuses on creating intelligent machines capable of performing tasks that typically require human intelligence. AI technologies are used to automate processes, analyze large amounts of data, and make informed decisions. AI enables machines and systems to learn, adapt, and improve over time.

1. **AI** enables predictive maintenance, **reducing unplanned downtime, enhancing overall equipment reliability** and improving economic sustainability**.**

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

2. **AI** optimizes production schedules and resource allocation**, improving operational efficiency** and **reducing waste** which leads to economic sustainability**.**

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

3. **AI-based** quality control systems **enhance product consistency** and **minimize defects,** leading to **improved customer satisfaction** and **Organizational Sustainability.**

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

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4. **AI-powered** data analytics and insights enable **proactive decision-making,** fostering **continuous process improvement** and **organizational sustainability.**

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

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5. **AI-powered** workforce optimization considers employee well-being**, workload balancing,** and **skill development** promoting social sustainability within the organization**.**

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

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6. **AI-based** demand forecasting and resource planning **enhance inventory management, reducing waste** and **optimizing resource utilization** leading to improved economics and environmental sustainability**.**

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

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Autonomous Robots (AuR): Autonomous robots are advanced machines designed to perform tasks without human intervention or with minimal human involvement.

Autonomous robots are used to automate repetitive or hazardous tasks, such as assembly, material handling, and inspection. These robots can navigate and operate within their environment, make decisions based on sensors and algorithms, and collaborate with human workers or other machines.

1. **Autonomous robots** enhance workplace safety by taking over hazardous or repetitive tasks, **minimizing the risk of accidents,** and contributing to **social sustainability.**

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

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2. **Autonomous robots** enable round-the-clock operations, **increasing production capacity** and **responsiveness to customer demands** thereby increasing economic sustainability**.**

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

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3. **Autonomous robots** optimize inventory management through automated tracking, **reducing stock-outs** and **excess inventory,** thus **improving resource utilization** and **financial sustainability.**

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

---

4. **Autonomous robots** improve energy efficiency by **optimizing routes** and **minimizing idle time**, contributing to both **economic** and **environmental** sustainability**.**

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

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5. **Autonomous robots** enable **flexible manufacturing setups, facilitating customization** and **personalized production,** thereby promoting **social sustainability** by meeting customer demands**.**

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

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6. **Autonomous robots** optimize production processes, **reducing cycle times** and **resource usage**, thereby enhancing economic sustainability**.**

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

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Mobile Technologies (MT): Mobile technologies, such as smartphones and tablets, are portable computing devices that enable users to access information, communicate, and perform various tasks while on the go. They provide real-time access to critical data, enabling employees to monitor production status, inventory levels, and equipment performance remotely. Mobile apps and platforms facilitate collaboration among teams, allowing seamless information sharing and coordination.

1. **Mobile technologies** facilitate seamless communication and collaboration among teams, **enhancing productivity** and **reducing response times,** thereby contributing to social sustainability**.**

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

---

2. **Mobile technologies enhance supply chain visibility** and **traceability,** enabling **efficient inventory management, order tracking,** and **delivery coordination,** thus **improving customer satisfaction**, thereby promoting both social and economic sustainability**.**

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

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3. **Mobile technologies** support paperless operations, **reducing waste** and promoting **environmental sustainability.**

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

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4. **Mobile technologies** enable **remote collaboration** and **flexible work arrangements,** promoting **work-life balance,** promoting social sustainability**.**

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

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Organizational Ambidexterity (OA): Organizational ambidexterity refers to an organization's ability to effectively balance and manage two seemingly contradictory activities: exploration and exploitation. It means striking a balance between fostering innovation and adaptability (exploration) while maintaining efficiency and optimizing existing processes (exploitation).

1. The organization's utilization of **AI technologies** effectively balances the **exploration** of new opportunities and the **exploitation** of existing resources, contributing to enhanced **organizational sustainability**.

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

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2. **AI** implementation enables the organization to simultaneously prioritize **innovation** and **operational efficiency**, leading to improved **organizational sustainability**.

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

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3. The integration of **IoT technologies** in the organization promotes **collaboration** and **knowledge-sharing** across different functions or units, fostering **organizational sustainability**.

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

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4. The organization's ability to adapt to **market changes** and **customer demands** is enhanced through the utilization of **IoT technologies**, resulting in improved **organizational sustainability**.

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

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5. The organization's ability to adapt to **market changes** and **customer demands** is enhanced through the utilization of **autonomous robots,** resulting in improved **organizational sustainability.**

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

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6. The implementation of **autonomous robots** in the organization supports the achievement of both **short-term profitability** and **long-term sustainability goals**, driving **organizational sustainability.**

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

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7. The organization's use of **mobile technologies** effectively balances the **exploration** of new opportunities and the **exploitation** of existing resources, contributing to enhanced **organizational sustainability**.

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

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8. **Mobile technology** implementation enables the organization to simultaneously prioritize **innovation** and **operational efficiency**, leading to improved **organizational sustainability.**

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

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Organizational Sustainability (OS): Organizational sustainability refers to the ability of a company to operate in an economically, socially, and environmentally responsible manner over the long term. It involves integrating sustainable practices into various aspects of the organization, such as resource management, supply chain, waste reduction, employee well-being, and community engagement.

1. **EIT technologies** improve the organization's **efficiency**, **productivity**, and **competitiveness**.

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

2. **EIT technologies** enable an organization to gain tangible benefits like **cost savings**, **increased revenue**, or **improved market position**?

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

3. **EIT technologies** enable an organization to attain measurable improvements in key performance indicators (KPIs) related to sustainability, such as **resource utilization**, **waste reduction**, or **energy efficiency**.

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

4. **EIT technologies** positively impact the organization's ability to **innovate**, **develop new products/services**, or **enter new markets**?

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

5. **EIT technologies** enhance the organization's **agility**, **responsiveness**, and **ability to meet customer demands**?

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree

6. **EIT technologies** contribute to the organization's overall **growth**, **resilience**, and **ability to create sustainable value**?

☐ Strongly Disagree ☐ Disagree ☐ No Change Expected ☐ Agree ☐ Strongly Agree