

Assessing the Impact of Industry 4.0 Technologies on Innovative Work Behavior: A
Quantitative Study in Malaysian SMEs

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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ABSTRACT

This study research investigates the dynamics of Innovative Work Behavior (IWB) among employees in the manufacturing Small and Medium Enterprises (SMEs) in Malaysia, particularly focusing on the adoption of Industry 4.0 (IR4.0) technologies. It seeks to dissect the multifaceted factors influencing IWB, an essential determinant for competitiveness and adaptability in the rapidly evolving industrial sector. Central to this exploration are the constructs from the Technology Acceptance Model (TAM), namely Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) of technical skills, and their impact on the behavioral intention to adopt IR4.0 technologies. The study also examines the influence of governmental policies and the role of Personal Innovativeness in Automation (PIA) and Learning & Development (LD) initiatives in nurturing innovative work cultures. Employing a quantitative approach, this research utilized nonprobability sampling to gather data from a sample of 356 employees across various SMEs in the Klang Valley region focused on manufacturing sector. Data collection was conducted via a carefully designed survey questionnaire, enabling an in-depth analysis of responses using Partial Least Squares Structural Equation Modeling (PLS-SEM), processed through SmartPLS software. This approach provided a nuanced understanding of the factors driving IWB within the manufacturing sector. The findings offer a comprehensive view, with most hypotheses being validated. Notably, LD and PIA emerged as significant drivers of IWB, while Government Support was found to have an insignificant impact. These results hold substantial implications for theory and practice, highlighting the need for SMEs to focus on internal strategies and resources for fostering innovation. This study contributes significantly to the academic discourse on technology adoption and IWB in manufacturing SMEs and provides actionable insights for business leaders and policymakers. By identifying key drivers and challenges of IR4.0 technology adoption, the research offers strategic guidance for nurturing a robust, innovative, and technologically adept manufacturing sector in Malaysia..

Keywords: Innovative Work Behavior (IWB), Small and Medium Enterprises (SMEs), Industry 4.0 Adoption, Technology Acceptance Model (TAM), Personnel Innovativeness, Learning and Development (LD)

CHAPTER ONE

1 INTRODUCTION

1.1 BACKGROUND

In today's globalized world, innovation is widely recognized as a key component of the competitive advantage for companies and nations. (Lam, 2010) defines organizational innovation as "the creation or adoption of ideas or behaviors that are new to the organization." Factors contributing to organizational innovation include market forces, environmental changes, and technological advancements driven by the market (Kahn, 2018a). Organizational innovation encompasses changes in the organization's structure, knowledge creation, cognitive foundation, and adaptations necessitated by environmental shifts and technological advancements ((Lam, 2010). While the analysis of organizational innovation is primarily conducted at the organizational level (e.g., firms, groups), it also pertains to the individual level, focusing on employees' personal innovative behaviors (Demircioglu, 2016). Increasingly, firms are dependent on innovation from Industry 4.0 technological resources to have sustainable organization growth . (Kamble, Gunasekaran, & Dhone, 2020). In a study involving 154 U.S. industrial firms, Kishore (2024) found that technology of Industry 4.0 develops innovation capabilities in firms. The capability to innovate is a crucial determinant of firm performance in today's knowledge-driven economy (Crossan & Apaydin, 2010)(Nwachukwu et al., 2018).

This study centers on the Industrial Revolution 4.0 technology, which has been a driving force behind innovation in both services and manufacturing industry. Industry 4.0 encompasses industrial automation, robotization, and digitization (Rymarczyk, 2022). It has significantly impacted industries globally, requiring manufacturers to adapt to enhance their company's performance (Industry 4.0: Critical Investigations and Synthesis of Key Findings, 2023; Rashid & Kausik, 2024). Industry 4.0 (IR4.0) is transforming global industries, yet its adoption remains uneven, predominantly large-scale enterprises leverage smart technologies, while SMEs lag due to cost, expertise, and infrastructure gaps. However, IR4.0's benefits, efficiency, competitiveness, and data-driven decisions, are critical for SMEs to thrive in digital economies (OECD, 2023)

Recent studies show that while Industry 4.0 (IR4.0) has transformed large enterprises through advanced automation and digitization, Malaysian SMEs lag significantly behind in adoption (Shahzad et al., 2023). These smaller firms often lack the strategic, technical, and financial capacity to implement complex digital infrastructure, contributing to an innovation deficit (Yuen & Ng, 2021). Unlike their counterparts in other Southeast Asian economies such as Vietnam and Indonesia, Malaysian SMEs face greater

barriers in workforce readiness and ecosystem support (Na & Kang, 2019). Consequently, IR4.0 poses both a challenge and an opportunity for SMEs, with innovation behavior at the employee level becoming essential for bridging the adoption gap.

(Robert B. & Tucker, 2008) describe innovation involves generating ideas and bringing them to life that requires important drivers such as technological facilities, trained workforce and management support for innovative activities. A study by Ahmed et al. (2025) on pharmaceutical industry finds that effective knowledge sharing practices enhance innovation capabilities, leading to improved organizational performance. Organizational learning and knowledge management remain pivotal in sustaining competitive advantage through innovation. Wang et al. (2023) explore how open innovation contributes to sustainable competitive advantage via organizational learning, emphasizing the mediating role of learning processes in translating innovation into performance gains.

1.1.1 IMPORTANCE OF SMES IN MALAYSIA

Malaysian Small and Medium Enterprises (SMEs) represent the largest sector of business establishments and are a crucial component of the country's economic development, accounting for more than 90% of all business entities in Malaysia (Rusly et al., 2020a). According to the Department of Statistics, SMEs contributed 38.1% to Malaysia's GDP and were responsible for 48.0% of national employment as of 2020 (Jia, 2022). Globally, SMEs constitute the majority of businesses and play a significant role in job creation and economic growth (Musa & Chinniah, 2016a).

The significance of SMEs in the national economy is highlighted by their involvement in a diverse range of industries, contributing substantially to economic growth (Saleh & Ndubisi, 2006). As illustrated in Table 1 below, SMEs in Malaysia predominantly operate in two major sectors: services and manufacturing. In terms of Gross Domestic Product (GDP), SMEs in Malaysia accounted for 37.4% in the year 2021. As of 2021, a total of 1,226,494 establishments were classified as Micro, Small, and Medium Enterprises (MSMEs), making up 97.2% of all registered companies in the country. Of these, 83.8% were engaged in the services sector, 8.0% in construction, 5.8% in manufacturing, 1.9% in agriculture, and 0.4% in mining and quarrying as portrayed in Figure 1.1.

The COVID-19 pandemic has precipitated the most severe global economic crisis in over a century. Since its onset in early 2020, the pandemic has profoundly altered the business landscape for SMEs in Malaysia, decelerating the progress previously achieved by these enterprises. Many SMEs faced challenges with their working capital, while others struggled to sustain their workforce. Consequently,

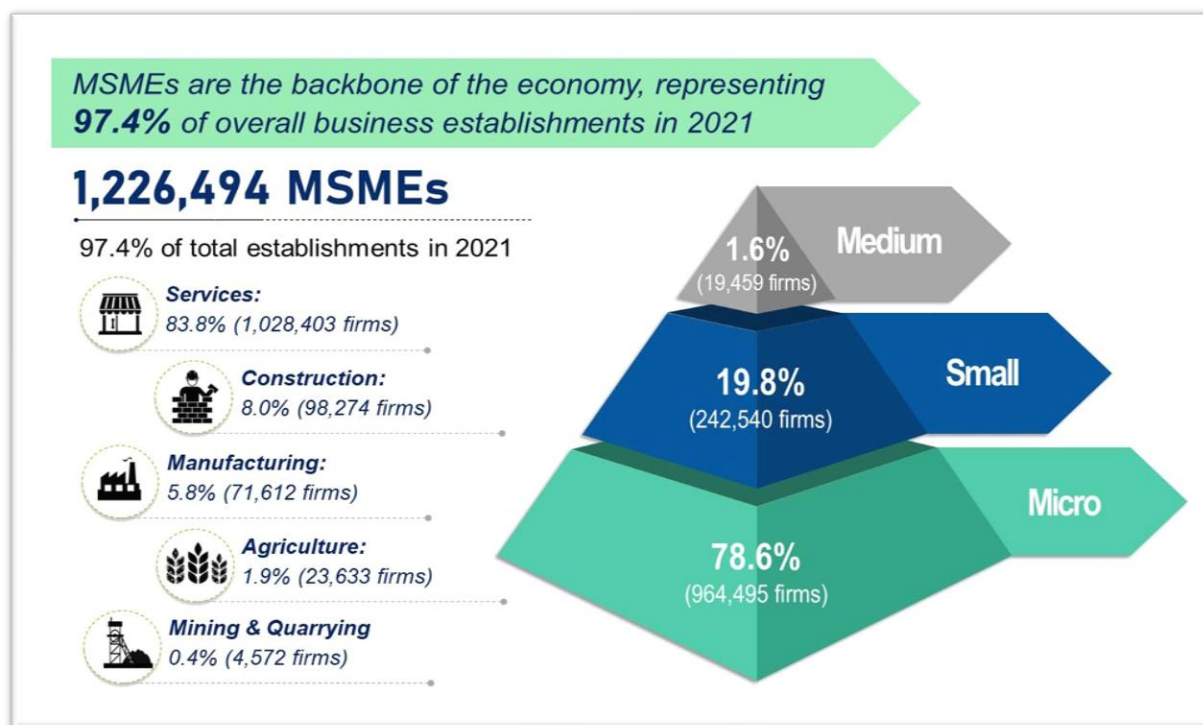


Figure 1.1 - SMEs in Malaysia

approximately 37,000 SMEs were unable to withstand these challenges and were forced to shut down (The Star, 2021b).

During the pandemic, the Malaysian government introduced stimulus packages totalling RM14.2 billion through a special fund from Bank Negara. These included a wage subsidy program of RM20 billion to aid the SME sector in paying staff salaries and keeping businesses afloat; 0% microcredit loans from Bank Simpanan Nasional and Agrobank for the first six months of the loan tenure; a six-month deferment of income tax installment payments until June 30, 2022; a RM100 million matching grant for Bumiputera SMEs to venture into the aerospace sector; and RM25 million allocated to the Halal Development Corporation to foster more halal SMEs (The Star, 2021; Zufazlin Baharuddin, 2021) (The Star, 2021; Zufazlin Baharuddin, 2021). These stimulus packages and financing facilities were crucial for Malaysian SMEs, which constitute 90% of all business establishments in Malaysia. According to the Department of Statistics, SMEs accounted for 48.0% of national employment as of 2020 (Zufazlin Baharuddin, 2021).

1.1.2 SME IN MANUFACTURING SECTOR

The digitalization of the manufacturing industry, which began in Germany, has garnered significant global attention and has been gradually adopted across various industries. Industry 4.0 (I4.0) has heightened the importance of digital transformation and its potential applications in manufacturing (Kamble et al., 2020). Industry 4.0 integrates "artificial intelligence, the Internet of Things, additive manufacturing, robotics, cloud computing, and other digital and physical technologies." Given that SMEs form the backbone of most countries' economies, the readiness and success of digital transformation hinge on the adoption and implementation of I4.0 technologies (Kilimis et al., 2019a). Consequently, innovation capability is a crucial driver for the growth and development of SME manufacturing in Malaysia (Jalil et al., 2022a).

Industry 4.0 digital technologies are categorized into four concepts as proposed by (Hermann et al., 2016): Industrial Internet of Things (IIoT), Internet of Services, Cyber-Physical Systems (CPS), and Smart Factory. Research conducted by (Kilimis et al., 2019) on 50 SMEs in Brandenburg-State, Germany, revealed that these SMEs faced the greatest challenges with ERP

systems, followed by automation, factory planning, logistics and supply chain, production planning and control, and lastly, CAD/CAM digitalization.

Many SME across countries have known and have basic knowledge on I4.0. In Malaysia SME only 30% are at the Industrial 3.0 that covers adoption of advanced technologies and about 10% manufacturing companies adopted the I4.0 that integrates the information communication technology (ICT). This rate is low in comparison to Asian developed countries like Singapore, South Korea and Japan whereby their adoption rate of I.T is 50%(Shahzad et al., 2023a). In Malaysia, only about 20–25% of SMEs have adopted basic Industry 4.0 technologies such as the Internet of Things (IoT), artificial intelligence (AI), and automation, with key barriers including high implementation costs (45%), a shortage of skilled workers (30%), and low awareness (25%); adoption is most prominent in the manufacturing sector (35%), followed by logistics (20%) and retail (15%) - study by SME Corp Malaysia & World Bank Report (2023/2024). `Malaysian SMEs are gradually adopting IR4.0, but cost, skills gaps, and awareness remain major hurdles.

Past research on the manufacturing sector in Malaysia has indicated poor innovation and production performance, attributed to the conventional methods employed in their production processes ((Ang, Hong Loong, Stephen Laison Sondoh Jr., and Lee, 2019). Despite significant government initiatives, local manufacturers are hindered by a lack of skilled and experienced workers to transform their production systems ((Ang, Hong Loong, Stephen Laison Sondoh Jr., and Lee, 2019).

1.1.3 MALAYSIA ECONOMY & SME

Regarding economic sector contributions, the services sector remained the predominant contributor, accounting for 60.9% of the MSME GDP in 2021, followed by the manufacturing and agriculture sectors at 22.1% and 10.5% respectively (see Table 1.1). The accelerated pace of vaccinations, increased adoption of digitalization and automation, along with greater adaptability of firms to new norms, helped mitigate the negative impacts in 2021 (SME Corporation Malaysia, 2020a). To further encourage digitalization among SMEs and support high-tech, innovation-driven enterprises, various measures have been implemented. These include the SME Automation and Digitalisation Facility, offering loans of up to RM3 million at rates up to 4% per annum, and the High-Tech Facility, providing loans up to RM1 million for working capital or up to RM5 million for capital expenditures, or a combination of both, at rates up to 5%, including the guarantee fee. These initiatives were made available to facilitate digital adoption (The Star, 2021b).

Table 1.1: MSME GDP and Overall GDP Share by Economic Sector

SECTOR	Percentage Share to Total (%)		
	2021 MSME GDP	2022 MSME GDP	2022 Overall GDP
Services	60.99	63.6	58.3
Manufacturing	22.1	21.0	24.1
Agriculture	10.5	9.3	6.6
Construction	4.8	4.5	3.5
Mining & Quarrying	0.5	0.5	6.4
Plus: import duties	1.1	1.1	1.1
Total	100	100	100

Source : (National Entrepreneur and SME Development Council, 2022)

Source : Department of Statistics

The Economic Census 2016 revealed that over 60% of SMEs in Malaysia are concentrated in the top five states: Selangor (19.8%), Kuala Lumpur (14.7%), Johor (10.8%), Perak (8.3%), and Pulau Pinang (7.4%). The SME sector in Selangor is particularly dynamic and advanced. Selangor, with 179,000 SME

establishments (19.8% of the total in Malaysia) as of 2016, leads the country, surpassing even Kuala Lumpur, the capital city, which has 134,000 SME establishments (Invest Selangor, 2020).

The significant contribution of Selangor's SME sector is primarily due to its diverse and well-rounded economic environment. Selangor possesses several attributes that attract large conglomerates and multinational corporations while remaining supportive of startups and small-medium businesses. Factors such as a large workforce, mature infrastructure, strategic geographical location, and advancements in digital and technological sectors make Selangor an ideal destination for SMEs in Malaysia.

1.1.4 SME READINESS FOR INDUSTRY 4.0

Despite the Malaysian government's aggressive promotion of innovation among SMEs, there remains a noticeable lack of innovation in this sector in Malaysia (DHESI, 2023). RS Malaysia's country general manager, Sean Er Lim, highlighted the need for greater awareness of Industry 4.0 among Malaysian SMEs (DHESI, 2023). According to SMECorp (2022), around 77% of Malaysian SMEs are still at the basic stage of digitalization, as estimated by consulting firms. A survey by SME Corp and Huawei Technologies revealed that the use of IoT, cloud computing, and data analytics is rare among Micro, Small, and Medium Enterprises (MSMEs) (The Star Malaysia, 2021). Datuk William Ng, chairman of the Small and Medium Enterprises Association Malaysia (Samenta), expressed concern about the low digital adoption compared to larger corporations, which is leading to a digital divide. He emphasized the necessity of allocating the right resources to encourage SMEs to adopt technology, which will accelerate automation, reduce reliance on manpower, and elevate the educational level of future entrepreneurs (The Star, 2021b).

Malaysia's response to Industry 4.0 technologies is more of a technology-follower stance (Faizal et al., 2019a). The prerequisite for technology acceptance is assessing SMEs' readiness level. Technology readiness is defined as "people's propensity to embrace and use new technologies for accomplishing goals in home life and at work" (Parasuraman, 2000). This is measured by the Technology Readiness Index (TRI), which has been integrated with the Technology Acceptance Model (TAM) to understand technology adoption better (Hallikainen, H., & Laukkanen, 2016). A survey conducted by (Faizal et al., 2019) on SME IoT readiness revealed that directors' optimism scored the highest, acknowledging the potential benefits of IoT. According to the Malaysia Digital Economy Corporation (MDEC) SME Digitalisation Survey 2024, only 18% of Malaysian SMEs are fully digitalised, while 40% remain in the early stages of digital transformation. The most commonly adopted technologies include e-commerce (65%), cloud solutions (35%), and automation and robotics (12%) (MDEC, 2024).

The slow pace of transformation for SMEs is attributed to a lack of digital competence, including knowledge and skills to apply new technologies in production (Hamim et al., 2021; Marques, Maria;

Agostinho, Carlos; Zacharewicz, 2017). SMEs find it challenging to become skilled in the use of IR4.0 technologies due to a lack of organizational resources to look beyond their current production processes (Faller & Feldmüller, 2015). Hecklau et al. (2016) noted that the experience and skills of the workforce are key to the success of a highly innovative factory, emphasizing the importance of developing a skilled workforce within SMEs.

This perspective is supported by industry leaders in the manufacturing sector. The SME Association of Malaysia stresses the importance of workers demonstrating their value by being reliable, productive, and continuously developing skills and knowledge (Zahoor et al., 2023). Chin, speaking to FMT, emphasized that workers must be open to change and willing to take on new challenges to help their companies through difficult times. The World Economic Forum (2017) also encourages individuals to acquire skills aligned with industry evolution to sustain a long-term career. Samenta's chairman, William Ng, stated the importance of a life-long learning mindset for employees, as "what we know today may no longer be useful tomorrow." As IR 4.0 takes hold, all workers, including engineers, will need to embrace these digital tools and technologies, calling for forward-thinking engineers to produce higher-quality products more efficiently (Ismail & Hassan, 2019).

Innovative work behavior plays a crucial role in helping small and medium enterprises (SMEs) adapt to the challenges and opportunities presented by the Fourth Industrial Revolution (IR4.0). In the context of IR4.0, SMEs need to find innovative solutions to leverage emerging technologies effectively. Employees who exhibit innovative work behavior can contribute fresh ideas and insights that expedite adoption of IR4.0 technologies in SME's (Faris et al., 2024). Individuals innovate are needed in manufacturing companies to cope with challenges related to new technologies and process of Industry 4.0 (Hecklau et al., 2016). The current work environment requires a certain level of complexity of technology. Employees tacit knowledge, high level of education and competence enables organization to gain and sustain competitive advantage such as employees need to become more strategic, coordinating and creativity (Hecklau et al., 2016).

1.1.5 ROLE OF TECHNOLOGICAL DEVELOPMENT IN SME MANUFACTURING

Industry 4.0 represents the forefront of automation technologies in manufacturing, encompassing cyber-physical systems, cloud computing, and Internet of Things (IoT) technologies. These components facilitate effective information sharing across various departments, thereby streamlining manufacturing operations. The primary aim of Industry 4.0 is to establish highly efficient and automated processes, transitioning from mass production to enhanced productivity (Zadjali & Ullah, 2021). Numerous studies have highlighted the importance of SMEs adopting the principles of Industry 4.0 (Faizal et al., 2019b; Mustafa et al., 2021; Saleh & Ndubisi, 2006; Sciarrelli et al., 2022). In response, many SMEs have begun

to focus on digitizing products and processes, integrating Information and Communication Technology (ICT) with Industry 4.0 concepts to transform their facilities into smart factories. Nonetheless, SMEs face significant challenges in readiness and organizational capability, particularly in adapting to new knowledge. Each region presents unique challenges, necessitating further research and strategic planning to guide SMEs technically and organizationally.

The Tidd & Bessant model on innovation identifies the key drivers of a firm's innovation capacity as strategy, organization, learning, processes, and networks (Ferreira et al., 2015a). This research paper examines the role of technology development in Malaysian SMEs, focusing on employee perception, innovative work behavior, process innovation, organizational learning, and the government's role.

Literature on product innovation often discusses the nature of what is produced, delivered, and consumed. In contrast, process innovation concentrates on how these activities are executed (Bessant and Tidd, 2007; Trott, 2012). Traditional measures of innovation, typically centered around R&D, may not be fully applicable in developing countries like Malaysia, especially in comparison with developed countries, due to varying levels of technological advancement (Hobday, 2005). A more pertinent approach might involve assessing incremental innovation, the application of new knowledge and skills, or minor innovations (Govindaraju et al., 2013a). Adaptations in existing designs, processes, or even machine modifications are increasingly recognized as significant sources of innovation. (Rasiah, 2013) emphasizes that machinery adaptation is a vital source of innovation. Therefore, process innovation indicators are particularly relevant for Malaysian MSMEs, as improvements can be made in product design, production systems, service systems, and overall organizational processes. These improvements often stem from experiential learning or 'learning by doing' (Govindaraju et al., 2013a; Kahn, 2018b).

In Malaysia, the government, in collaboration with various industry bodies, has been vigorously promoting and supporting digitalization initiatives among SMEs, particularly at the firm level, through both tax and non-tax incentives (Govindaraju et al., 2013b; Shahzad et al., 2023a). The five primary areas of governmental support focus on access to financing, human capital development, market access, innovation and technology adoption, and infrastructure (SME Corporation Malaysia, 2023a). The Twelfth Malaysia Plan (RMKe-12) for the period 2021 – 2025, tabled in September 2021, aims to transform MSMEs into a new growth engine. This plan includes measures to equip MSMEs with the knowledge and skills needed for digitalizing their business processes, establishing centers of excellence to guide in adopting new technologies, and ensuring a conducive and holistic ecosystem to support MSMEs. The government's Twelfth Malaysia Plan (12MP) emphasizes the revival and growth of local micro, small, and medium enterprises (MSMEs) into a technology-based economy, highlighting a significant role in advancing the digitization of MSMEs (MIDF, 2021). To further enhance MSMEs' productivity and

development, the government intends to develop entrepreneurial capabilities towards innovation. MSMEs are also encouraged to leverage government support provided through business associations and cooperatives. Studies have shown that in developing countries, government involvement in aiding firms with technological capabilities through various policy instruments and programs has a positive institutional impact (Rasiah, 2011; Rasiah & Lin, 2005).

In the context of firm innovation, two critical drivers are the innovation work behavior (IWB) of knowledge workers (Ferreira et al., 2015b) and their inclination to engage with digital transformation initiatives (Wu & Yu, 2022). In the manufacturing sector, particularly within SMEs that are increasingly adopting automation and advanced tools, understanding the workforce's perception of the resourcefulness and practicality of these advancements is essential. This understanding includes recognizing the utility and convenience of digital mechanisms at the workplace.

The goal for knowledge workers is to effectively utilize technology and integrate digital resources in their roles, thereby fostering innovation (Luksyte et al., 2018). IWB involves generating new ideas related to technology, processes, and products, sharing knowledge within work groups, creatively solving existing problems, and supporting the implementation of innovative ideas (Luksyte et al., 2018; Yuan & Woodman, 2010). Consequently, technology development in SMEs depends not only on organizational structure but also on the IWB of employees, which is crucial for competitiveness and success in today's digital business landscape.

Organizational learning is increasingly recognized as a key component of firm performance, as it adds value to acquired knowledge and facilitates its dissemination throughout the firm. Digital skills have become necessary in SME as create digital upskilling that is needed to be productive and innovative in their jobs (Valdez-Juárez LRamos-Escobar EHernández-Ponce ORuiz-Zamora J (2024)

Sharing of knowledge and skills is integral to innovation and crucial for competitive advantage, however SME lacks sufficient resources to leverage on this knowledge pool (Salvador López and Víctor Yepes, 2024). Human capital is a fundamental element for a firm's survival and long-term economic growth.

1.2 RESEARCH PROBLEMS

1.2.1 POST COVID 19 SITUATIONS

The COVID-19 pandemic has radically altered the operational landscape for local Micro, Small, and Medium Enterprises (MSMEs), significantly impacting their performance. The sudden onset of the pandemic caught firms unprepared, compelling them to adapt to labor shortages, disrupted supply chains, and shifts in consumer buying patterns (Nambiar & Ming, 2023). Furthermore, many companies had not fully embraced advanced technologies such as 4G, automation, robotics, and artificial intelligence (AI)

(Nambiar & Ming, 2023). This similar effect was also experienced by SME in Indonesia where both Malaysia and Indonesia SME performance was hampered due to the pandemic (Lestari et al., 2024). Sanusi et al. (2023) highlighted that the resilience of SMEs during the pandemic was strongly influenced by factors such as technology acceptance, government support, and financial literacy, which enabled them to better withstand market challenges. Similar findings were observed in the entrepreneurial ecosystems of Latin America and the Caribbean, where characteristics like innovativeness, adaptability to change, and the inherent traits of SMEs contributed significantly to their ability to navigate the crisis (Kantis & Angelelli, 2020).

Empirical evidence on the role of digitalization in mitigating the pandemic's effects on manufacturing is still limited. Research by (Guo et al., 2020) in China indicated that digitally advanced firms were better equipped to manage the crisis and mitigate COVID-19's negative impact on their operations, a finding echoed by (Belhadi et al., 2021). Given the scarcity of research in the field of MSMEs' sustainability manufacturing digitalization, particularly in the Malaysian context, this study aims to explore the adoption of Industry 4.0 (IR4.0) technologies and their impact on Malaysian MSMEs in the post-COVID-19 era. Previous study had showed that Industry 4.0 adoption play a significant in SME sustainability (Jayashree et al., 2022) Moreover, the pandemic highlighted the SMEs' insufficient digital resilience and exposed structural limitations in human capital and innovation culture. Despite government support schemes, many firms were unable to pivot quickly due to underdeveloped digital capabilities and lack of internal innovation processes (Sapiai et al., 2024). This situation reaffirms the need for fostering Innovative Work Behavior (IWB) as a strategic capability to help SMEs adapt and innovate under uncertain environments.

1.2.2 PREVIOUS STUDIES ON IWB

Employees' innovative readiness plays an important role in an organization level readiness to change (Tan et al., 2021). Innovation Work Behavior (IWB) serves as a critical catalyst in facilitating technology adoption within organizations. Employees who actively engage in innovative behaviors—such as generating new ideas, promoting novel approaches, and implementing creative solutions—significantly contribute to the organization's readiness and ability to embrace technological advancements. By fostering a culture of innovation, organizations can better navigate digital transformation, reduce resistance to change, and enhance overall adaptability in an increasingly competitive and technology-driven environment. Jacobis et al., 2024 conducted with 200 employees from the Population and Civil Registration Office in Surabaya, Indonesia, using the Structural Equation Modeling (SEM) to analyze that Innovative Work Behavior significantly affects technology adoption, which in turn mediates the

relationship between IWB and employee performance. This underscores the importance of fostering a culture that encourages innovation to facilitate successful technological integration within organizations. Previous research on Innovation Work Behavior (IWB) has spanned a variety of domains. Johari et al. (2021) focused on educational reform, particularly how teachers' innovative work behavior can enhance the learning process. In the context of Malaysian SMEs, (Noori et al., 2017) explored the influence of transformational leadership on employees' commitment levels and its impact on IWB. (Leong & Rasli, 2014) examined the relationship between work role performance, demographics, and employee performance in the Malaysian automotive sector.

In the manufacturing area, a study by (Sapie et al., 2015), involving 254 SME production employees from Kelantan, Terengganu, and Pahang, investigated the relationship between the work environment and IWB. This study emphasized the critical role of a supportive workplace environment in encouraging IWB. Additionally, the impact of Human Resource (HR) practices on IWB has been recognized. For instance, research conducted in a Dutch manufacturing company demonstrated the positive effect of perceived supportive supervision on IWB (Veenendaal & Bondarouk, 2015).

Studies like (Alnajjar & Hashim, 2020) have examined the role of IWB induced by transformational leadership through altruism, though they did not address the influence of process innovation in their work. In the manufacturing sector, research in Switzerland by (Mustafa et al., 2021) highlighted the effects of job satisfaction on innovative work behaviors among SME employees, considering the moderating effects of personality traits. Jaaffar et al. (2024) found that an innovative mindset and proactive behaviors among SME owner-managers significantly enhance innovation performance and competitive advantage. Knowledge sharing at the individual level demonstrates IWB with the support of transformation leadership (Rihayana & Aristana, 2024). Similarly, Helmy et al. (2023) highlighted that transformational leadership is a key enabler of IWB, particularly when mediated by employee engagement and goal alignment. However, these drivers are inconsistently present in Malaysian manufacturing SMEs, suggesting a gap in both leadership development and organizational learning mechanisms.

While numerous studies have explored Innovation Work Behavior (IWB) in the context of human resource management (HRM), there is a notable scarcity of research on IWB within the SME manufacturing sector in Malaysia, particularly in relation to Industry 4.0 (IR4.0) technology. This study aims to fill this gap by examining the perceived usefulness of automation systems under IR4.0 and their adaptation towards fostering IWB in SMEs. It seeks to assess SME employees' perceived usefulness of skills in automation systems, both directly and indirectly, through the mediating effect of organizational learning, and how this influences their intention to adopt IR4.0 innovations, thereby creating IWB in particular Malaysia's SME manufacturing-sector. The study also aims to understand the presence of IWB

in SMEs, in conjunction with the government's current initiatives on finance and education, particularly the technical and vocational education and training (TVET) programs designed to develop skilled talent to meet the demands of a growing economy.

The existing literature underscores the necessity of investigating the impact of IR4.0 on IWB within the SME sector. This study will contribute to this area by exploring how IR4.0 technologies influence IWB among employees in the SME manufacturing sector in Malaysia.

1.2.3 MANUFACTURING STUDIES --

Many authors, including (Keller et al., 2014; Vrchota et al., 2019), have recognized Industry 4.0 (I4.0) as a driving force for sustainability in the manufacturing sector. However, the transition of SMEs to digitalization and automation faces several challenges. Key among these is a general lack of understanding about the controlling factors of I4.0 technologies (Horváth & Szabó, 2019), financial barriers and issues of affordability for SMEs (Ghobakhloo et al., 2022), and a deficit in digitalization knowledge or skilled labor (Benitez et al., 2022; Huang et al., 2019). (Maisiri et al., 2021) note that many SMEs are stuck at the initial decision phase of adopting I4.0 technologies, with implementation yet to follow.

The suboptimal adoption rate of I4.0 technologies among SMEs is also linked to deficiencies in strategic management practices, particularly in developing a digitalization roadmap (Pech & Vrchota, 2020). Issues such as inadequate digitalization planning, limited organizational capabilities, lack of management support (Huang et al., 2019), and resistance from employees within the firm's culture (Ingaldi & Ulewicz, 2020) further impede progress. Conversely, creating an environment that encourages innovation and digitalization among employees, backed by strong management support and improved competencies, can significantly speed up the integration of I4.0 technologies in SMEs (Michna & Kmiecik, 2020).

The benefits of adopting I4.0 technologies are undeniable, including improved operational efficiency, enhanced reliability, better financial performance, and marketing outcomes (Masood & Sonntag, 2020). Scholars assert that digital transformation necessitates government support, addressing infrastructure and financial gaps, incentives, and supporting policies (Ghobakhloo et al., 2022). Equally important is the development of employees' digital knowledge, technical competencies, and expertise, as highlighted in a systematic literature review by (Ghobakhloo et al., 2022).

1.2.4 MALAYSIAN SME

In Malaysia, the rate of technological adoption among SMEs is approximately 20% (Abdulaziz et al., 2023). Despite government efforts to promote technological advancements, less than 50% of manufacturing businesses in Malaysia have implemented automation (Yatid, 2019). The manufacturing sector in Malaysia faces significant challenges in adopting Industry 4.0, mainly due to the limited

availability of technical facilities and infrastructure, as well as a shortage of highly skilled labor and resources. A survey conducted by MDEC revealed that 54% of SMEs had started their digital journey, primarily focusing on front-end operations like digital presence and marketing (AZALEA AZUAR & VEISHNAWI NEHRU, 2024). The Khazanah Research Institute (KRI) found that SMEs' digital adoption is primarily in front-end computing devices and connectivity, with only 44% and 54% using cloud computing and data analytics. A small fraction of SMEs have explored frontier technologies (Salleh et al., 2023)

Malaysian SMEs are gradually developing an understanding of Industry 4.0 and are making strides towards its integration. However, they face several hurdles, including the need for education and training, financial constraints, and a lack of experience and expertise within their workforce (Abdulaziz et al., 2023).

Recent studies on SMEs in Malaysia have delved into various facets of Industry 4.0. These studies have explored areas such as the development of new frameworks for Industry 4.0 and sustainability (Jayashree et al., 2019a), the readiness of IoT implementation among Malaysian SMEs (Zaidi & Belal, 2019) and the relationship between strategic planning, leadership management, and knowledge management in enhancing SME innovation capability and performance (Jalil et al., 2022b). Additionally, research has been conducted on the influence of technology adoption characteristics, with a focus on Cyber-Physical Systems (CPS) (Aziz & Wahid, 2020; Jayashree et al., 2021), the technological competencies needed for Industry 4.0 (Amiron et al., 2019; Ismail & Hassan, 2019), and the impact of employer role performance in uncertain environments (Ahmad et al., 2020). According to Shahzad et al. (2023), only a small proportion of Malaysian SMEs have reached moderate digital maturity levels, with many still struggling at the initial awareness phase. The gap is exacerbated by financial limitations and a workforce lacking advanced digital skills. Compared to SMEs in Vietnam and Indonesia, Malaysian firms demonstrate lower levels of innovation intensity, underscoring systemic issues in strategy, education, and ecosystem integration (Na & Kang, 2019). Similar challenges are observed in less urbanized Malaysian regions like Sabah, where SMEs operate with limited infrastructure and human capital support. Musneh et al. (2021) observed that despite efforts to promote innovation in Sabah's service sector SMEs, the lack of consistent policy execution and regional training facilities continues to hamper IWB and digital transformation efforts. These challenges are reflective of broader regional disparities within Malaysia's SME development landscape (SME Corp Malaysia)

1.2.5 FILLING THE RESEARCH GAPS

This study aims to address several critical gaps identified in the existing literature on Malaysian SMEs. Since 2017, skill and talent shortage has been a significant challenge for Malaysian employers, as

highlighted by recent studies from SME Corporation, the Ministry of International Trade and Industry (MIDA), and the FMM-MIER Business Conditions Survey 2019. This ongoing issue has caused concern for both employers and the government, especially with the current skillsets in the market being inadequate to support the digital transformation of Industry 4.0 (Shah, 2019). Employers are increasingly inclined to invest in internal skill-enhancement programs to train their workforce in specific skillsets, thereby safeguarding their business projects and prospects (Shah, 2019).

This research aims to explore the dilemmas faced by manufacturing-SMEs regarding the perceived usefulness of technological skills in adopting Industry 4.0 and how this translates to innovation work behaviors. It will explore into SMEs' perceptions and willingness to invest in their workforce's technical know-how, aiding in their digital transformation journey. Crucially, the study will examine the relationship between perceived usefulness, organizational process innovation, behavioral intention to adopt innovation, government support, and innovative work behavior, aspects which have not yet been thoroughly explored.

Particularly, the study will investigate the user's intention to adopt technology. This research seeks to assist Malaysian SMEs in creating an innovative climate that fosters increased intention to adopt new technologies and encourages knowledge sharing, leading to innovative work behavior. It will also examine how an organization's innovative structure influences staff behavior, by establishing an environment where innovative behavior is both safe and encouraged.

Despite the increasing urgency for digital transformation among Malaysian SMEs, especially within the manufacturing sector, there remains a significant gap in understanding how behavioral and perceptual factors influence innovation outcomes. While policy interventions have aimed at boosting IR4.0 adoption, many SMEs continue to experience low integration of automation and data-driven systems due to financial constraints, talent shortages, and limited innovation readiness (Shahzad et al., 2023; Yuen & Ng, 2021). The problem is compounded by an underdeveloped innovation culture and low Innovative Work Behavior (IWB), which limits firms' capacity to adapt technologies meaningfully. Compared to larger firms or SMEs in more advanced economies, Malaysian manufacturing SMEs lack a structured framework to link employee perceptions and behaviors to technological adoption (Na & Kang, 2019). Moreover, few empirical studies explore how cognitive drivers like Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) affect employees' intention to adopt IR4.0 technologies. To address this void, this research applies the Technology Acceptance Model (TAM) as its sole underpinning framework, offering a focused lens through which to examine employee-level behavioral intentions. Unlike most existing research that treats IWB and technology adoption separately, this study uniquely integrates TAM constructs with IWB to explore how perceived value and usability of technical skills relate to innovation

behavior. In doing so, it provides a novel contribution by positioning employees not merely as passive adopters of technology, but as proactive innovators within the SME ecosystem. This is particularly important for under-resourced firms, where bottom-up innovation can compensate for structural limitations. Thus, the study aims to extend the application of TAM beyond mere system adoption, framing it within the broader context of behavioral innovation, and delivering actionable insights for improving IR4.0 readiness in Malaysia's most economically critical business segment.

1.3 RESEARCH OBJECTIVES

This research is dedicated to an in-depth exploration of Innovative Work Behavior (IWB) within Small and Medium Enterprises (SMEs), particularly emphasizing the impact of Industry 4.0 (IR 4.0) technologies. The primary aim is to decode how the integration of IR 4.0 technologies influences IWB in the manufacturing processes of SMEs. Concurrently, the study endeavors to evaluate the effectiveness of learning and development initiatives that are specifically aligned with these advanced technologies. Additionally, it will critically examine the role of government support and policies in facilitating the technological transition for SMEs, assessing their tangible effects on enhancing innovation within these businesses. Another central objective involves dissecting employee perceptions related to the essentiality and applicability of technical skills relevant to IR 4.0 within the manufacturing sector.

This will encompass an analysis of variables such as Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) of these technical skills, understanding their influence on the innovation process within SMEs. Moreover, the research will probe into the significance of Personal Innovativeness in Automation (PIA) in employee learning and development, exploring its contribution to upskilling the workforce and nurturing a culture of continuous improvement and innovation. By integrating these insights, the study seeks to paint a comprehensive picture of how technical skill adoption interplays with IWB in SMEs. It aims to identify the facilitators and barriers to SMEs' readiness in adopting IR 4.0 technologies. The ultimate objective is to formulate substantial, evidence-based strategies to promote an innovative and technologically proficient SME sector within the Malaysian manufacturing industry. The specific objectives of the study are as follows:

1. To examine the influence of TAM model variables, namely Perceived Usefulness of technical skills (PU) and Perceived Ease of Use of technical skills (PEOU), along with the Behavioral Intention to adopt IR4.0 (IRA), on Innovative Work Behavior among SME employees in the manufacturing sector of Malaysia.

2. To assess the impact of Government Support (GOV) on Innovative Work Behavior among SME employees in the Malaysian manufacturing sector.
3. To analyze the role of Personal Innovativeness in Automation (PIA) in shaping Innovative Work Behavior among SME employees in the Malaysian manufacturing sector.
4. To investigate the relationship between Learning and Development (LD) and Innovative Work Behavior among SME employees in the Malaysian manufacturing sector..

1.4 RESEARCH QUESTIONS

1. To what extent do Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) of technical skills, along with Behavioral Intention to adopt IR4.0 (IRA), predict Innovative Work Behavior (IWB) among SME employees in the Malaysian manufacturing sector?
2. Does Government Support (GOV) affect the level of Innovative Work Behavior among employees in manufacturing SMEs across Malaysia?
3. What impact does Personal Innovativeness in Automation (PIA) have towards facilitating Innovative Work Behavior (SIWB) among SME employees in manufacturing sector of Malaysia?
4. What influence does Learning and Development (LD) have towards facilitating the Innovative Work Behavior (SIWB) among SME employees in manufacturing sector of Malaysia?

1.5 RESEARCH HYPOTHESIS

In line with the research objectives, it is posited that SME employees will exhibit a higher inclination towards adopting IR4.0 technologies when the perceived usefulness, ease of use, and quality of technical skills are demonstrably beneficial. The propensity to engage in Innovative Work Behavior (IWB) is anticipated to be influenced by a constellation of factors, including the effectiveness of government policies, the innovativeness awareness of automatization, and the scope of learning and development programs. As such, the research hypotheses in this study are formulated to explore the extent to which these multifaceted variables impact employees' behavioral intentions and innovative practices within the Malaysian SME sector. Following hypotheses are formulated accordingly:

H1a: Perceived Usefulness (PU) has a positive effect on IR4 Adoption Intention (IRA).

H1b: Perceived Usefulness (PU) has a positive effect on Learning & Development (LD).

H2a: Perceived Ease of Use (PEOU) has a positive effect on IR4 Adoption Intention (IRA).

H2b: Perceived Ease of Use (PEOU) has a positive effect on Learning & Development (LD).

H3: Government (GOV) support has a positive effect on SME Innovative Work Behavior (SIWB).

H4a: Personal Innovativeness of Automation (PIA) has a positive effect on IR4 Adoption Intention (IRA).

H4b: Personal Innovativeness of Automation (PIA) has a positive effect on Learning & Development (LD).

H4c: Personal Innovativeness of Automation (PIA) has a positive effect on SME Innovative Work Behavior (SIWB) through IR4 Adoption Intention (IRA).

H4d: Personal Innovativeness of Automation (PIA) has a positive Indirect effect on SME Innovative Work Behavior (SIWB) through Learning & Development (LD).

H5a: Learning & Development (LD) initiatives have a positive effect on IR4 Adoption Intention (IRA).

H5b: Learning & Development (LD) initiatives have a positive effect on SME Innovative Work Behavior (SIWB).

H6: IR4 Adoption Intention (IRA) has a positive effect on SME Innovative Work Behavior (SIWB).

1.6 RESEARCH SIGNIFICANCE

This research holds considerable significance in the study of Innovative Work Behavior (IWB) within manufacturing SMEs, especially in the context of a developing economy like Malaysia. It addresses a notable gap in existing literature by concentrating on the unique ways these enterprises engage with and foster innovative behaviors amidst the challenges and opportunities presented by Industry 4.0. The empirical examination of IWB in this specific context not only enriches the understanding of this construct but also potentially extends its applicability, reflecting the distinctive dynamics of the SME sector. From a practical viewpoint, the insights derived from this study are invaluable for SMEs navigating the complexities of nurturing innovation within their workforce. The findings offer guidance on key factors that influence IWB, such as workforce development strategies, the role of leadership, and the creation of an organizational culture that supports innovation. These aspects are crucial for SMEs aiming to enhance their innovative capabilities and maintain competitiveness in a technology-driven market. Moreover, the research bears significant implications for policymakers, underscoring the need for initiatives and programs that support SMEs in fostering a culture of innovation, thereby contributing to broader economic development and growth. Additionally, this study makes a substantial contribution to promoting a culture of innovation within the SME sector. By identifying and understanding the determinants of innovative behavior, manufacturing SMEs can establish environments conducive to creativity, problem-solving, and continuous improvement. These are essential qualities for staying relevant and successful in an ever-changing technological landscape. While the study primarily focuses on the Malaysian context, its findings have broader implications, offering valuable insights to SMEs in

other developing countries confronting similar challenges in fostering innovation. The research's focus on IWB within manufacturing SMEs marks a critical contribution to both academic discourse and practical implementation. It effectively bridges theoretical gaps, provides strategic insights for business leaders and policymakers, and deepens the comprehension of the factors driving innovation in the manufacturing SME sector. This dual contribution underscores its comprehensive importance in the realm of business research and practice.

1.7 RESEARCH SCOPE

The scope of this research is centered around a detailed exploration of Innovative Work Behavior (IWB) within the manufacturing SME sector in Malaysia. This study aims to unravel the various factors that influence and drive IWB among employees in this critical economic sector. It investigates how organizational elements such as Learning & Development (LD) and Personal Innovativeness in Automation (PIA), as well as external factors like Government Support (GOVT), impact the propensity for innovative behaviors within SMEs. The research also examines the roles of individual perceptions, particularly Perceived Usefulness (PU) and Perceived Ease of Use (PEOU), in shaping employees' attitudes towards engaging in innovative activities. Furthermore, this study seeks to identify and understand the barriers and enablers of IWB within SMEs. By doing so, it provides valuable insights into how these organizations can foster a culture of innovation and adaptability, crucial for thriving in the rapidly evolving global market. While the primary focus is on the Malaysian context, the insights and findings have wider relevance, offering potential applications and strategies that can be beneficial to manufacturing SMEs in other regions facing similar challenges in nurturing innovation.

1.8 OPERATIONAL DEFINITION

1.8.1 PERCEIVED USEFULNESS (PU):

PU refers to the degree to which SME employees believe that using a particular system or technology will enhance their job performance (Davis, 1989).

1.8.2 PERCEIVED EASE OF USE (PEOU):

PEOU is defined as the degree to which a person believes that using a particular system or technology would be free of effort (Davis, 1989).

1.8.3 BEHAVIORAL INTENTION TO ADOPT IR4.0 (IRA):

IRA refers to the measurable intention of SME employees to adopt and utilize IR4.0 technologies in their work processes (Davis, 1989).

1.8.4 INNOVATIVE WORK BEHAVIOR (IWB):

IWB is the behavior exhibited by employees involving the generation, promotion, and implementation of new ideas within a work role, group, or organization (Janssen, 2000a).

1.8.5 GOVERNMENT SUPPORT (GOV):

GOV refers to the initiatives and policies implemented by the government that facilitate the adoption and integration of IR4.0 technologies in SMEs (Mishrif & Khan, 2023).

1.8.6 PERSONAL INNOVATIVENESS IN AUTOMATION (PIA):

PIA refers to the tendency of an individual to embrace and use new information technologies such as automation at workplace (Agarwal & Prasad, 1998).

1.8.7 LEARNING AND DEVELOPMENT (LD):

Operational Definition: LD involves the initiatives undertaken to improve skills, knowledge, and competencies of employees in adapting to new technologies (Noe, 2023).

1.8.8 CHAPTER SUMMARY

Chapter 1 of the study lays the foundation for a comprehensive exploration into the adoption and integration of Industry 4.0 (IR4.0) technologies within Malaysian Small and Medium Enterprises (SMEs). It establishes the research context, emphasizing the pivotal role of IR4.0 in modernizing the manufacturing sector and the challenges SMEs face in this technological transition. The chapter outlines the primary objectives of the research, focusing on understanding the impact of Technology Acceptance Model (TAM) variables like Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) on the Innovative Work Behavior (IWB) of SME employees, assessing the influence of government policies on IWB, and analyzing the role of Personal Innovativeness in Automation (PIA) and Learning & Development (LD) in fostering IWB. It also delineates the research hypotheses, aiming to investigate the relationships between these variables and their combined effect on the adoption of IR4.0 technologies and innovation within SMEs. The chapter sets the stage for the study by highlighting its significance in contributing to the understanding of technological adoption in SMEs, providing valuable insights for businesses and policymakers, and enhancing Malaysia's competitive edge in the global market.

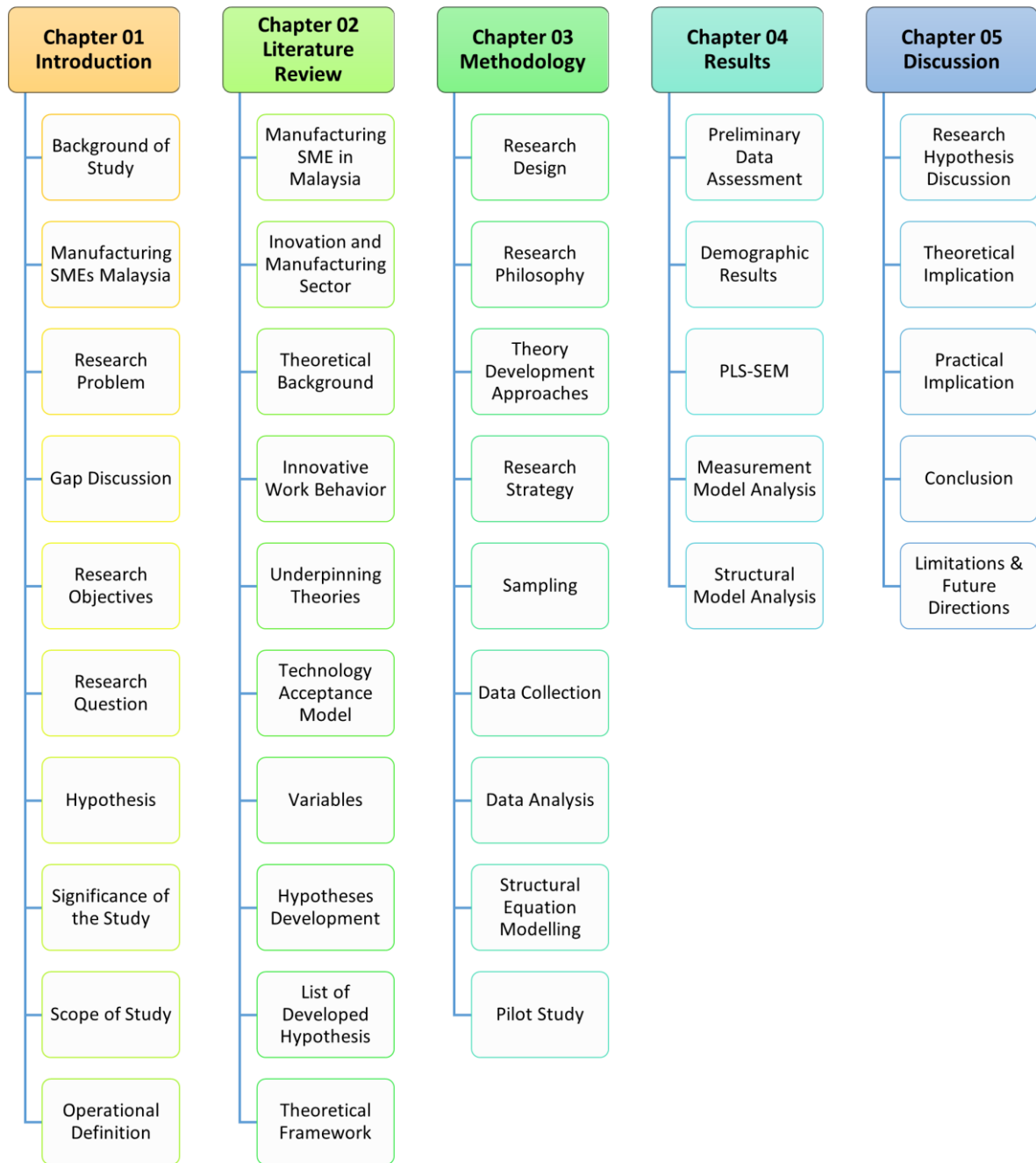


Figure 1.2 – Thesis Structure

CHAPTER TWO

2 LITERATURE REVIEW

2.1 INTRODUCTION

Chapter 2 sets out to establish a solid theoretical foundation for understanding Innovative Work Behavior (IWB) in the context of Malaysian manufacturing SMEs. It begins by reviewing existing literature, focusing on key theoretical models such as the Technology Acceptance Model (TAM) and its relevancy in the SME environment. The chapter then delves into how psychological empowerment, knowledge sharing, digital literacy, and organizational support contribute to fostering IWB among employees. This comprehensive literature review serves as the basis for developing specific hypotheses, which are designed to test the relationships between these various factors and IWB. Additionally, the chapter introduces a research framework that maps out the interconnections between these elements, providing a structured approach to investigating IWB in SMEs.

2.2 MANUFACTURING SME IN MALAYSIA

The role of small and medium-sized enterprises (SMEs) in national economic development is universally recognized, yet their innovation maturity varies substantially across countries. Economies such as Germany, Singapore, and South Korea have integrated advanced digital ecosystems within their SME sectors by fostering innovation-friendly policies, strong digital infrastructure, and human capital development initiatives (OECD, 2023). In contrast, Malaysian SMEs, particularly in the manufacturing sector, face persistent limitations related to workforce capabilities, fragmented technology adoption, and underutilization of government support programs. According to a 2022 ASEAN SME Digitalization Survey, only 36% of Malaysian SMEs had initiated structured innovation or digital transformation activities, compared to 64% in Thailand and 58% in Vietnam (ASEAN SME Monitor, 2022). This performance gap highlights not just technological disparity, but also a lag in behavioral and organizational readiness to adopt and adapt to innovation.

While Malaysian SMEs represent over 97% of business establishments and play a vital role in employment and GDP contribution, their innovation outcomes remain constrained by internal and systemic barriers. These challenges include limited strategic planning for innovation, low digital literacy among staff, and inconsistent leadership focus on innovation practices. Importantly, the human factor, especially employee engagement in innovation processes, is underexplored in both research and practice. Thus, exploring how employees perceive, adopt, and champion innovation within SMEs becomes

essential. This makes the concept of Innovative Work Behavior (IWB) central to understanding how Malaysian SMEs can close the regional innovation gap. By focusing on IWB as a behavioral driver of innovation in IR4.0 adoption, this review provides a foundation for examining how organizational, technological, and policy-level enablers interact to support sustainable innovation in the Malaysian manufacturing sector.

The landscape of Malaysian manufacturing small and medium-sized enterprises (SMEs) is a critical study area for understanding the dynamics of economic growth, resilience, and sustainability within emerging markets. As an integral component of the nation's economic structure, SMEs in the manufacturing sector offer valuable insights into the adaptive capabilities and investment attractiveness of Malaysia's industrial segment. This discussion will elucidate the background, scope, and significance of manufacturing SMEs in Malaysia, while also reflecting on the implications of their recent economic performance (SME Corp, 2022b).

SMEs in Malaysia are characterized by their size and contribution to employment, GDP, and exports. Manufacturing SMEs, in particular, are engaged in a variety of industrial activities, ranging from food processing to advanced electronics. Historically, these enterprises have benefited from Malaysia's strategic location, a conducive business environment, and government incentives aimed at promoting industrial growth. Manufacturing SMEs in Malaysia represent a significant portion of the national economy, accounting for nearly 97.3 percent of all business establishments. Their performance is not only indicative of the economic health of the sector but also reflects the broader trends in Malaysia's industrial resilience and adaptive capacity (MIDA, 2023). The sector's ability to attract substantial investments despite economic fluctuations demonstrates its importance as a driver of economic development and a bellwether for investor confidence (Jia, 2022b; SME Corp, 2022b).

The economic performance of Malaysian manufacturing SMEs has shown a pattern of resilience. After a challenging year in 2020 with a decline in GDP growth, there was a turnaround in 2021, albeit at a slower pace than the national economy. However, in 2022, the MSMEs outperformed the national GDP growth rate, indicating a robust recovery and a potential for rapid expansion. The resilience can also be ascribed to the substantial investments directed towards the manufacturing sector, which signal confidence in its long-term prospects. The shift towards sustainability is becoming increasingly significant for Malaysian manufacturing SMEs. The MSME Insights Report 2021 emphasizes the importance of sustainable practices as a catalyst for recovery. This strategic orientation towards sustainability is not only essential for the long-term viability of the enterprises but also for meeting the evolving regulatory requirements and consumer preferences globally (Jayashree et al., 2019b; Musa & Chinniah, 2016b; SME Corporation Malaysia, 2020b).

The implications of the recent economic performance of manufacturing SMEs in Malaysia are multifaceted. The rapid recovery and growth in 2022 have the potential to encourage further investments into the sector, driving innovation and technological advancements. Additionally, the emphasis on sustainability suggests that Malaysian manufacturing SMEs are positioning themselves to be competitive on a global scale, where environmental and social governance factors are becoming critical in business operations. Lastly, the sector's performance has policy implications, as it may inform government strategies for supporting SMEs through incentives, infrastructure development, and training programs to enhance competitiveness and sustainability (SME Corporation Malaysia, 2023b).

2.2.1 COMPARATIVE OVERVIEW OF MALAYSIA'S MANUFACTURING SECTOR IN THE REGIONAL CONTEXT

Malaysia's manufacturing sector has long been a cornerstone of its economy, contributing approximately 23.4% to the national GDP in 2023 (MIDA, 2024). This sector employs around 2.8 million individuals and is characterized by a diversified industrial base encompassing electronics, machinery, and palm oil processing. When compared to its regional counterparts, Malaysia's manufacturing sector exhibits both strengths and areas for improvement. In terms of labor productivity, Malaysia stands out with higher average wages in manufacturing, at approximately US\$797 per month, surpassing countries like Vietnam and Indonesia (Medina, 2024). However, this also indicates higher production costs, which can impact competitiveness. Digital technology adoption is another critical area where Malaysia is making strides. The government's Industry4WRD policy aims to transform the manufacturing sector through the adoption of Industry 4.0 technologies, including automation, artificial intelligence, and the Internet of Things. Despite these initiatives, digital adoption remains relatively slow among Malaysian manufacturing companies, with only 11% reported to have transformed most of their business processes (bin Abdul Samad, 2022). In contrast, countries like Singapore have advanced further in integrating digital technologies into manufacturing, supported by robust infrastructure and innovation-friendly policies. Vietnam and Indonesia are also rapidly developing their manufacturing sectors, focusing on attracting investments in assembly and testing operations.

2.3 INNOVATION AND MANUFACTURING SME

Innovation plays a critical role in the sustainability and competitive edge of manufacturing small and medium-sized enterprises (SMEs), particularly in the context of Malaysia's rapidly evolving economic landscape. Innovation in manufacturing SMEs involves the implementation of new ideas, products, processes, and services that can lead to enhanced efficiency, productivity, and market expansion, which are crucial for these businesses to thrive in both domestic and global markets (Jalil et al., 2022b).

2.3.1 TECHNOLOGY ADOPTION

Recent technologies such as automation, robotics, and The Internet of Things (IoT) offer new ways to transform Malaysian manufacturing SMEs in areas like competitiveness, productivity, and flexibility. The integration of intelligent control systems and robotics with complex task execution capabilities greatly redefines the production dynamics (Vidner et al., 2022; Kamble et al., 2020). These technologies enable continuous operation, streamline processes, improve adaptive response to market changes, and accelerate adaptation to market changes (Jalil et al., 2022). Moreover, automation improves operational efficiency and product quality, and also reduces critical errors and material waste, which is vital for cost-sensitive SMEs. Additionally, the Shengzhen periodical reports that despite the initial capital expenditure automation offers reduced labor costs, optimal throughput, and enhanced energy efficiency which together drive economic growth for SMEs (Selicati & Cardinale, 2021; Poorkiany et al., 2013). Unfortunately, widespread adoption is slowed down due to financial constraints and lack of requisite tailored skills most SMEs experience. To counteract these policies the Malaysian government initiated the Smart Automation Grant (SAG) under MDEC framework and other financing policies coupled with digitalization incentives designed specifically for SMEs and intended to reduce barriers to adoption and investment risk (Lim, 2021; SME Corp, 2022a).

The most relevant advances in technology improve safety, ergonomics, and job functions across various industries. Automation and robotics bolster occupational safety and health by reducing hazardous materials and repetitive strain exposure, critical to the automotive and electronics manufacturing sectors (Pivoto et al., 2018; Abdulaziz et al., 2023). In addition, feedback IoT systems and sensors offer real-time data for further ergonomic optimization of the worker-machine interface, as cited in Bitkina et al. (2020) and Meske & Junglas (2019). Enhanced productivity due to fewer injuries and associated downtime directly reduces costs. While Malaysia aims to promote itself as a responsible high-tech manufacturer, these technologies also align with the country's international labor obligations and economic goals (MIDA, 2023). More broadly, automation catalyzes the growth of SMEs by transforming non-value-added activities into strategic, high-value roles, thus enhancing IWB. This application of human and digital resources demonstrates that automation is not merely an instrument of efficiency, but a driver of sustainable innovation within the SME ecosystem (Benitez et al., 2022; Ghobakhloo & Ching, 2019).

2.3.2 INDUSTRY 4.0 TECHNOLOGIES AND INNOVATIVE WORK BEHAVIOR

Industry 4.0 (IR4.0) technologies are transforming how SMEs approach innovation by shifting the focus from manual, siloed processes to interconnected, intelligent systems. Technologies such as automation, robotics, the Internet of Things (IoT), Cyber-Physical Systems (CPS), and Big Data Analytics enhance not only operational efficiency but also stimulate Innovative Work Behavior (IWB) at the employee level (Kamble et al., 2020; Masood & Sonntag, 2020). When employees are empowered with access to real-

time data, flexible systems, and smart tools, they are more likely to engage in problem-solving, suggest improvements, and adapt processes, hallmarks of IWB. Moreover, IR4.0 technologies support continuous learning and experimentation by making workflows transparent and adaptive. IoT sensors, for instance, provide operational insights that allow employees to detect anomalies or inefficiencies and proactively intervene, turning routine tasks into opportunities for innovation (Faizal et al., 2019). Smart and connected products also encourage employees to interact with customer feedback loops, translating data into user-driven improvements. In essence, the digital infrastructure of IR4.0 becomes a behavioral enabler: the more intuitive, transparent, and data-rich the work environment, the higher the likelihood of employees engaging in innovation (Gao & Bai, 2014a; MAÇIK, 2017). However, the effectiveness of IR4.0 technologies in driving IWB is highly dependent on organizational readiness, leadership support, and workforce competence. Without these behavioral and structural foundations, the adoption of digital tools may remain superficial. Therefore, SMEs must invest not only in systems but also in fostering innovation-oriented behavior to unlock the full potential of IR4.0 capabilities.

2.3.3 CHALLENGES AND GOVERNMENT SUPPORT IN FOSTERING IWB

Despite the recognized importance of innovation, Malaysian SMEs often encounter structural, financial, and behavioral barriers that hinder the development of Innovative Work Behavior (IWB). Limited digital literacy, outdated management practices, and insufficient strategic planning continue to restrict the ability of employees to engage in creative problem-solving and technology-driven improvement (Ghobakhloo et al., 2022). These challenges are compounded by underutilization of national support frameworks, leading to inconsistent adoption of IR4.0 practices and a fragmented innovation landscape. Government support, when effectively implemented, can significantly influence the internal environment required to foster IWB. Policies such as the Industry4WRD Readiness Assessment and the Smart Automation Grant (SAG) provide not only financial assistance but also strategic direction and capability-building support. These incentives reduce technological uncertainty and signal to SME leaders the importance of empowering employees as active contributors to innovation (Tam & Gray, 2016; Majidli, 2022). The Malaysia Digital Economy Corporation (MDEC), in particular, plays a crucial role in enabling SMEs to transform digitally. Through programs like the Digital Skills Training Directory and the Global Acceleration and Innovation Network (GAIN), MDEC helps upskill workers, improve management practices, and embed a digital-first mindset within SME operations. These initiatives indirectly fuel IWB by creating a culture of lifelong learning and encouraging autonomy, creativity, and employee involvement in digital transformation. Ultimately, government support must go beyond funding to shape behaviors, organizational cultures, and systems that reward innovation from within (Jayeola et al., 2022; MDEC, 2023).

2.3.3.1 MALAYSIA DIGITAL ECONOMY CORPORATION (MDEC):

The Malaysia Digital Economy Corporation (MDEC) plays an indispensable role in the advancement of the digital economy, especially in its support for small and medium-sized enterprises (SMEs) to adopt digital technologies. MDEC's strategies are comprehensive and are designed to address the multifaceted challenges that SMEs face in their digital transformation journey (MDEC, 2021). MDEC offers financial incentives, which are crucial for SMEs considering the significant initial investment required for digital adoption. Programs such as the SME Digital Accelerator Fund and the Smart Automation Grant (SAG) provide targeted financial support to SMEs to defray the costs associated with implementing digital systems, including automation and IoT technologies (HSBC, 2023).

Workforce development is another critical area where MDEC provides assistance. Through initiatives like the Digital Skills Training Directory, MDEC helps upskill employees in SMEs, ensuring that they are adept in navigating and optimizing digital tools and systems. This upskilling is essential for SMEs to effectively manage and maintain new technologies as they are integrated into their operations.

Recognizing the growing threat of cyberattacks, MDEC also emphasizes cybersecurity, offering tools and training to help SMEs safeguard their digital operations. This includes collaborations with cybersecurity firms to provide SMEs with access to security tools and services at preferential rates (Lim, 2021).

Infrastructure is a foundational component of digital adoption, and MDEC collaborates with various stakeholders to improve Malaysia's digital infrastructure. Ensuring that SMEs, regardless of their location, have access to reliable and fast internet is a priority. This is supported by national initiatives such as the National Fiberisation and Connectivity Plan (NFCP), which aims to provide widespread access to affordable, high-speed internet. In fostering a digital innovation ecosystem, MDEC facilitates linkages between SMEs, technology vendors, academia, and industry leaders. This ecosystem approach encourages collaborative efforts in innovation, research, and development. MDEC's Global Acceleration and Innovation Network (GAIN) program, for instance, connects Malaysian digital companies with global tech ecosystems to spur growth and cross-border collaborations (MDEC, 2021; SME Corp, 2022a).

Policy advocacy is also a significant aspect of MDEC's role. MDEC advocates for policies that encourage digital transformation and investment in digital technologies (Jia, 2022b). It works in tandem with government agencies to ensure that policies are in place to support the digital growth of SMEs, aligning with Malaysia's broader digital economy agenda. MDEC's initiatives are in sync with Malaysia's National Policy on Industry 4.0, known as Industry4WRD, which aims to bolster the manufacturing sector through the adoption of technologies such as automation, robotics, and IoT. The agency's alignment with national policy ensures a concerted and cohesive effort in advancing the digital economy (MDEC, 2021; MIDA, 2023). MDEC's support encompasses financial aid, skills development, cybersecurity, infrastructure,

ecosystem building, and policy advocacy to comprehensively address the needs of SMEs in their digital transformation. As Malaysian SMEs navigate the challenges of the digital economy, MDEC's role as a facilitator and enabler is crucial, positioning Malaysia as a burgeoning digital hub in the ASEAN region and beyond.

2.3.4 EVALUATION OF EXISTING LITERATURE AND GAPS

Much of the literature on innovation and digital adoption in Malaysian SMEs provides valuable foundational insights, but a closer examination reveals methodological shortcomings and inconsistent findings that limit generalizability. For instance, while Shahzad et al. (2023) and Jayashree et al. (2021) highlight barriers to Industry 4.0 (IR4.0) adoption among SMEs, their approaches rely primarily on cross-sectional data and self-reported surveys, which may not fully capture the long-term, dynamic impact of adoption on innovative work behavior (IWB). The lack of longitudinal analysis restricts the ability to assess causality or trace sustained behavioral change over time. Another concern lies in construct operationalization. Studies such as Faiz et al. (2024) and Shahadat et al. (2023) explore digital adoption using frameworks like the Technology-Organization-Environment (TOE) or Technology Acceptance Model (TAM). However, they often fail to address behavioral constructs like psychological empowerment, innovative mindset, and organizational culture, factors identified as critical to IWB by Helmy et al. (2023) and Jaaffar et al. (2024). This leads to an incomplete understanding of how digital tools are not only adopted but internalized and championed by employees. Furthermore, findings vary in terms of what drives adoption, some emphasizing technological readiness (Jayashree et al., 2022), others pointing to top management support or external pressure (Faiz et al., 2024), suggesting a lack of consensus. Regional and policy-based analyses (e.g., bin Abdul Samad, 2022; Medina, 2024; MIDA, 2024) also tend to offer macro-level views without delving into SME-specific challenges like resource constraints or workforce digital literacy. This disconnect between strategic policy and operational execution has been noted in recent assessments by OECD (2021) and Sapiai et al. (2024), calling for more integrative frameworks that bridge behavioral, organizational, and policy domains. Addressing these limitations, the current study contributes by integrating TAM with behavioral variables such as IWB, government support, and learning development, offering a more holistic framework to understand innovation within Malaysian SMEs under IR4.0.

2.4 UNDERPINNING THEORY

Underpinning theories in research provide a foundational framework that guides the study's conceptual understanding and methodology (Hammell, 2009). These theories offer a lens through which researchers can view their subject matter, helping to define concepts, establish boundaries, and suggest relationships between variables. In essence, they form the backbone of research, offering explanations for why and

how certain phenomena occur, and often predicting outcomes based on theoretical constructs (Cuthbertson et al., 2020). In the sphere of information systems and technology innovation, several theories have been developed to understand and predict how individuals and organizations adopt and use new technologies. These theories are crucial in guiding both academic research and practical applications, especially in an era where technology is rapidly evolving and its adoption is critical for operational success and competitive advantage (Iyamu, 2013).

2.4.1 INFORMATION SYSTEM THEORIES

2.4.1.1 TECHNOLOGY ACCEPTANCE MODEL (TAM)

Technology Acceptance Model (TAM) is developed by Fred Davis in 1989. TAM is based on the premise that two main factors influence the adoption and usage of technology: perceived usefulness and perceived ease of use. Perceived usefulness is the degree to which a person believes that using a particular technology would enhance their job performance. At the same time, perceived ease of use refers to the degree to which a person believes that using the technology would be effort-free (Davis, 1989).

2.4.1.2 TAM2 & TAM3

TAM2 and TAM3 are extensions of the original TAM. TAM2 incorporates additional variables like social influence processes (subjective norm, voluntariness, image) and cognitive instrumental processes (job relevance, output quality, result demonstrability) (Venkatesh & F.D. Davis, 2000). TAM3 further extends this model by including the effects of technology characteristics, individual differences, and the impact of interventions on usage behavior (Altay & Okumuş, 2021).

2.4.1.3 UNIFIED THEORY OF ACCEPTANCE AND USE OF TECHNOLOGY (UTAUT)

Unified Theory of Acceptance and Use of Technology (UTAUT) is proposed by Venkatesh et al. in 2003, aims to explain user intentions to use an information system and subsequent usage behavior. The theory holds that four key constructs (performance expectancy, effort expectancy, social influence, and facilitating conditions) are direct determinants of usage intention and behavior (Venkatesh et al., 2003).

2.4.1.4 DIFFUSION OF INNOVATIONS (DOI)

Diffusion of Innovations (DoI) theory, developed by Everett M. Rogers in 1962, is another foundational theory that has significantly contributed to understanding how new ideas and technologies spread within societies. DI theory explains the process by which an innovation is communicated over time among the participants in a social system. At the heart of this theory is the classification of adopters into categories based on their readiness and speed of adopting an innovation: innovators, early adopters, early majority, late majority, and laggards. Innovators are the first to adopt an innovation, followed by early adopters, who are more integrated within the social system than innovators. The early majority adopts innovations before the average member of a society, while the late majority is skeptical and adopts only after the

majority of society has done so. Laggards are the last to adopt an innovation, typically due to reasons such as economic constraints or resistance to change (Değerli et al., 2015; Rogers, 1995).

The Diffusion of Innovations explains how innovations are communicated and adopted over time through social systems. However, the model primarily classifies users based on timing of adoption, innovators, early adopters, and so on, without considering how internal organizational behavior and personal motivation influence innovation outcomes. As such, DOI is limited in explaining how or why individuals within firms engage in innovation at the behavioral level, particularly in response to workplace culture, empowerment, or leadership (Greenhalgh et al., 2004). For SMEs navigating IR4.0 transitions, these behavioral factors are essential to sustaining innovation.

2.4.1.5 THEORY OF PLANNED BEHAVIOR (TPB)

Theory of Planned Behavior (TPB) developed by Icek Ajzen, is a theory that predicts deliberate behavior, because behavior can be deliberative and planned. TPB posits three conceptually independent determinants of intention: attitude toward the behavior, subjective norms, and perceived behavioral control (Ajzen, 1991).

2.4.1.6 TECHNOLOGY-ORGANIZATION-ENVIRONMENT (TOE)

Technology-Organization-Environment (TOE) Framework proposed by Tornatzky and Fleischer in 1990, is used to analyze the process of adopting technological innovations in organizations. It suggests that the decision to adopt innovations is influenced by the technology itself, the organizational context, and the external environment (Cooper & Zmud, 1990).

2.4.2 TECHNOLOGY ACCEPTANCE MODEL (TAM)

The Technology Acceptance Model (TAM), developed by Fred Davis in 1989, is a seminal theoretical model in the field of information systems that aims to predict and explain user behavior regarding technology adoption. TAM has its roots in the Theory of Reasoned Action (TRA), a psychological theory that explains behavior through specific beliefs. At its core, TAM posits that there are two primary determinants of technology acceptance and usage: Perceived Usefulness (PU) and Perceived Ease of Use (PEOU). The Technology Acceptance Model (TAM), while highly regarded for predicting user acceptance of technologies, is primarily focused on cognitive determinants such as perceived usefulness and perceived ease of use (Davis, 1989). However, TAM does not inherently address the motivational and behavioral constructs essential for driving Innovative Work Behavior (IWB) such as employee initiative, knowledge sharing, and organizational learning. Scholars have noted that while TAM is effective for measuring adoption intent, it lacks the depth to explain proactive, discretionary behaviors that go beyond

mere system usage (Venkatesh & Bala, 2008; Bagozzi, 2007). In rapidly evolving IR4.0 environments, where innovation depends on behavioral engagement, this is a critical limitation.

Although each of the above discussed theoretical models such as TAM, UTAUT, DOI, and TOE, offers important insights into how technology is adopted, they remain limited in explaining how individuals within organizations behave beyond adoption. Notably, they do not explicitly account for factors such as leadership influence, psychological empowerment, learning culture, or motivational triggers, which are central to fostering Innovative Work Behavior (Messmann & Mulder, 2012; Anderson et al., 2014). This gap is particularly important in the context of Malaysian SMEs, where behavioral readiness and internal innovation capabilities are as critical as technological adoption. Hence, this study builds on TAM as a base but extends it to incorporate contextual, organizational, and behavioral constructs that better reflect the realities of IR4.0 transformation in SMEs.

2.4.3 PERCEIVED USEFULNESS (PU)

This refers to the degree to which a user believes that using a particular system or technology would enhance their job performance or productivity. In TAM, this is considered a direct determinant of a user's attitude towards using the system and their intention to use it. The underlying assumption is that if potential users believe that a technology or system will significantly contribute to their work effectiveness or provide substantial benefits, they are more likely to adopt and use it.

2.4.4 PERCEIVED EASE OF USE (PEOU)

This concept relates to the degree to which a user expects the technology to be free of effort. It is the extent to which a potential user expects that using the system will be effortless. PEOU influences both the user's attitude towards using the system and their perception of its usefulness. The easier a technology is to use, the more likely it is that a user will find it useful and, consequently, be more inclined to adopt it.

The model further delineates that the intention to use a technology (behavioral intention) leads to actual system use. Both PU and PEOU directly influence this behavioral intention, with PU also being influenced by PEOU. In essence, if a technology is perceived as easy to use, it is more likely to be perceived as useful, and this perception positively affects the user's attitude towards using it, leading to higher actual usage.

2.4.5 SIGNIFICANCE OF TAM

TAM has been widely used in various fields to understand users' acceptance of different types of technologies, ranging from software applications to e-commerce platforms. The model's robustness and adaptability have made it one of the most cited and employed models in the field of technology acceptance. It has been instrumental in guiding the development, implementation, and evaluation of technology systems, helping organizations to better tailor their technology strategies to user needs and

preferences (Natarajan et al., 2017). The Technology Acceptance Model (TAM) holds significant importance in today's era, especially in understanding the adoption of innovation, owing to its ability to simplify the complex dynamics of technology acceptance. As new technologies continually emerge, TAM provides a clear and effective framework for analyzing why and how they are adopted. It narrows down the focus to two primary factors: perceived usefulness and perceived ease of use. This simplification is crucial in an environment where choices in technology are abundant and diverse (Cheunkamon et al., 2020).

Central to TAM's enduring relevance is its user-centric approach. The current technological landscape is intensely focused on user experience, with products and services being designed with user preferences and usability in mind. TAM aligns perfectly with this trend by emphasizing the user's perspective and focusing on their perceptions of technology. This approach is vital for understanding user attitudes and predicting their behavior towards new technologies, which is a critical component for successful innovation adoption (Sheikh Muhamad Hizam et al., 2021; Kanwal & Rehman, 2017). In the sphere of strategic planning and decision-making, TAM offers valuable insights. Businesses and organizations often face critical decisions about adopting new technologies. By evaluating perceived usefulness and ease of use, they can better understand whether a new technology aligns with their operational needs and capabilities, guiding strategic planning and resource allocation (W. Ahmed, Hizam, Sentosa, Akter, et al., 2020; S M Hizam et al., 2021; Koundinya, 2019). TAM also plays a crucial role in the design and development of new technologies. It provides key insights into what users value and expects from new technologies. This understanding drives the development process, ensuring that new products are not only technologically advanced but also user-friendly and perceived as beneficial by their target audience (W. Ahmed et al., 2022a; W. Ahmed, Hizam, Sentosa, Ali, et al., 2020; Patil et al., 2022; Salimon et al., 2023).

2.4.6 TAM IN MANUFACTURING SECTOR

The Technology Acceptance Model (TAM) has been extensively utilized in understanding technology adoption in the manufacturing sector. Various empirical studies have applied and extended TAM to explore how manufacturing industries, particularly SMEs, approach new technologies.

(GIRI et al., 2019) employed TAM to study the intention to adopt electronic Human Resource Management (e-HRM) in the Indian manufacturing industry. They found that both perceived usefulness and ease of use significantly influenced the intention to adopt e-HRM, highlighting TAM's applicability beyond traditional IT systems to specialized management systems in manufacturing. (Arpacı, 2019) extended TAM to evaluate the factors affecting the decision of SME decision-makers in the manufacturing industry to adopt ERP systems. The study underscored the importance of external

variables such as social influence and facilitating conditions in conjunction with TAM's original constructs, suggesting that the model can be effectively expanded to suit the complex decision-making environment of manufacturing SMEs.

(Gartner et al., 2022) explored the role of the fear of missing out (FOMO) and experience in the formation of SME decision-makers' intentions to adopt new manufacturing technologies. Their study integrated psychological factors with TAM, demonstrating the model's flexibility in incorporating emotional and experiential elements that influence technology adoption decisions in the manufacturing sector. (Chatterjee et al., 2021) applied an integrated TAM-TOE (Technology-Organization-Environment) model to understand AI adoption in manufacturing and production firms. This integration highlights how TAM's core constructs interact with organizational and environmental factors, providing a more comprehensive understanding of technology adoption in complex manufacturing settings.

In the context of sustainable manufacturing, (Tang et al., 2020) discussed the role of innovation in recycling municipal and construction solid wastes for sustainable construction materials. While not directly applying TAM, their study aligns with the model's principles by emphasizing the necessity of perceived usefulness and ease of use in adopting sustainable manufacturing practices. (Chin & Lin, 2015) investigated the perspectives of users in building energy management systems in Indonesian manufacturing companies using an extended TAM. Their findings emphasized how perceived ease of use and usefulness, along with additional factors like environmental concern, influence the acceptance of such systems in the manufacturing sector. (Liu & Wang, 2010) presented a strategy for enterprise information planning in manufacturing based on the TOE-TAM model, which combined the Technology-Organization-Environment framework with TAM. This approach demonstrated how external, organizational, and technological factors collectively influence the acceptance of information systems in manufacturing enterprises.

In a study by (GRESHAM, 2020), TAM was linked with business change management to understand the trends in automated inspection equipment in manufacturing. The research illustrated how TAM could be employed to gauge the acceptance of sophisticated manufacturing technologies in the context of broader business transformation strategies. (HUSSEIN et al., 2019) explored technology factors in B2B e-commerce with a mediating effect of perceived usefulness among Jordanian manufacturing SMEs. The study highlighted the importance of perceived usefulness as a mediator in the relationship between technology factors and adoption, in line with TAM's assertions. While (Calisir et al., 2014) used TAM to predict the intention to use a web-based learning system in the context of perceived content quality and system quality. Their findings support the notion that TAM's constructs are relevant and influential in diverse technology acceptance scenarios, including those relevant to the manufacturing industry.

These studies collectively underscore the adaptability and relevance of TAM in various contexts within the manufacturing sector, from specific technologies like AI and ERP systems to broader aspects like sustainable practices and e-commerce. They demonstrate that while the original constructs of TAM are robust, the model's flexibility allows for extensions and integrations that cater to the unique challenges and dynamics of technology adoption in manufacturing.

While these studies affirm the utility of TAM in examining technology adoption, they do not capture the full behavioral spectrum associated with innovation within SMEs. Specifically, the model does not consider proactive behaviors such as idea generation, problem-solving, and implementation by employees, core elements of Innovative Work Behavior (IWB). In the IR4.0 context, innovation stems not only from acceptance of technology but from how employees interact with, adapt, and extend its use within dynamic environments (Bagozzi, 2007; Anderson et al., 2014). Thus, while TAM informs the foundational constructs in this study, it is extended through behavioral and contextual variables to better suit the Malaysian SME landscape.

2.4.7 TAM IN MALAYSIAN CONTEXT

The exploration of technology adoption in Malaysian manufacturing SMEs, through the lens of the Technology Acceptance Model (TAM), presents a fascinating tapestry of interpretations and adaptations, as evidenced by various scholarly works. Each study contributes to a nuanced understanding of how TAM's fundamental principles interact with the unique characteristics of the Malaysian manufacturing landscape.

(Lee, Mah Hang Siti-Nabiha, A.K. Norfarah, Nordin, 2023) propose a framework that interweaves TAM with contextual nuances specific to the Malaysian manufacturing sector. This approach underscores the argument that while TAM's core constructs are universally applicable, their influence can be significantly modulated by local contextual factors. This perspective is crucial in acknowledging the diversity and specificity of technology adoption scenarios across different cultural and economic landscapes. In contrast, (Ghobakhloo & Ching, 2019) present a more universalist view of TAM, emphasizing its broad applicability across various contexts. Their research suggests that the intrinsic attributes of TAM – perceived usefulness and ease of use – are fundamentally relevant in shaping technology adoption decisions, regardless of the geographical or sectoral context. This stance posits that the core of TAM remains robust and applicable across diverse settings, including the distinct environment of Malaysian SMEs.

Meanwhile, (Tien et al., 2020) offer a middle ground by extending TAM with additional variables that reflect the specificities of the Malaysian SME environment. Their model suggests that while TAM's foundational constructs are essential, the integration of contextual factors enhances the model's predictive

power and relevance. This approach exemplifies a tailored application of TAM, where its fundamental principles are respected but also augmented to suit specific business realities. (Rahamaddulla et al., 2021) indirectly align with TAM's principles in conceptualizing a smart manufacturing readiness model. Their focus on factors analogous to perceived usefulness and ease of use within the readiness and maturity framework for smart manufacturing in Malaysian SMEs illustrates the implicit influence of TAM in broader technology adoption models.

The qualitative exploration by (Abdullah et al., 2013) into the enablers of technology adoption complements the TAM framework by highlighting the significance of both internal and external factors. This study enriches the TAM discourse by arguing for a more holistic view of technology adoption that considers a wider range of influencing factors beyond the traditional TAM constructs. (Mokhtar et al., 2020) add a layer of complexity by highlighting the importance of innovation in adopting cloud computing, thereby suggesting an interplay between technological innovation and TAM's traditional constructs. Their study points to a dynamic interaction between evolving technological landscapes and the foundational principles of TAM in the Malaysian manufacturing context.

Finally, (Salimon et al., 2023) advocate for an integrative approach, combining TAM with other models to better understand technology adoption in Malaysian SMEs. This synthesis approach acknowledges the limitations of TAM when used in isolation and underscores the value of a multifaceted analytical framework in capturing the complexities of technology adoption in SMEs. Connecting these diverse perspectives paints a picture of TAM as a flexible, yet fundamentally solid framework that can be adapted and extended to suit the specific needs of Malaysian manufacturing SMEs. These scholarly works collectively argue for a nuanced application of TAM, one that respects its core principles but also embraces the need for contextual adaptation and integration with additional theoretical constructs. This discourse not only enriches our understanding of technology adoption in Malaysian SMEs but also illustrates the dynamic nature of applying theoretical models in practical, real-world scenarios.

2.5 VARIABLES & HYPOTHESES

The selection of variables covers a spectrum, from individual-level characteristics like Personal Innovativeness in Automation (PIA) to broader organizational and environmental factors such as Government Support (GOVT) and Learning & Development (LD). Each variable is strategically chosen for its relevance and potential influence on technology adoption and innovation, reflecting a comprehensive approach to capturing the complex dynamics in the manufacturing sector. Alongside these variables, the section introduces the hypotheses – conjectures and theoretical assertions poised for empirical testing. These hypotheses are formulated based on a synthesis of existing theoretical insights and empirical findings, positing relationships between the identified variables. They function as guiding

propositions for the research, exploring how factors like Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) influence employees' intentions towards adopting Industry 4.0 technologies, or the role of governmental support in fostering innovative behaviors in SMEs. The formulation of these hypotheses is not only pivotal in driving the research forward but also in enriching the academic discourse. The empirical examination of these hypotheses aims to yield insights that are both theoretically robust and practically significant, particularly in shedding light on the nuances of technology adoption and innovation within Malaysian manufacturing SMEs.

2.5.1 SME INNOVATIVE WORK BEHAVIOR (SIWB)

Innovative Work Behavior (IWB) in SMEs emerges as a multifaceted phenomenon, where various factors intricately converge to drive innovation at the employee level. The complexity of fostering IWB in SMEs requires a nuanced understanding of these interrelated factors (Alnajjar & Hashim, 2020). The psychological empowerment and knowledge sharing nexus, as illustrated by (Helmy et al., 2019), serves as a foundational element in cultivating IWB. When employees feel empowered, possessing a sense of control and recognition of their work's impact, they are more inclined to engage in innovative activities. This empowerment, when synergized with a culture that promotes the free exchange of ideas, creates a fertile ground for innovation. Further extending this idea, (Johari et al., 2021) emphasize the significance of a supportive organizational context. The extent to which employees perceive their environment as conducive to innovation, characterized by supportive leadership, effective teamwork, and an overall positive work culture, directly influences their propensity to engage in creative and innovative tasks. Such an environment not only nurtures creativity but also provides the necessary psychological safety for employees to take risks associated with innovative behaviors. In the era of digital transformation, the role of digital literacy becomes increasingly pivotal. (Pilav-Velić et al., 2021) argue that an employee's competency in digital tools is a key determinant of their ability to contribute innovatively. As digital tools become integral to business processes, employees' comfort and skill in utilizing these tools directly impact their innovative output.

Organizational justice and its influence on knowledge sharing further compound the complexity of fostering IWB. A workplace perceived as fair and equitable encourages knowledge sharing, a critical ingredient for innovation. Employees in such environments feel valued and are more likely to share ideas and insights, contributing to a collective pool of knowledge that fuels innovation (Akram et al., 2019). The role of intergenerational knowledge transfer, highlighted by (J. Wang et al., 2022) et al. (2022), adds another layer to understanding IWB. The exchange of knowledge and ideas between different generational cohorts within an organization can spark innovative thinking, combining the wisdom of experience with fresh, novel perspectives. Flexible human resource management practices and their

impact on IWB cannot be overstated. HR policies that offer flexibility and autonomy are key drivers of innovation. By empowering employees with greater control over their work and providing an environment that encourages experimentation, organizations can significantly enhance their innovative capacity (Javed et al., 2017). The concept of ambidextrous leadership is instrumental in facilitating IWB. Leaders capable of balancing explorative and exploitative strategies create an environment where innovation is not only encouraged but is also strategically aligned with the organization's broader objectives (Usman et al., 2022). Fostering IWB in SMEs is a multifaceted endeavor that requires a strategic alignment of various organizational elements. From psychological empowerment and supportive organizational cultures to digital literacy and ambidextrous leadership, each factor plays a pivotal role in shaping an environment conducive to innovation. Understanding and effectively managing these dynamics are key to unlocking the innovative potential within SMEs, a critical factor for success and sustainability in today's fast-paced business world.

2.5.2 PERCEIVED USEFULNESS (PU)

In the rapidly evolving landscape of the Fourth Industrial Revolution (IR 4.0), understanding the factors that drive the adoption of advanced technologies is crucial for organizations, particularly in the manufacturing sector. Perceived Usefulness (PU), as conceptualized in the TAM, refers to an individual's subjective belief that using a particular technology will enhance their job performance or effectiveness (Davis, 1989). In the context of IR 4.0, PU specifically refers to the extent to which employees believe that acquiring and using technical skills related to advanced manufacturing technologies will boost their job performance. This belief is a critical factor influencing the decision of SMEs to adopt such technologies. Employees' perception of the usefulness of these skills directly impacts their motivation to learn and engage with IR 4.0 technologies, thereby playing a pivotal role in the technology adoption process.

For the successful implementation of IR 4.0, a comprehensive skill set encompassing areas like the Internet of Things (IoT), Artificial Intelligence (AI), robotics, and big data analytics is essential. These technical skills are crucial not just for the basic operation of IR 4.0 technologies but also for their seamless integration into the existing manufacturing processes of SMEs. The perceived usefulness of these skills is directly linked to how effectively these technologies can be utilized in the manufacturing environment. Employees' understanding of this relevance is a key driver for the adoption and optimal use of IR 4.0 technologies (Faizal et al., 2019b). One of the primary justifications for adopting IR 4.0 technologies is the substantial improvement they bring in productivity and efficiency. Techniques such as automated manufacturing processes, real-time data analytics, and predictive maintenance, facilitated by IR 4.0 skills, enable SMEs to optimize their operations. Employees' recognition of how these skills

contribute to reducing operational costs, improving product quality, and enhancing production speed is a significant aspect of their perceived usefulness. This recognition motivates employees to embrace IR 4.0 technologies, thereby supporting the broader adoption goals of SMEs (Mokhtar et al., 2020).

Malaysia's manufacturing sector is undergoing a significant transformation, embracing digitalization and automation as part of its national policy objectives. In this context, the PU of technical skills becomes a cornerstone for success. SMEs, which form a substantial part of Malaysia's industrial backbone, must align with these national objectives (Jia, 2022b). The workforce's belief in the usefulness of IR 4.0-related skills directly correlates with the eagerness and speed at which these SMEs can adapt to new technologies. This alignment is crucial for Malaysia's competitive standing in the global market, making the PU of technical skills not just an organizational priority but also a national imperative. In the rapidly evolving global market, consumer demands are shifting towards customization, quality, and sustainability. For Malaysian manufacturing SMEs to meet these demands, adopting IR 4.0 technologies becomes essential (Yacob & Peter, 2022). The PU of technical skills in this regard is vital as it enables employees to efficiently manage and deploy these technologies, ensuring that the products meet the evolving market standards. This adaptability, driven by skilled employees who perceive these new skills as beneficial and essential, is key to maintaining and enhancing market relevance and customer satisfaction (HUSSEIN et al., 2019).

The adoption of IR 4.0 in Malaysian manufacturing SMEs is not just about keeping pace with technology; it's also about fostering a culture of innovation and sustainability. The PU of technical skills in this context goes beyond operational efficiency; it extends to enabling employees to contribute to sustainable practices and innovative solutions (Hussein et al., 2007). Employees who perceive these skills as useful are more likely to experiment, propose new ideas, and find ways to incorporate sustainable practices into manufacturing processes. This mindset is crucial for long-term growth and for positioning Malaysia as a hub of innovative and sustainable manufacturing practices.

2.5.2.1 PU & IRA

In the perspective of Manufacturing SMEs, PU becomes a critical factor influencing employees' attitudes towards the adoption of IR 4.0 technologies in terms of technical skills and digital inclination. This could encompass technologies such as Internet of Things (IoT), Artificial Intelligence (AI), and automation, all integral components of IR 4.0 (Thathsarani & Jianguo, 2022). Employees who perceive these technologies as useful are more likely to view them as valuable tools that can improve their work efficiency, effectiveness, and overall job performance. This positive perception forms as PU increases, the intention of employees to adopt IR 4.0 technologies will also increase. On the other hand, the Adoption Intention of IR 4.0 (IRA) is a forward-looking measure that reflects the inclination of employees in the Manufacturing

sector to embrace and integrate IR 4.0 technologies into their daily work routines. It's a precursor to actual adoption behavior and signifies the willingness of employees to commit to using these advanced technologies (Ta & Prybutok, 2018).

TAM posits that PU is a key determinant of users' behavioral intentions to adopt technology. Numerous studies applying TAM or its variants have consistently found a positive association between perceived usefulness and adoption intention across various technological contexts. In the specific case of IR 4.0 technologies, the concept is strengthened by the transformative nature of these technologies. Employees are more likely to express an intention to adopt technologies they believe will enhance their job performance, aligning with the core tenet of PU (Zhou, 2008).

Empirical studies in the field of technology adoption provide consistent support for the positive influence of PU on adoption intention. Research across diverse sectors and technological domains has repeatedly demonstrated that users are more inclined to adopt technologies perceived as useful (Altamimi et al., 2022). In the context of IR 4.0, studies exploring the adoption of specific technologies such as AI, IoT, and automation have corroborated the importance of PU. Employees who recognize the practical benefits of these technologies are more likely to exhibit a positive attitude and intention towards their adoption (Mital et al., 2018).

The unique characteristics of the Manufacturing SMEs context, including the size of the organizations and the regional industrial landscape, necessitate a nuanced understanding of factors influencing technology adoption. The organizations may face distinct challenges and opportunities in adopting IR 4.0 technologies. Employees' perceptions of the usefulness of these technologies can be influenced by factors such as the relevance of technology to their job roles, the perceived impact on productivity, and the alignment with organizational goals (Inayatulloh, 2020; Sciarelli et al., 2022; Thathsarani & Jianguo, 2022). Drawing from the above discussion, the subsequent hypothesis is posited:

Hypothesis 1a (H1a): Perceived Usefulness (PU) positively influences the Adoption Intention of IR4.0 (IRA).

2.5.2.2 PU & LD

Perceived Usefulness (PU) plays a pivotal role in Learning and Development (L&D) within the context of Industry 4.0 (IR 4.0) adoption in manufacturing SMEs. When employees perceive the technical skills associated with IR 4.0 as beneficial for their job performance and career advancement, their engagement and motivation in L&D initiatives increase significantly (Saenphon, 2017). This belief in the utility of new skills not only drives a more enthusiastic participation in training programs but also fosters a proactive learning culture within the organization. As employees recognize the tangible benefits of mastering these skills - such as improved efficiency, enhanced problem-solving capabilities, and greater

adaptability to technological changes - they become more invested in their own professional development. This investment is crucial for the effective implementation and utilization of IR 4.0 technologies, thereby directly contributing to the overall growth and competitiveness of the SMEs.

Literature addresses a crucial aspect of technology adoption within (SMEs): the relationship between perceived usefulness (PU) and employees' proclivity to engage in continuous learning and development (LD) initiatives. LD refers to the continuous process of acquiring new knowledge, skills, and competencies relevant to one's role and the evolving demands of the industry. In the context of IR 4.0, LD encompasses activities aimed at helping employees adapt to technological advancements and acquire the necessary skills to navigate the changing landscape (Mauro et al., n.d.). One of the primary reasons for emphasizing the relationship between PU and LD in the Manufacturing SMEs context is the need to address the skills gap. As these SMEs strive to integrate IR 4.0 technologies, employees must acquire the skills and knowledge required to operate and leverage these technologies effectively. Study supports that more employees perceive these technologies as useful, the more motivated they will be to engage in LD plans (Al-Rahmi et al., 2019).

The Malaysian manufacturing sector, particularly within SMEs, may encounter challenges in adapting to the rapid technological changes. Employees' perception of the usefulness of these technologies is likely to play a pivotal role in their willingness to invest time and effort in learning new skills. This indicates the importance of LD as a strategic response to the technological shifts in the industry (Inayatulloh, 2020). PU not only influences ones' behavioral intention but also has implications for their commitment to continuous learning. LD, in this context, is seen as a means to enhance job performance and remain competitive in a technologically evolving environment. Employees who recognize the utility of skills development are more likely to proactively engage in learning activities, viewing them as instrumental for personal and professional growth (Chin & Lin, 2015; Esmaeilpour, 2016).

From an organizational perspective, it has implications for talent development strategies within SMEs. Recognizing the positive influence of PU on LD allows organizations to tailor their training and development programs to align with employees' perceptions and needs. This targeted approach can contribute to a more effective utilization of resources and a workforce that is better equipped to drive technological innovation (Al-Azawei et al., 2016). Where agility and adaptability are often critical for survival and growth, aligning LD initiatives with employees' perceptions of usefulness fosters a culture of innovation and responsiveness. Therefore, speaks to the broader goal of integrating technology and human capital development in a way that is mutually reinforcing. It underscores the importance of a strategic approach to talent development that is attuned to employees' perceptions and contributes to the

overall competitiveness and sustainability of SMEs in the manufacturing sector (Faizal et al., 2019b).

Based on the above discussion, the following hypothesis is proposed:

Hypothesis 1b (H1b): Perceived Usefulness (PU) positively influences Learning & Development (LD).

2.5.3 PERCEIVED EASE OF USE (PEOU)

PEOU, in the domain of IR 4.0, specifically refers to the extent to which employees believe that learning and utilizing technical skills related to IR 4.0 technologies is effortless (Davis et al., 1989). This perception is crucial in a manufacturing environment, particularly in SMEs, as it directly influences the willingness and ability of the workforce to engage with new technologies. When employees perceive these new technical skills as easy to learn and use, their inclination to embrace IR 4.0 technologies increases, thereby facilitating smoother adoption and integration within the organization. The perception of ease in acquiring IR 4.0 skills significantly affects the effectiveness of training and development initiatives in SMEs. If employees perceive these skills as accessible and straightforward, they are more likely to participate actively in training programs. This perception reduces the psychological barriers to learning complex technologies such as AI, robotics, and big data analytics, making the training process more efficient and productive. It's imperative for SMEs to design training programs that are perceived as user-friendly and relevant, thereby enhancing the overall learning experience (Acheampong et al., 2017).

PEOU is a key determinant in the Technology Acceptance Model, which suggests that the ease with which employees can learn and use new technologies directly impacts their acceptance and usage of these technologies. In the context of Malaysian manufacturing SMEs, where IR 4.0 is still a relatively new frontier, simplifying the learning curve is essential. The more intuitive and straightforward the employees perceive the technology, the more likely they are to use it regularly and effectively, which is crucial for reaping the full benefits of IR 4.0 (Patil et al., 2022). Change resistance is a common challenge in implementing new technologies, especially in SMEs with limited resources. A high level of PEOU can mitigate this resistance. When employees perceive that the effort required to learn and adapt to new technologies is manageable, their apprehension and resistance to change diminish. This perception fosters a more receptive and adaptable workforce, which is essential for the successful transition to more advanced manufacturing practices under IR 4.0 (Rusly et al., 2020b). From a strategic perspective, fostering a perception of ease of use in learning IR 4.0 skills is vital for SMEs to stay competitive. In the rapidly advancing industrial landscape, the ability to quickly adapt and integrate new technologies is a key differentiator. SMEs that successfully cultivate a workforce that perceives these skills as easy to learn and use can accelerate their adoption of IR 4.0, leading to enhanced innovation, efficiency, and market responsiveness (Yuen et al., 2021).

The concept of Perceived Ease of Use (PEOU) is crucial in understanding the adoption and integration of Industry 4.0 technologies across different sectors and regions. Studies on Hungarian, Malaysian, and Indian SMEs consistently highlight the importance of PEOU in the digital transformation journey. In Hungarian SMEs, the ease of adopting new technologies is significantly influenced by government support and internal digital readiness, suggesting a strong interplay between external assistance and internal capabilities in facilitating technological adoption. In Malaysia, the decision to embrace Industry 4.0 is shaped by factors such as the availability of resources, technical skills, and the challenges posed by technical complexities and mindset changes, underscoring the role of PEOU in overcoming these barriers. Similarly, in Indian manufacturing SMEs, the relevance and ease of use of these technologies in specific operational areas emerge as key drivers of their adoption, indicating that PEOU is a decisive factor in the successful implementation of digital initiatives. This varying understanding and implementation of Industry 4.0 across sectors further emphasize the significance of PEOU, as it affects the pace and extent of technology adoption and integration in diverse business contexts (Abdullah et al., 2013; Chatterjee et al., 2021; Cuthbertson et al., 2020; Gartner et al., 2022; GRESHAM, 2020; Nezakati & others, 2019).

2.5.3.1 PEOU & IRA

The relationship between perceived ease of use (PEOU) and Industrial Revolution (IR) adoption behavior has also been extensively studied in the context of SME manufacturing (Chatterjee et al., 2021). PEOU refers to an individual's perception of how easy it is to use a particular technology. IT adoption behavior, in this context, refers to the willingness of SMEs in the manufacturing sector to adopt and integrate IT systems or tools into their operations. Prior study suggests that employees' perceptions of how effortless it is to use IR 4.0 technologies will positively influence their intention to adopt these technologies (Utomo et al., 2023).

The Adoption Intention of IR 4.0 (IRA) signifies employees' willingness and readiness to embrace and incorporate IR 4.0 technologies into their daily work routines. It serves as a precursor to actual adoption behavior and is influenced by various factors, including PEOU. If employees believe that integrating novel technologies into their tasks is straightforward and uncomplicated, they are more likely to express a positive intention to adopt. When individuals efforts are made to design and implement user-friendly interfaces and systems, it is likely to positively impact their perceptions and, subsequently, their intention to adopt the system (Lee & Park, 2023).

Research conducted by (C. F. Chen & Chao, 2011) provides support for the positive relationship between PEOU and IT adoption behavior. Their findings suggest that when individuals perceive a technology as easy to use, they are more likely to adopt and utilize it within their work processes. This aligns with the TAM, where PEOU is considered a crucial determinant of users' intention to adopt and use technology.

As SMEs navigate the complexities of the IR 4.0, it simplify the user experience can positively impact the adoption dynamics, fostering a more seamless integration of transformative technologies in the workplace. In the perspective of SME manufacturing, the perceived ease of use of technology can significantly influence adoption behavior. When SMEs perceive the adoption and integration of IT systems in their manufacturing processes as user-friendly, intuitive, and compatible with their existing operations, they are more likely to embrace and implement such technologies. In these settings, where resources may be constrained and training opportunities limited, the PEOU becomes particularly significant. Ensuring that technology integration is perceived as accessible aligns with the practical considerations and constraints faced by SMEs in the region (Salimon et al., 2023). This relationship between PEOU and IT adoption behavior in SME manufacturing validated in plenty of research and frameworks (Abdullah et al., 2013; Lee & Park, 2023; Mokhtar et al., 2020; Rahamaddulla et al., 2021; Utomo et al., 2023; Zhang et al., 2021). Creating upon the existing literature, the following hypothesis is proposed:

Hypothesis 2a (H2a): Perceived Ease of Use (PEOU) positively influences the Adoption Intention of IR4.0 (IRA).

2.5.3.2 PEOU & LD

Perceived ease of use (PEOU) and Learning & Development (LD) share a close relationship. When individuals perceive the ease of using tools or technology, it serves as a catalyst for taking steps toward LD. In any firm, where the adoption of technologies may be pivotal for staying competitive, LD becomes crucial for adapting to changes in the industrial landscape. It is grounded in the understanding that when employees perceive the ease of use in adopting new technologies, they are more likely to engage in LD activities. If the integration of digital tools is perceived as user-friendly, employees are more inclined to explore and adopt these technologies, contributing to their ongoing learning process (Mohammadyari & Singh, 2015). Resistance to change can be a significant barrier to technology adoption. If employees find the new technologies easy to use, it helps mitigate resistance, fostering a more positive attitude towards LD. This is particularly crucial in smaller enterprises where adaptability is vital for sustained growth (Ahmed et al., 2022a). When employees perceive technological tools as user-friendly, they are inclined to dedicate time and effort to cultivate the essential skills. This corresponds with the essential need for Manufacturing SMEs to elevate their technological competence, ensuring competitiveness and adaptability in the swiftly changing industrial environment (Ahmed et al., 2021).

For SMEs, resource optimization is often a critical consideration. The positive correlation between PEOU and LD may lead a pathway wherein guaranteeing the perceived simplicity of technology usage enables SMEs to streamline their investments in LD endeavors. This targeted strategy resonates harmoniously

with the prevalent resource constraints experienced by SMEs, presenting an avenue for more efficient utilization of limited resources (Khalil et al., 2011; Tam & Gray, 2016b). In the dynamic landscape of the manufacturing industry, marked by perpetual technological evolution, LD becomes a linchpin for employee adaptation. Should PEOU exert a positive influence on LD, it signifies a proactive stance toward remaining adaptable and abreast of technological advancements. This proactive approach is particularly germane in the distinctive context of Manufacturing SMEs, where staying at the forefront of technological progress is integral to sustaining competitiveness and navigating the ever-changing industrial terrain (Abdulaziz et al., 2023; Hecklau et al., 2016).

Striking a balance between technological ease and skill development not only optimizes resource allocation for companies but also underscores the proactive ethos necessary for navigating the intricate dynamics of modern industry. The interplay between PEOU and LD encapsulates a strategic paradigm, wherein perceived ease becomes a catalyst for targeted learning initiatives, propelling organizations towards enhanced competitiveness and sustained agility in the face of rapid technological shifts (Acheampong et al., 2017; Cakır & Solak, 2015). Drawing from the established literature, the next hypothesis is:

Hypothesis 2b (H2b): Perceived Ease of Use (PEOU) positively influences Learning & Development (LD).

2.5.4 GOVT SUPPORT (GOV)

Government support for Small and Medium Enterprises (SMEs), as defined by (Ruchkina et al., 2017), is characterized by policy measures that promote innovation within these enterprises. This definition provides a comprehensive understanding of government intervention in the SME sector, especially in manufacturing, and sheds light on the Malaysian context. The role of government support, enriched by additional scholarly references, can be discussed in a more nuanced manner. This approach includes creating a regulatory environment conducive to innovation, facilitating access to technology, and providing market opportunities. It's further supported by (Pham Thi Ngoc et al., 2022) findings, which emphasize that government supportive behavior significantly enhances SMEs' innovation performance, especially when mediated by service intermediaries.

This support involves not only policy creation but also infrastructure development, market access facilitation, and regulatory simplification. (Jayeola et al., 2022) highlight the positive impact of institutional support, such as participation in trade shows and staff training, on SME growth. Similarly, (Z. Zhang et al., 2021) illustrate how government financial support positively influences the adoption of technologies like cloud ERP systems, enhancing financial performance. In manufacturing, government support is crucial for providing access to advanced technologies, ensuring quality compliance, and

integrating SMEs into global supply chains. (Brako Ntiamoah et al., 2016) underscore the significant effect of government support on the performance of SMEs in sectors like agribusiness, indicating the importance of targeted interventions in manufacturing. The Malaysian government's approach, mirroring Ruchkina et al.'s (2017) definition, is innovation-centric, evident in the SME Masterplan and the National Policy on Industry 4.0. These policies aim to elevate Malaysian SMEs in the manufacturing sector to a competitive position in global markets. However, it's essential to note, as (Zulu-Chisanga et al., 2018) and (Majidli, 2022) point out, that the impact of government support can vary based on the economic context and the sector's maturity. In Ho Chi Minh city, for instance, government financial support positively influences technological innovation in SMEs, but its effectiveness is reduced in higher-grossing enterprises (Pham Thi Ngoc et al., 2022).

2.5.4.1 GOVT & SIWB

In the context of this study, Government Support (GOVT) is defined as the degree to which government initiatives, policies, or interventions provide a supportive environment for Small and Medium-sized Enterprises (SMEs). This concept encompasses a range of governmental efforts, including policy measures, financial incentives, and infrastructural support aimed at fostering a conducive atmosphere for SME growth and innovation (Ruchkina et al., 2017; YU Zhi-yang, 2012). SMEs Employees' Innovative Work Behavior (SIWB), on the other hand, refers to the proactive and creative actions undertaken by employees within SMEs to contribute to innovation within their organizational setting. This behavior is characterized by employees' engagement in novel, creative, and proactive tasks that drive the innovative capacity of their organizations (Brako Ntiamoah et al., 2016; Khalil et al., 2011; Majidli, 2022; Tam & Gray, 2016b).

A positive correlation between government support and innovative work behavior among employees in SMEs is well-documented in the literature. Governmental policies and resources dedicated to supporting SMEs create an environment that encourages and facilitates innovative practices among employees (Osei et al., 2016; Jayeola et al., 2022). Such a conducive environment is crucial for fostering a culture where experimentation and creativity are not only accepted but encouraged. Robust government initiatives, such as financial incentives, skill development programs, or technological infrastructure support, play a critical role in eliminating barriers to innovation adoption within organizations. When employees operate in an environment bolstered by government support, they are more likely to perceive it as conducive to innovation, thereby positively influencing their innovative work behavior (Mai Pham Thi Ngoc et al., 2022; Ntiamoah et al., 2016).

The active support of the government creates a ripple effect that instills confidence among employees, providing them with the necessary resources and motivation to explore novel ideas and approaches. This

alignment with the broader national agenda for economic growth and competitiveness turns government support into a catalyst for nurturing a culture of innovation within businesses. Such a culture is instrumental in driving employees towards innovative work behavior (Zulu-Chisanga et al., 2018; Majidli, 2022). Recent studies suggest that the positive influence of government support on the innovative work behavior of employees is a multifaceted interplay between external support structures and individual behaviors within a company. This synergy creates an environment where employees are not only open to innovation but are also actively engaged in shaping the innovative trajectory of their workplace (Ruchkina et al., 2017; YU Zhi-yang, 2012). Building upon these arguments, another hypothesis of this study is formulated as follows:

Hypothesis 3 (H3): Government Support (GOVT) positively influences the Innovative Work Behavior of SMEs Employees (SIWB)

2.5.5 PERSONAL INNOVATIVENESS OF AUTOMATION (PIA)

Personal Innovativeness in the use of automation, as defined by (Agarwal & Prasad, 1998), refers to the willingness of individuals to embrace and use new technologies for completing tasks in a more efficient and effective manner. Agarwal conceptualizes this trait as an aspect of individual differences in the adoption and use of new information technologies. In the manufacturing sector, personal innovativeness plays a crucial role in how quickly and effectively new technologies, particularly in automation, are adopted. Individuals with high personal innovativeness are more likely to be early adopters of automation technologies, exploring and utilizing these tools to optimize production processes (W.-T. Wang & Lin, 2021). The introduction of automation in manufacturing often encounters resistance due to the fear of job displacement or the challenges of adapting to new systems (Benitez et al., 2022). Employees with high personal innovativeness are generally more open and adaptive to these changes. They can act as change agents, influencing their peers' attitudes and easing the transition to automated systems.

Personal innovativeness is not only about the initial adoption of technology but also about continuous improvement and innovation in its use. In manufacturing, this means constantly seeking ways to enhance efficiency, reduce waste, and improve product quality through automation (Nuryyev et al., 2020). As manufacturing processes become more automated, the skill sets required for employees evolve. Those with high personal innovativeness are more likely to proactively engage in learning and developing new skills necessary for operating and managing automated systems (Kala et al., 2013). The collective personal innovativeness of employees in a manufacturing setting can significantly impact the overall effectiveness of automation. It leads to better utilization of technological resources, higher productivity, and, ultimately, a more robust and competitive manufacturing sector (Hsu, 2016).

Individuals with a high level of personal innovativeness in automation tend to be naturally inclined towards learning about and experimenting with new technologies. This curiosity drives them to be early adopters, often leading the way in implementing new systems and processes within their organizations. Their adaptability and flexibility become crucial in industries like manufacturing, where technological advancements are rapid and constant. These individuals are not just quick to learn new technologies; they are also resilient and adaptable in the face of change, demonstrating a capacity to adjust and thrive in new technological environments (Mustafa et al., 2021). The proactive initiative is another defining feature of this trait. Innovative individuals don't merely react to technological changes; they actively seek out new tools and solutions, often becoming the driving force behind their adoption in the workplace. This proactiveness is closely linked to a willingness to take risks. Experimenting with new technologies often involves navigating uncertainties, and individuals with high personal innovativeness are typically more comfortable with this aspect of innovation (Joo et al., 2014a).

The implications of personal innovativeness in automation are far-reaching. For one, it significantly enhances learning and development within organizations. Individuals with this trait engage more deeply with training programs, particularly those focused on new technologies, accelerating the overall skill development within the company (ManpowerGroup, 2019). Furthermore, their innovative approach can significantly contribute to an organization's capacity for innovation. By championing the use of new technologies and demonstrating their value, they can drive improvements in processes and products, directly impacting the organization's competitiveness.

In the context of Industry 4.0, organizations strive to integrate more automated, data-driven processes, individuals who are innovative in this regard play a key role in facilitating this transition, ensuring that the adoption of new technologies aligns with strategic business goals (Joo et al., 2014a)(Ghosh et al., 2016). Moreover, the presence of such individuals can positively influence an organization's culture, creating an environment that values continuous learning and adaptation. Their enthusiasm for and success with new technologies can inspire others, fostering a more innovative and forward-thinking workplace culture. In manufacturing SMEs, PIA encompasses the willingness and ability of employees to engage with, learn, and proficiently use emerging automation tools and processes. This innovative disposition is influenced by several factors including prior experience with technology, perceived ease of use, perceived usefulness, and the overall technological culture within the organization (Nazir & Khan, 2022a). In the Malaysian context, where manufacturing SMEs are increasingly looking towards automation as a means to enhance productivity and competitiveness, PIA takes on a heightened significance. It is not merely about the capacity to use new technologies but also involves a mindset that is open to experimenting with and adapting to these changes. Employees with high PIA are more likely to explore and embrace

automation, contributing to a culture of innovation and continuous improvement within their organizations (Ghobakhloo & Ching, 2019; Tien et al., 2020). The following hypotheses explore various dimensions of how PIA impacts different aspects related to IR4.0, learning and development, and innovative work behavior within SMEs:

2.5.5.1 PIA AND IRA

Personal Innovativeness in Automation (PIA) can exert a positive influence on the Adoption Intention of Industrial Revolution 4.0 (IR4.0) (IRA). In this context, PIA refers to an individual's inclination and ability to embrace and adopt automation technologies. Adoption Intention of IR4.0 encapsulates an individual's willingness and readiness to incorporate IR4.0 technologies into their professional practices. This suggests a direct and positive correlation between an individual's innovativeness in automation and their inclination to adopt advanced technologies associated with IR4.0 (Faizal et al., 2019b). The argument supporting a recent study is rooted in the premise that individuals characterized by a higher degree of PIA are more likely to exhibit a positive intention to adopt IR4.0 technologies. PIA reflects an individual's proclivity to engage with and embrace automation technologies autonomously. When this inclination is directed towards the IRA, it implies a predisposition towards technological advancements and a proactive approach to integrating these advancements into one's professional sphere. This aligns with established theories in technology adoption, which posit that individuals with a higher degree of innovativeness are more likely to be early adopters of new technologies (Alnajjar & Hashim, 2020; Joo et al., 2014b).

As the industrial landscape undergoes transformative changes associated with IR4.0, individuals who exhibit a proactive stance towards automation are better positioned to perceive the advantages and potential of these technologies. Their positive intention to adopt IR4.0 technologies can be seen as a natural extension of their innovative mindset. It is further justified by empirical evidence suggesting that individuals with a higher level of personal innovativeness are more likely to explore and adopt technological innovations, contributing to the evolving landscape of industrial practices (Iranmanesh et al., 2017a). Embracing a proactive and innovative mindset toward automation lays the groundwork for individuals to cultivate a positive predisposition toward integrating the transformative technologies associated with IR4.0 into their professional practices. This symbiotic relationship between personal innovativeness and technology adoption assumes critical importance in navigating the multifaceted challenges presented by the Fourth Industrial Revolution. By embracing an ethos of continuous innovation, individuals position themselves not only to adapt to but also to lead amidst the ever-evolving landscape of technological advancements characterizing IR4.0 (Asadi et al., 2019; Iranmanesh et al., 2017b; Javed et al., 2017).

Recent empirical studies have highlighted the critical role of the intention to adopt technology (IRA) as a mediating variable between personal innovativeness and innovative work behavior (IWB) within small

and medium-sized enterprises (SMEs). For instance, Shahadat et al. (2023) utilized the Technology-Organization-Environment (TOE) framework combined with the Diffusion of Innovation (DOI) theory to explore determinants of digital technology adoption in SMEs across emerging countries. Their findings indicated that factors such as relative advantage, complexity, observability, perceived cost, top management support, and innovativeness of top management significantly influence the adoption of information and communication technologies (ICTs) in SMEs. These factors, in turn, affect employees' intentions to adopt new technologies, thereby mediating the relationship between individual innovativeness and actual innovative behaviors. Furthermore, studies have shown that organizational support and a conducive digital culture are pivotal in enhancing IRA among SME employees. For example, recent research emphasizes that adoption costs, top management support, human resources, digital culture, and trading partner pressure are significant determinants of digital technology adoption in innovative SMEs (Faiz et al., 2024). These organizational factors not only influence the initial intention to adopt technology but also facilitate the translation of this intention into innovative work behaviors by providing the necessary support and resources. Therefore, integrating IRA as a mediating variable in the relationship between personal innovativeness and IWB is both theoretically sound and empirically supported, offering a nuanced understanding of how individual and organizational factors converge to foster innovation in SMEs.

This interaction between personal innovativeness and the embrace of cutting-edge technologies is indispensable for professionals navigating the broader currents of technological evolution. Beyond individual adaptation, it contributes to a collective resilience and agility within organizations, creating an environment that thrives on innovation and is well-equipped to meet the complexities posed by the Fourth Industrial Revolution (Abdullah et al., 2013; Calisir et al., 2014; Esmailpour, 2016; Gartner et al., 2022; Liu & Wang, 2010; Tang et al., 2020). Therefore, a hypothesis is suggested as a logical extension of the aforementioned arguments:

Hypothesis 4a (H4a): Personal Innovativeness in Automation (PIA) positively influences the Adoption Intention of IR4.0 (IRA).

2.5.5.2 PIA & LD

The relationship between personal innovativeness in automation (PIA) and Learning and Development (LD) is significant. Employees who exhibit high levels of personal innovativeness are typically more engaged in LD activities, especially those related to new technologies. Their innate curiosity and willingness to explore new systems make them ideal candidates for training programs focused on advanced manufacturing technologies. These individuals often become champions of new tools and processes, actively seeking out learning opportunities to enhance their skills and knowledge (Ye et al.,

2022). PIA encourages continuous learning and adaptability in the face of evolving technological landscapes. (Maity, 2019) emphasized that AI leads training and development processes in organizations, focusing on knowledge management and continuous training updates, which align with the concept of PIA enhancing LD. The interplay between innovation and automation in organizations, as noted by Luhn et al. (2005), leads to continuous learning, improved productivity, and speed in a learning organization. This suggests that PIA can create a learning culture that embraces automation for organizational efficiency (Luhn et al., 2005).

Ye et al. (2022) found that personal development support and participative decision-making positively influence employee innovation behavior. This aligns with the concept that PIA, by fostering an environment supportive of learning and development, can enhance innovative behaviors in employees. Anwar and Niode (2017) demonstrated that learning organizations positively affect employees' innovative behavior, which is mediated by increased work engagement. This indicates that PIA, by fostering a learning organization, can indirectly influence employees' innovative behavior (Anwar & Niode, 2017). Moreover, the efficacy of LD endeavors is significantly influenced by individual levels of personal innovativeness. Employees endowed with a propensity for innovation exhibit a greater inclination to assimilate acquired knowledge in inventive ways, thereby fostering a culture of continuous improvement within their work processes. Such individuals, driven by a proactive approach to embracing novel technologies, serve as catalysts for organizational progress. Their enthusiasm not only contributes to their personal growth but also radiates throughout the workforce, instigating a ripple effect that uplifts the collective technological competency of the entire organization (Frohman, 1999).

The nexus between personal innovativeness and the effectiveness of LD initiatives extends beyond individual skill development. It permeates the organizational fabric, advancing an environment where creativity and technological enthusiasm become integral to the collective ethos. By recognizing and cultivating the innovative potential of employees, organizations not only fortify their workforce's capacity for creative problem-solving but also position themselves on the forefront of technological evolution in an ever-changing landscape. Previous studies provide substantial backing for this hypothesis. Research has shown that individuals with a high degree of personal innovativeness are more likely to engage with and benefit from learning activities, especially those related to new technologies. For instance, a study published in the *Journal of Workplace Learning* highlights the correlation between individual traits such as innovativeness and the effectiveness of LD programs. Employees with a propensity for innovation tend to be more proactive in seeking out learning opportunities, more adaptable in assimilating new information, and more persistent in overcoming challenges associated with learning new technologies. This proactive and enthusiastic engagement with LD initiatives is crucial in SMEs, where the rapid

adoption of new technologies and processes is often necessary for competitive advantage (Anwar & Niode, 2017; Brako Ntiamoah et al., 2016; Frohman, 1999; Gerhard Luhn, n.d.; Jayeola et al., 2022; Maity, 2019; Majidli, 2022; Pham Thi Ngoc et al., 2022; Ye et al., 2022; Zulu-Chisanga et al., 2018). From this understanding, the following hypothesis is presented:

Hypothesis 4b (H4b): Personal Innovativeness in Automation (PIA) positively influences Learning & Development (LD).

2.5.5.3 PIA & SIWB: MEDITING ROLE OF IRA

The relationship between Personal Innovativeness in Automation (PIA) and the Innovative Work Behavior of SMEs Employees (SIWB), as mediated by the Adoption Intention of IR4.0 (IRA), offers a comprehensive understanding of how individual traits and technological adoption intentions collaborate to foster innovative behavior in the workplace. This relationship is particularly significant in understanding how personal traits like PIA facilitate the adoption of new technologies, which in turn influences employees' innovative behaviors. Role of IRA in Mediating PIA and SIWB: The willingness to adopt IR4.0 technologies (IRA) serves as a crucial link between personal innovativeness in automation and innovative work behaviors. Studies by Lee and Park (2023) and Utomo et al. (2023) demonstrate the significant role of learning environments and organizational support in fostering innovative behaviors, supporting the notion that the intention to adopt new technologies can be a key mediator in this relationship.

Individuals with a high degree of PIA are more likely to show positive intentions toward adopting IR4.0 technologies. This is supported by findings from Zhang, Liu, and Yang (2021), who explored the role of government support in enhancing innovative work behavior, indicating that external factors like PIA can influence the adoption of new technologies. Once individuals are inclined to adopt IR4.0 technologies, their innovative work behavior is positively influenced. Research highlights how organizational learning and team behaviors impact innovative work behavior, aligning with the idea that IRA catalyzes SIWB (Sapie et al., 2015; Widmann et al., 2016).

The relationship also underlines the synergy between individual traits and the adoption of advanced technologies. Studies by Luksyte, Unsworth, & Avery (2018), and Johari, Abdul Wahat, & Zaremohzzabieh (2021) reflect the impact of individual differences and support systems on innovative behaviors, supporting the interconnectedness of PIA, IRA, and SIWB. This relationship proposes a structured pathway from personal innovativeness in automation to innovative work behavior, influenced by the adoption intention of IR4.0 technologies. It emphasizes the importance of both individual characteristics and attitudes towards technology adoption in fostering innovative behaviors in SME

employees, an understanding that is supported and enriched by various studies in the field. According to this discussion, the following hypothesis emerges:

Hypothesis 4c (H4c): Personal Innovativeness in Automation (PIA) influences the Innovative Work Behavior of SMEs Employees (SIWB) through IRA.

2.5.5.4 PIA & SIWB: MEDIATING ROLE OF LD

The impact of Personal Innovativeness in Automation (PIA) on the SME's staff Innovative Work Behavior (SIWB) of employees is manifested, and this influence can be mediated by the role of Learning and Development (LD). PIA encompasses an individual's inclination and capacity to integrate innovative automation technologies into their professional domain. Within SMEs, where organizational success often hinges on adaptability and responsiveness, the proactivity and proficiency of employees in embracing automation innovations are anticipated to exert a substantial impact on the path of innovation within the organizational agenda (Gerhard Luhn, n.d.; Maity, 2019).

The mediating variable, LD, signifies the ongoing processes through which individuals acquire new knowledge, skills, and competencies. In this context, PIA is posited to influence the Innovative Work Behavior of employees by virtue of its impact on learning and development initiatives. Employees with heightened levels of PIA are expected to engage more proactively in learning and development activities related to automation technologies, thereby adopting an environment conducive to the manifestation of Innovative Work Behavior (Anwar & Niode, 2017; Frohman, 1999; Ye et al., 2022).

This relationship suggests that PIA positively impacts employees' engagement in learning and development activities, which in turn fosters innovative work behavior. The recent study on SMEs employees' learning support environment and its effect on innovative work behavior aligns with this perspective, indicating that an environment conducive to learning and development can significantly influence innovation at the workplace (Lee & Park, 2023). Individuals with high PIA are more likely to participate in learning and development activities, as their openness to automation technologies and new processes drives them to seek out and engage with opportunities for growth and skill enhancement. This is supported by the findings of Luksyte, Unsworth, & Avery (2018), who examined sex differences in perceptions and evaluations of innovative work behavior, highlighting how individual differences can impact participation in development activities (Luksyte et al., 2018).

Learning and development serve as catalysts in transforming the potential nurtured by personal innovativeness into actual innovative actions in the workplace. Johari, Abdul Wahat, & Zaremohzzabieh (2021) provide insights into how elements like principal support and humor in the educational context can enhance innovative work behavior, underlining the importance of supportive environments for learning and development. The relationship underscores the synergy between individual traits like PIA and

organizational initiatives for learning and development in shaping employee behavior. Studies such as those by Zhang, Liu, & Yang (2021) and Sapie et al. (2015) demonstrate how external factors and organizational learning determinants contribute to fostering innovative work behaviors, supporting the interconnectedness of PIA, LD, and SIWB.

Furthermore, employees with a tendency for innovativeness in automation are proposed to be instrumental in not only shaping their own LD strategies but also in influencing the broader Innovative Work Behavior of the organizational collective. By elucidating the mediating influence of LD, the idea contributes to a more comprehensive understanding of the complex dynamics at play within contemporary organizational settings, particularly within SMEs navigating the challenges of technological innovation and workforce development (Chintalapati & Daruri, 2017; Iqbal & Sidhu, 2022; Tam & Gray, 2016a). Building upon the existing literature, the following hypothesis can be proposed:

Hypothesis 4d (H4d): Personal Innovativeness in Automation (PIA) influences the Innovative Work Behavior of SMEs Employees (SIWB) through LD.

2.5.6 LEARNING & DEVELOPMENT (LD)

In the dynamic landscape of modern workplaces, the cultivation of innovative work behavior (IWB) is essential for organizational growth and adaptability. Learning and development (L&D) play a pivotal role in this context, serving as key drivers for fostering an environment where innovation can thrive.

Margaryan, Albert, and Charlton - Czaplicki (2022) define L&D in terms of self-regulated learning and skill development, particularly in the realm of online platform work. This conceptualization emphasizes the importance of continuous, self-directed learning and the acquisition of new skills as central to L&D in today's digital and automated work environments.

Widmann, Messmann, and Mulder (2016) provide crucial insights into the relationship between team learning behaviors and IWB. Their systematic review reveals a significant correlation between these domains, highlighting that a team that values learning and knowledge sharing is more likely to innovate effectively. Jo and Hong (2022) examine the impact of agile learning on IWB, mediated by employee engagement and moderated by perceived organizational support (POS). This study demonstrates that agile learning directly influences innovative behavior, and this relationship is enhanced in environments where employees feel engaged and supported by the organization. The role of leadership in fostering an environment conducive to IWB is emphasized by Anwar and Niode (2017), who highlight the effects of learning organizations on employees' innovative behavior, mediated by work engagement. This finding aligns with the concept that leadership styles, particularly those that promote learning and engagement, are crucial in enhancing IWB.

Wang, Zhao, and Zhao (2019) explore how modern educational technology impacts L&D. Their research suggests that integrating modern educational technologies into learning initiatives can significantly enhance innovative capabilities, pointing towards the importance of technological advancement in learning methodologies for fostering innovation. The integration of advanced technologies in learning and development initiatives is further explored by Faller and Feldmüller (2015), who focus on the Industry 4.0 learning factory concept for regional SMEs. Their study underscores the importance of adapting L&D strategies to include cutting-edge technological advancements. This approach not only equips employees with the necessary skills to thrive in a technologically advanced environment but also fosters an innovative mindset conducive to IWB. The adoption of Industry 4.0 technologies in L&D processes aligns with the increasing emphasis on digital and automated solutions in workplace learning, as highlighted by Margaryan, Albert, and Charlton - Czaplicki (2022).

Moreover, the role of organizational culture in fostering an environment conducive to learning and innovation is highlighted by Sapie et al. (2015). Their study on Malaysian SMEs emphasizes that organizational learning determinants significantly influence employees' innovative work behavior. This research aligns with the idea that creating a culture that prioritizes learning and development is crucial for fostering innovation within organizations. The study indicates that when organizations encourage continuous learning and skill development, they create a fertile ground for innovative behaviors to flourish, further reinforcing the findings of Jo and Hong (2022) and Anwar and Niode (2017) on the importance of a supportive learning environment.

2.5.6.1 LD & IRA

Learning and Development (LD) exerts a favorable impact on the Adoption Intention of Industrial Revolution 4.0 (IRA). This implies that engagement in learning and developmental initiatives positively contributes to the propensity of individuals to adopt the transformative technologies associated with the fourth industrial revolution (Faller & Feldmüller, 2015). It is crucial to acknowledge the contemporary business landscape, characterized by rapid technological evolution and the pervasive integration of Industrial Revolution 4.0 solutions. In this context, individuals actively participating in LD activities are postulated to acquire the requisite knowledge and competencies, encouraging a mindset conducive to embracing the advanced technologies encapsulated within Industrial Revolution 4.0 (Anwar & Niode, 2017). Employees undergoing continuous learning experiences are presumed to enhance their understanding and awareness of Industrial Revolution 4.0, thereby influencing a positive inclination toward adoption (Jo & Hong, 2022).

To explore into the rationale, it is essential to recognize that Industry 4.0 encapsulates a paradigm shift marked by the integration of digital technologies, automation, and data exchange. The success of this

transition hinges on the preparedness and adaptability of the workforce. LD initiatives serve as catalysts in enhancing the competencies and knowledge base of individuals, fostering a workforce that is not only receptive but also adept at navigating the complexities of Industry 4.0 (Sapie et al., 2015). Considering the dynamic nature of technological advancements, organizations must foster a learning culture that transcends traditional boundaries. LD initiatives facilitate the acquisition of cutting-edge skills, ensuring that employees remain abreast of the latest technological trends. This knowledge enrichment, in turn, contributes to a heightened Adoption Intention towards Industry 4.0, as individuals recognize the value of aligning their skills with the demands of the evolving industrial landscape (Margaryan et al., 2022).

Moreover, LD initiatives do more than impart technical proficiency; they cultivate a mindset conducive to innovation and adaptability. In the context of Industry 4.0, where flexibility and innovation are paramount, this attitudinal shift becomes a key determinant of Adoption Intention. Employees who undergo continuous learning are more likely to embrace change, view technological advancements as opportunities rather than challenges, and exhibit a proactive stance in integrating these advancements into their professional practices (Widmann et al., 2016). Based on this discussion, this study hypothesizes that:

Hypothesis 5a (H5a): Learning & Development (LD) positively influences the Adoption Intention of IR4.0 (IRA).

2.5.6.2 LD & SIWB:

Learning & Development (LD) can serve as a positive influencer on the SMEs employees' Innovative Work Behavior (SIWB). This assertion underscores the pivotal role of continuous skill enhancement and knowledge acquisition in fostering a work environment conducive to innovative practices within the context of the organization (Tam & Gray, 2016). To explicate the grounds, it is imperative to acknowledge the unique challenges and opportunities inherent to SMEs. These enterprises often operate in dynamic and resource-constrained environments, where the ability to innovate becomes a critical determinant of sustained competitiveness. LD initiatives, therefore, emerge as strategic instruments in augmenting the intellectual capital of SME employees, equipping them with the skills requisite for fostering innovative work behavior (Tam & Gray, 2016).

In the elaborate landscape of SMEs, where agility and adaptability are paramount, LD initiatives play a dual role. Firstly, they contribute to the cultivation of technical and cognitive skills necessary for generating novel ideas and implementing innovative solutions. This augmentation of individual competencies directly aligns with the exigencies of an environment characterized by rapid technological evolution and changing market dynamics (Anwar & Niode, 2017). Secondly, LD initiatives contribute to the development of a culture that nurtures and values innovation. As employees engage in continuous learning, they are more likely to embrace a mindset that perceives challenges as opportunities for

innovation. The acquisition of new knowledge and skills fosters a proactive stance, instilling in employees the confidence to explore novel approaches and contribute to the innovative trace of the organization (Jo & Hong, 2022).

Employees, equipped with enhanced skills and imbued with an innovation-centric mindset, are more inclined to engage in behaviors that contribute positively to the innovative work landscape of the SME. This alignment is imperative for SMEs seeking not only to survive but also to thrive in an environment characterized by dynamic market forces and the necessity for continual adaptation and innovation (Sapie et al., 2015). The premise, therefore, stands as a reasoned assertion grounded in the dynamics of LD and its profound impact on cultivating innovation within SMEs employees (Widmann et al., 2016). Following the above discussion, this study proposes the following hypothesis:

Hypothesis 5b (H5b): Learning & Development (LD) positively influences the Innovative Work Behavior of SMEs Employees (SIWB).

2.5.7 ADOPTION INTENTION BEHAVIOR (IRA)

Adoption Intention is another expression of Behavioral Intention to Adopt from TAM model which explain the intend to accept or adopt the certain system or technology (Davis, 1989). In this research Behavioral Intention to Adopt the Industrial Revolution 4.0 (IRA) in the context of manufacturing SMEs refers to the propensity or willingness of these small and medium-sized enterprises to embrace and integrate the technologies associated with the Fourth Industrial Revolution (IR 4.0). This concept is particularly crucial for understanding how these smaller businesses, which often have limited resources compared to larger corporations, approach the adoption of advanced technologies like AI, IoT, robotics, and big data analytics (Awa et al., 2015). In SMEs, the decision to adopt IR 4.0 technologies is often a significant strategic move. IRA in this context is influenced by various factors unique to smaller businesses, such as resource constraints, the scale of operations, and the nature of their market niche. The intention reflects not just an interest in technological advancement but also a strategic consideration of how these technologies can drive business growth and competitiveness (Thathsarani & Jianguo, 2022). Key drivers for IRA in manufacturing SMEs include the perceived benefits of IR 4.0 in improving efficiency, product quality, and market responsiveness. Additionally, the pressure to remain competitive in an increasingly technology-driven market can heighten the intention to adopt these technologies. Leadership vision and the internal culture towards innovation and change also play a crucial role in shaping IRA (Arpacı, 2019).

For many SMEs, challenges such as limited financial resources, lack of technical expertise, and fear of disruption can impede the intention to adopt IR 4.0. Concerns over the return on investment and the ability to integrate new technologies with existing systems are common. Therefore, IRA often involves a

careful consideration of these potential barriers and the development of strategies to overcome them. External support, be it in the form of government incentives, partnerships with technology providers, or collaboration with research institutions, can significantly influence IRA in SMEs. Such support can help in mitigating risks, providing necessary resources, and building the required skill sets within the organization (Awa et al., 2015; Esmaeilpour, 2016; Nazir & Khan, 2022b). The decision to adopt IR 4.0 technologies, as indicated by a high IRA, can have long-term implications for SMEs. It can determine their future growth trajectory, ability to innovate, and adaptability in a rapidly changing industrial landscape (Khazaei, 2020). Therefore, a well-considered IRA, backed by strategic planning and resource allocation, is crucial for the sustainable success of manufacturing SMEs in the era of IR 4.0. The transformative impact of Industry 4.0 (IR4.0) technologies on small and medium-sized enterprises (SMEs) is a subject of considerable interest in contemporary business research (Nazir & Khan, 2022a; Rusly et al., 2020b)vv. The integration of these advanced technologies, ranging from automation to digital commerce platforms, represents a paradigm shift in how SMEs operate, compete, and innovate. This discussion, drawing from a range of scholarly sources, delves into the nuances of this transformation, particularly focusing on the hypothesis that the intention to adopt IR4.0 (IRA) has a positive effect on SME Innovative Work Behavior (SIWB).

2.5.7.1 IRA & SIWB

Based on research insights, the relationship of IR4.0 Adoption Intention (IRA) towards the positive effect on SME Innovative Work Behavior (SIWB) is predicated on the notion that the intention to adopt advanced technologies provides the tools and platforms necessary for fostering innovation. The effectiveness of IR4.0 technologies in enhancing IWB is contingent on how prepared and mature an organization is in its adoption strategy. Furthermore, the external business environment, including market competition and technological trends, plays a crucial role in determining how effectively technology adoption translates into innovative work behavior (Pilav-Velić et al., 2021b). This relationship suggests that the intention to adopt Industry 4.0 (IR4.0) technologies, referred to as IR4.0 Adoption Intention (IRA), has a positive effect on Small and Medium-sized Enterprises' (SMEs) Innovative Work Behavior (SIWB). This relationship is based on the understanding that the intention to adopt advanced technologies provides SMEs with the necessary tools and platforms to foster innovation within their work processes and practices.

Several scholarly sources support this hypothesis and provide insights into the relationship between IRA and SIWB. (Song & others, 2023) and (Salimon et al., 2023) emphasize that the adoption of IR4.0 technologies goes beyond a mere technological upgrade but represents a strategic move that can redefine

the entire business landscape for SMEs. These technologies offer opportunities for increased efficiency, scalability, and innovation, enabling SMEs to compete effectively in a rapidly evolving global market.

(Gartner et al., 2022) highlight the psychological aspects influencing the intentions of SME decision-makers to adopt new manufacturing technologies. Their research suggests that a proactive approach to technology adoption is crucial for SMEs to remain relevant. This proactive mindset and intention to embrace IR4.0 technologies lay the foundation for fostering Innovative Work Behavior within SMEs. The proficiency in information and digital literacy among SME employees is another crucial factor influencing the adoption of IR4.0 technologies and its impact on SIWB (Nikou et al., 2022). Employee competence in utilizing digital tools and understanding their benefits plays a vital role in effectively integrating and utilizing IR4.0 technologies within the workplace. The perceived benefits of sustainable digital technologies also act as motivators for SMEs to invest in IR4.0 adoption, thereby fostering a culture of continuous learning and development (Yacob & Peter, 2022). The alignment of sustainable practices with IR4.0 technologies further reinforces the positive effects of IRA on SIWB, as it enables SMEs to meet evolving regulatory requirements and consumer preferences globally. The extended Technology Acceptance Model (TAM) by (Nazir & Khan, 2022b) and (Thathsarani & Jianguo, 2022) provides a comprehensive framework for understanding the adoption of Information and Communication Technologies (ICTs) in SMEs, which includes IR4.0 technologies. Their research highlights the influence of external factors, perceived ease of use, usefulness, and contextual factors on the decision to adopt ICTs. This extended TAM model can be applied to understand the factors influencing IRA and its impact on SIWB within SMEs. Organizational readiness and maturity in technology adoption are emphasized by (Rahamaddulla et al., 2021) as crucial factors in the adoption of IR4.0 technologies. Based on the literature, tis research has hypothesized that:

Hypothesis 6 (H6): Adoption Intention of IR4.0 (IRA) positively influences the Innovative Work Behavior of SMEs Employees (SIWB).

2.6 HYPOTHESES TABLE

Hypothesis	Statement
H1a	Perceived Usefulness (PU) positively influences the Adoption Intention of IR4.0 (IRA).
H1b	Perceived Usefulness (PU) positively influences Learning & Development (LD).
H2a	Perceived Ease of Use (PEOU) positively influences the Adoption Intention of IR4.0 (IRA).
H2b	Perceived Ease of Use (PEOU) positively influences Learning & Development (LD).

H3	Government Support (GOVT) positively influences the Innovative Work Behavior of SMEs Employees (SIWB).
H4a	Personal Innovativeness in Automation (PIA) positively influences the Adoption Intention of IR4.0 (IRA).
H4b	Personal Innovativeness in Automation (PIA) positively influences Learning & Development (LD).
H4c	Personal Innovativeness in Automation (PIA) influences the Innovative Work Behavior of SMEs Employees (SIWB) through IRA.
H4d	Personal Innovativeness in Automation (PIA) influences the Innovative Work Behavior of SMEs Employees (SIWB) through LD.
H5a	Learning & Development (LD) positively influences the Adoption Intention of IR4.0 (IRA).
H5b	Learning & Development (LD) positively influences the Innovative Work Behavior of SMEs Employees (SIWB).
H6	The Adoption Intention of IR4.0 (IRA) positively influences the Innovative Work Behavior of SMEs Employees (SIWB).

2.7 RESEARCH FRAMEWORK

The research framework, as shown in Figure 2.1, encapsulates a sequence of relationships hypothesized to influence Staff Innovative Work Behavior (SIWB) in SMEs. At its foundation lie Perceived Usefulness (PU) and Perceived Ease of Use (PEOU), both derived from the Technology Acceptance Model (TAM). These constructs are theorized to impact IR4 Adoption Intention (IRA) and Learning & Development (LD) positively. Hypotheses H1a and H2a link PU and PEOU to IRA, suggesting that favorable perceptions of technology's usefulness and usability boost the intention to adopt Industry 4.0 innovations. Concurrently, H1b and H2b associate these perceptions with an enhanced engagement in L&D activities, positing that when employees perceive new technologies as useful and user-friendly, their involvement in L&D is likely to increase. Government support (Hypothesis H3) is proposed to positively influence SIWB directly, highlighting the role of external factors in fostering an innovative climate. Personal Innovativeness in Automation (PIA) is also introduced as a key individual trait, with H4a, H4b, H4c and H4d suggesting that PI can drive both the intention to adopt new industrial technologies and active participation in L&D. Finally, the framework connects L&D initiatives to both IRA and SIWB (Hypotheses H5a and H5b), underscoring the role of organizational learning in technological adoption

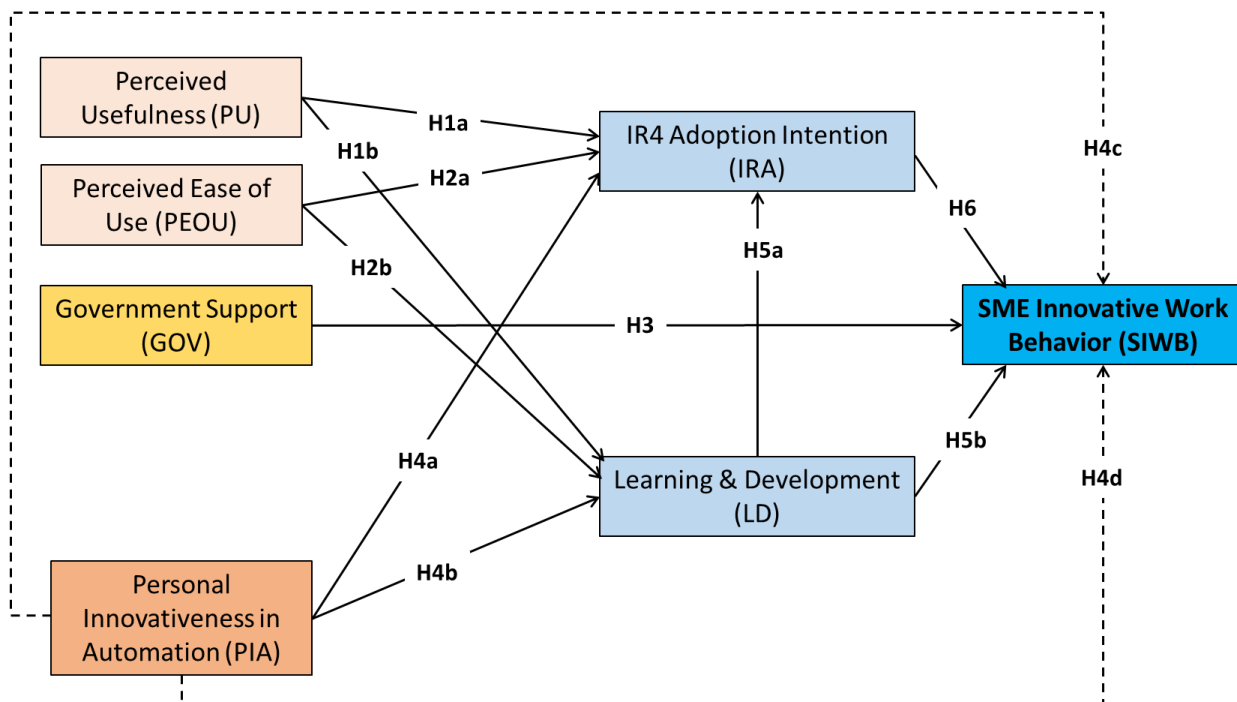


Figure 2.1 – Research Framework

and innovative employee behavior, while H6 suggests that the intention to adopt IR4 technologies will directly foster SIWB.

2.8 SUMMARY

Chapter 2 has been dedicated to laying the groundwork for understanding the complex interplay between various factors that contribute to Innovative Work Behavior (SIWB) among employees in SMEs, with a focus on the manufacturing sector. The chapter began by introducing the concept of Personal Innovativeness in Automation (PI), a trait indicative of an individual's inclination towards adopting and utilizing new automation technologies. The discussion then progressed to how PI influences employees' engagement with Learning & Development (LD) initiatives, positing that individuals with higher PI are likely to be more proactive in their learning pursuits, especially regarding new technologies. The chapter further explored the implications of PI on SIWB, suggesting that personal innovativeness is a significant driver of innovative actions within the SME context. Through the formulation of hypotheses, the chapter sought to establish theoretical linkages between constructs derived from the Technology Acceptance Model (TAM), specifically, Perceived Usefulness (PU) and Perceived Ease of Use (PEOU), and their impact on both LD and SIWB. The role of government support was also examined, positing its potential to positively affect the innovative behaviors of SME employees. A comprehensive research framework was presented, visually mapping out the hypothesized relationships and serving as a guide for the subsequent empirical investigation. This framework underscores the anticipated positive effects of PU and PEOU on the intention to adopt Industry 4.0 (IR4) technologies and on LD, while also highlighting the proposed influence of LD on both IR4 adoption and SIWB.

CHAPTER 3

3 RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter describes the methodology employed in the study and the subsequent data analysis procedures, utilizing a quantitative research approach. The initial segment introduces the methodological techniques based on the research onion framework. Following this, the second part provides an in-depth overview of the sampling process for data collection, encompassing details such as the sampling frame, population, location, and associated techniques. The third section outlines the survey questionnaire implemented in the study. Subsequently, the chapter concludes with an elucidation of the data analysis process, incorporating descriptive statistics and the application of partial least squares structural equation modelling (PLS-SEM). The PLS-SEM analysis comprises two fundamental steps: the examination of the measurement model, encompassing item reliability (outer loadings), construct reliability (α , composite reliability), and construct validity (convergent validity and discriminant validity); and the scrutiny of the structural model, encompassing collinearity assessment (VIF), path coefficients (hypothesis testing), coefficient of determination (R^2), and f-square effect sizes. A comprehensive discussion of these PLS-SEM techniques is provided within this chapter. Additionally, this chapter includes insights into the pilot study and preliminary analysis. Finally, it concludes with a concise summary and overview of the subject matter under consideration.

3.2 RESEARCH DESIGN

The term "research design" indicates the methodology employed in identifying, selecting, processing, and analysing data relevant to the research theme. It serves as a blueprint or framework that delineates the philosophical assumptions, analytical approaches, and specific methods to be employed throughout the research process. The objectives of the research design are to align with the research goals, ensuring relevance to the research objectives by appropriately addressing research questions, employing suitable data collection procedures, sampling methods, and data analysis techniques. Additionally, it may involve the organization and review of research questions. In this thesis, the research onion model proposed by (Saunders et al., 1996) is adopted to provide a comprehensive perspective for the overall research design. The research onion model visually represents the various layers of considerations essential in planning

and executing a research study, aiding in systematic and transparent research planning and implementation. Figure 3.1 provides a graphical representation of the research onion model.

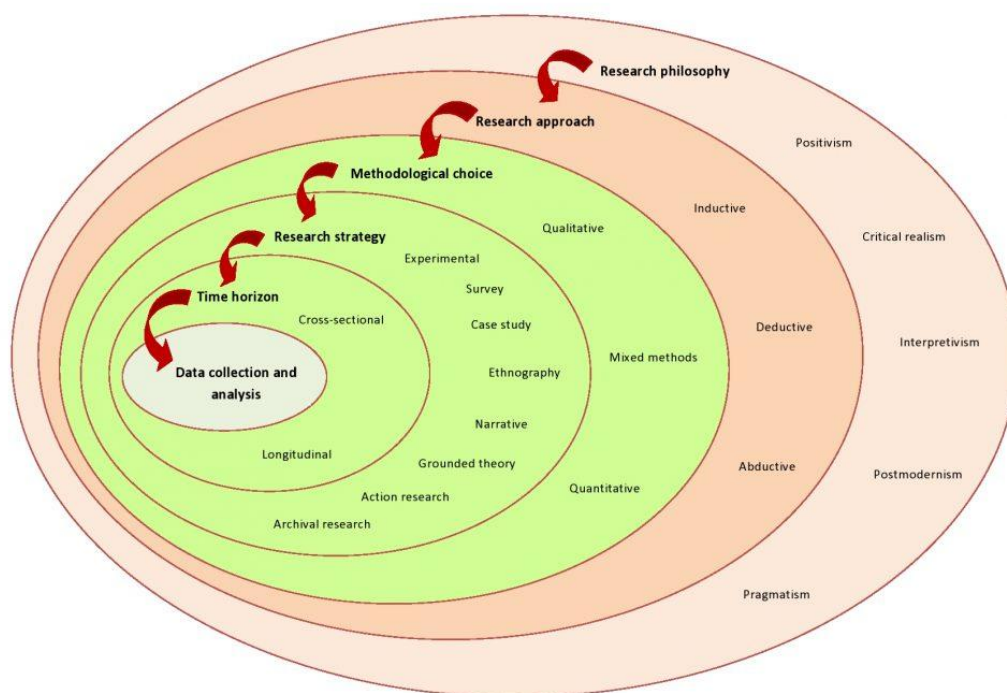


Figure 3.1. Research Onion Model by (Saunders et al., 1996).

3.2.1 RESEARCH PHILOSOPHY

The research onion comprises multiple layers, with the initial layer designated as research philosophy. Research philosophy assumes a pivotal role in guiding researchers to comprehend and substantiate the methodologies they employ, along with the potential outcomes associated with these methods. It is firmly grounded in the research objectives and the devised strategies for their attainment, thereby establishing the bedrock for the entire research process. This encompasses the delineation of ontology (the nature of reality), epistemology (the nature and sources of understanding or truths), and axiology (morals, beliefs, and ethics) in the research context (Creswell & Creswell, 2018a). Within the framework of the research onion model, the route of research philosophy extends from the formulation of the research proposal to the ultimate research conclusions, manifesting variations that span from positivism to alternative approaches. In the context of this study, a positivist research philosophy was embraced.

3.2.1.1 POSITIVISM

Positivism, a philosophical perspective closely aligned with the natural sciences, embodies an objectivist assumption wherein the constituents, or "atoms," of events are posited to exist independently of subjective interpretations. This philosophical stance advocates for an impartial examination of these

elements, suggesting that empirical evidence derived from meticulous observations stands as the sole basis for credibility within the positivist ontology. The underpinning methodology accentuates achieving equilibrium in events through the discernment of causative, law-like, and rational relationships (Saunders et al., 1996).

Central to positivism is the conviction in steadfast, quantifiable truths and a singular external reality elucidated through the application of conceptual frameworks and theories. Positivists assert a belief in the neutrality of knowledge, contending that it can be acquired through the application of quantitative methodologies that remain detached from subjective human perceptions. Consequently, non-experimental methods are often excluded from systematic consideration within positivist research, as they are perceived to lack sufficient alignment with external reality. In the dominion of positivist research, the efficacy of a study is routinely evaluated by the congruence of its outcomes with those of other research endeavors. The overarching objective is to mitigate the influence of qualitative methods by translating them into quantitative methodological terms expressed in mathematical terms (Creswell & Creswell, 2018b).

3.2.2 THEORY DEVELOPMENT APPROACHES

Diverse interpretations of the concept "theory" emerge from distinct philosophical viewpoints. Broadly defined, a theory constitutes a systematic set of principles that elucidates a wide spectrum of phenomena through a comprehensive array of illustrative instances. Alternatively, it serves as a conceptual framework for comprehending and elucidating specific social or real-world occurrences by positing relationships between variables. The development of a theory typically follows one of three principal approaches: inductive, deductive, and abductive. Each approach entails distinct modes of reasoning and methods for assembling evidence to substantiate the proposed theoretical framework (Saunders et al., 1996). This study adopts a deductive approach.

3.2.2.1 DEDUCTIVE APPROACH

The deductive process serves to derive a specific conclusion by aligning similarities with a set of established data. This involves the scrutiny of hypotheses, which originate from a general idea and are subsequently applied to specific circumstances. In essence, deductive research commences with a theoretical concept and progresses toward defined objectives (Creswell & Creswell, 2018b). In a nutshell, the deductive approach entails the application of theory to substantiate empirical evidence, wherein a hypothetical or conceptual framework is initially formulated and then applied to practical observations. Moreover, the quantitative approach, often linked with the deductive method, centers on the testing and validation of phenomena in the real world. It is crucial to acknowledge that employing the deductive approach in research studies lacking a well-defined research design or deviating from established

assumptions can present challenges (Saunders et al., 1996). In the deductive paradigm, the journey begins with a well-established theory, progressing from ideas to observation and data collection. This methodology is conventionally affiliated with quantitative research, wherein a hypothesis is scrutinized through systematic data collection. In the context of this research, the well-established and validated resource-based value theory has been chosen as the underpinning framework for the research design.

3.2.3 METHODOLOGICAL CHOICE

The selection of research methods within the research onion constitutes a pivotal and influential layer in the research endeavor. It encompasses the identification of specific techniques and procedures employed by the researcher for the collection and analysis of data. The determination of these methods necessitates a careful consideration of their appropriateness in addressing the research question and aligning with the overarching objectives of the study. Practicality, feasibility, and ethical considerations are additional facets that the researcher must judiciously contemplate when making this selection (Creswell & Creswell, 2018b). A deliberate choice has been made to employ a quantitative research methodology as the methodological framework for both data collection and analysis. This decision reflects a strategic alignment with the research objectives and ensures a rigorous and systematic approach to deriving meaningful insights.

3.2.3.1 QUANTITATIVE RESEARCH TECHNIQUE

Quantitative research constitutes a systematic scientific inquiry methodology entailing the meticulous collection and analysis of numerical data. Widely employed to comprehend and explicate phenomena, this method involves the rigorous testing of hypotheses and the derivation of conclusions pertinent to a given population. The primary aim of quantitative research is to establish causal relationships and extrapolate findings from a sample to a broader population. This approach relies on numerical data and employs statistical analyses to elucidate and interpret phenomena, facilitating the researcher in accumulating substantial data from a sample and subsequently subjecting it to statistical scrutiny (Sekaran & Bougie, 2016a).

Typically characterized by structured research methods, including surveys, experiments, and statistical analyses, quantitative research holds to a positivist or post-positivist philosophy. This philosophical stance presupposes the existence of an objective reality that can be objectively measured and studied. In comparison to qualitative research, quantitative research is often perceived as more reliable and valid, given its utilization of statistical analysis to rigorously scrutinize and interpret the amassed data (Saunders et al., 1996).

3.2.4 RESEARCH STRATEGY

Within the research onion framework, the layer pertaining to research strategy delineates the comprehensive plan or methodology the researcher intends to employ in conducting the study. This encompasses the deliberate selection of the specific design, methods, and procedures governing the collection of data (Sekaran & Bougie, 2016a). The choice of a research strategy is intricately linked with both the research philosophy and approach layers, contingent upon the unique research question and overarching objectives of the study. Commonly employed research strategies include experimental, survey, case study, among others (Saunders et al., 1996). In this study, a survey strategy has been chosen for data gathering, a decision grounded in the pragmatic, feasible, and ethical considerations of the selected methodology. This selection aligns with the study's aims and ensures a systematic and ethical approach to data collection.

3.2.4.1 SURVEY STRATEGY

The survey, as a research strategy, entails the systematic querying of a sample of individuals using a standardized set of questions. Widely employed in quantitative research, surveys prove particularly advantageous when the researcher seeks to efficiently collect data from a substantial number of participants within a concise timeframe. Administration methods for surveys vary and may include in-person interviews, surveys, or online questionnaires. Participants can either self-complete the surveys or engage with an interviewer. Surveys afford researchers the capacity to amass data across diverse subjects, with subsequent analysis facilitated by statistical techniques (Saunders et al., 1996). The survey strategy stands out for several merits, especially its efficiency in swiftly collecting data from a large participant pool and its ability to furnish detailed insights into specific topics. Furthermore, surveys are cost-effective to administer and lend themselves to straightforward analysis, rendering them an accessible and practical research tool (Creswell & Creswell, 2018b).

3.2.5 TIME HORIZONS

Embedded within the research onion framework is the layer denoting the time horizon, a critical aspect connecting to the study's duration. Two primary types of time horizon exist: cross-sectional and longitudinal. The selection of a specific time horizon involvedly ties into the research question, overall study objectives, data availability, feasibility, and ethical considerations (Saunders et al., 1996). Given a thoughtful evaluation of these factors, it has opted for the cross-sectional method as the most fitting approach for this study.

3.2.5.1 CROSS-SECTIONAL

A cross-sectional study represents a research design employed to gather data at a singular point in time from a representative sample of participants. This methodology primarily aims to elucidate information regarding the prevalence of a specific phenomenon or to conduct comparative analyses among different

participant groups. Cross-sectional studies find application across various disciplines, including the social sciences (Bell et al., 2018).

The key advantages of cross-sectional studies include their expediency and cost-effectiveness, rendering them a swift and economical research option. Providing a snapshot of the prevailing situation, these studies prove valuable for identifying trends or patterns. Moreover, their versatility allows for the exploration of a diverse array of phenomena and the investigation of various research questions, thereby contributing to the establishment of cause-and-effect relationships (Creswell & Creswell, 2018b).

3.2.6 JUSTIFICATION OF RESEARCH DESIGN

To address the research objectives effectively and ensure methodological coherence, each methodological choice in this study was carefully justified based on the nature of the research problem and context. A positivist research philosophy was adopted as it supports objective measurement and hypothesis testing, aligning with the study's aim to examine quantifiable relationships between constructs such as perceived usefulness, learning and development, and innovative work behavior within Malaysian manufacturing SMEs. A deductive theory development approach was selected to test pre-established theories, specifically the Technology Acceptance Model (TAM), enabling a structured assessment of causal links. The decision to employ a quantitative research method was driven by the need to collect statistically analyzable data across a broad respondent base, ensuring reliability and generalizability. The use of a survey strategy further supports this goal, offering a practical and scalable tool for gathering data from SME employees across diverse sectors, especially given logistical constraints and post-pandemic limitations on in-person research. A cross-sectional time horizon was deemed appropriate to provide a snapshot of the current state of IR4.0 adoption, learning initiatives, and innovation behavior, which is particularly relevant in the dynamic and evolving context of digital transformation in SMEs. These methodological choices were also informed by gaps in existing literature, where the integration of behavioral theories with innovation outcomes in SME contexts remains limited. Collectively, these decisions ensure a coherent and rigorous research design that can yield valid, actionable insights for academics, policymakers, and SME stakeholders aiming to foster innovation and digital readiness in the Malaysian manufacturing sector.

3.3 TECHNIQUES AND PROCEDURES

The research process in the framework of the research onion entails a systematic sequence of actions, encompassing the collection and scrutiny of data, whether sourced as primary or secondary. It further involves critical elements such as sample selection, questionnaire design, and the execution of interviews, among other appropriate components. Subsequent to this introduction, a comprehensive discussion

follows, elucidating the specific steps involved in the research techniques and approaches employed in this study.

3.3.1 SAMPLE SELECTION

The selection of sampling technique for this study is based on ensuring representativeness of the sample and generalizability of the findings to the population of interest. By carefully choosing the sampling location, respondents, sample size, and data collection method, this study will be able to collect the necessary data. The primary dataset utilized in this research was meticulously gleaned from the authoritative SME Corp website, a comprehensive and reliable source that encompasses a wide array of SMEs operating prolifically across Malaysia. This platform was instrumental in facilitating access to an exhaustive list of SMEs, thereby providing a robust foundation upon which the subsequent stages of data collection were assiduously built. The geographical locus of this research was strategically centered around the Klang Valley region. This decision was underpinned by a confluence of factors, most prominently the observation that this particular region hosts a significant conglomeration of manufacturing SMEs, thereby rendering it a pivotal hotspot conducive to the execution of a research of this nature and scope. Given that approximately 41% of Malaysia's SMEs are situated within the Klang Valley region, this area offers a highly representative and accessible context for the present study (Hudi et al., 2024). The concentration of SMEs in this urban agglomeration provides a robust foundation for examining SME dynamics. While extending the research to include SMEs from other regions could yield diverse insights and enhance the generalizability of findings, such an expansion would necessitate additional resources and time. Consequently, this study focuses on SMEs located in the Klang Valley, acknowledging that future research could explore regional variations to build upon the findings presented here.

3.3.1.1 SAMPLING TECHNIQUE

The study employed a convenience sampling method to contact and select SMEs for participation. The unit of analysis was all employees in Manufacturing SMEs in Malaysia. This approach was instrumental in facilitating the selection of a diverse and representative array of SMEs. Convenience sampling allowed for efficient and practical access to potential respondents, crucial for gathering a wide range of perspectives and experiences within the manufacturing SME sector. This method, while pragmatic, was carefully executed to mitigate potential biases and to ensure that the sample adequately reflected the study's target population.

3.3.1.1.1 Rationale for Choosing Convenience Sampling

Convenience sampling, a non-probabilistic sampling technique, was selected for its practicality and efficiency in accessing a diverse range of participants from manufacturing SMEs in Malaysia. This

method is particularly appropriate given the specific logistical and resource constraints often encountered in extensive field research. It allows for the rapid collection of data from a readily accessible subset of the target population, which is especially beneficial in studies where time and resources are limited.

3.3.1.1.2 Implementation of Convenience Sampling

In implementing convenience sampling, a deliberate approach was taken to identify and select participants. The primary criterion was accessibility, focusing on SMEs that were readily approachable and willing to participate. This approach included reaching out to SMEs within the researcher's network, as well as those located in business hubs and industrial parks, particularly in the Klang Valley region, known for its concentration of manufacturing businesses.

3.3.1.1.3 Mitigating Potential Biases

While convenience sampling offers practical advantages, it is also acknowledged that this method can introduce certain biases, as the sample may not perfectly represent the broader population. To mitigate potential biases inherent in convenience sampling, this study employed Partial Least Squares Structural Equation Modeling (PLS-SEM). PLS-SEM is particularly effective in this context as it is well-suited for complex models and smaller sample sizes, typical in convenience sampling scenarios. It can handle non-normal data distributions and provides flexibility in model assessment, which is crucial for ensuring the validity of the findings from a convenient sample.

3.3.1.1.4 Justification for Research Context

In the context of this research, which focuses on understanding the adoption of Industry 4.0 technologies and innovative work behaviors in manufacturing SMEs, convenience sampling provided a feasible and effective means to gain insights quickly. The method facilitated the gathering of data that could yield meaningful patterns and trends relevant to the research objectives, even though the results might not be as generalizable as those obtained from probability sampling.

3.3.2 SAMPLE SIZE

The selection of an appropriate sample size in research is not merely a procedural requirement but a fundamental determinant of statistical soundness and the interpretive strength of the findings. As emphasized by (Sekaran & Bougie, 2016a), the sample size critically influences the representativeness of the sample and, consequently, the generalizability of the study's results to the broader population. This aspect of research design is particularly salient in statistical analysis methods such as Partial Least Squares Structural Equation Modeling (PLS-SEM), where the sample size can directly affect the power and stability of the model. In the field of PLS-SEM, (Kline, 2016) articulates that while a minimum sample size of 200 is typically recommended to ensure analytical validity, this is merely a baseline figure. It is pertinent in scenarios where the population size is limited or when a preliminary exploratory analysis

is conducted. However, to solidify the robustness of PLS-SEM results and to enhance the confidence in the model's predictive capability, a larger sample size is invariably advantageous. A sample size surpassing 260, for instance, is generally advised to attain more stable and reliable parameter estimates, especially in models featuring multiple latent constructs and complex path relationships.

This study, with a sample size of 356 participants from the manufacturing SME sector, not only adheres to but exceeds these recommended thresholds. Such a sample size moves beyond the minimum requirements, entering a realm where the statistical power is significantly bolstered. This increase in sample size enhances the ability to detect true effects and reduces the likelihood of Type II errors (failing to identify existing relationships). Furthermore, a larger sample size contributes to the stability of the PLS-SEM findings, ensuring that the model is not unduly influenced by outliers or anomalies within the data. The adequacy of this sample size is particularly noteworthy given the intricacies involved in understanding technological adoption and innovation within SMEs. This number allows for a comprehensive and nuanced exploration of the relationships between multiple variables, offering insights that are both statistically valid and richly informative. It also ensures that the findings are not only reflective of the sample but also hold relevance and applicability to the broader population of manufacturing SMEs (J. F. Hair et al., 2021; Joe F Hair et al., 2009).

3.4 DATA COLLECTION

The data collection for this study was meticulously approached, utilizing both primary and secondary sources to ensure a comprehensive understanding and analysis. The primary data was sourced directly from the workforce of SMEs in the manufacturing sector. This direct approach involved engaging with employees from various levels within these organizations, enabling the collection of first-hand, empirical data that is vital for assessing and understanding the dynamics of technology adoption, personal innovativeness, and innovative work behaviors in the context of Industry 4.0.

3.4.1 SECONDARY DATA COLLECTION

To complement and contextualize the primary data, an extensive review of related literature was conducted as the secondary source. This literature review delved deep into existing academic and industry-specific publications to gather insights on the nuances of Innovative Work Behavior (IWB) within the manufacturing industry. By analyzing studies, reports, and theoretical frameworks from previous research, the study was able to draw upon a rich tapestry of knowledge, enhancing the understanding of IWB in the specific setting of manufacturing SMEs. This blend of primary data from the workforce and secondary literature insights provided a robust foundation for the research, enabling a well-rounded exploration of the variables at play and their interrelationships in the manufacturing sector.

The combination of these sources ensured that the study was grounded in both real-world experiences and established academic theories, thereby bolstering the credibility and relevance of the findings.

3.4.2 PRIMARY DATA COLLECTION

The primary data for this study was gathered through first hand source i.e., workforce of SMEs in manufacturing sector. To gather the response, an online survey questionnaire, a method well-regarded for its efficiency and convenience was utilized. These questionnaires were distributed via a web link to the participants, the survey was specifically crafted to align with the research objectives. The utilization of online surveys, as outlined by (Sekaran & Bougie, 2016b)., offers a cost-effective and flexible approach for data collection, enabling the acquisition of responses from a broad participant pool. This approach is particularly advantageous in terms of its user-friendly nature, allowing respondents the flexibility to complete the survey at their own pace and convenience. The survey itself comprised a series of carefully constructed questions pertinent to the research goals. These questions were designed for clarity and ease of response, undergoing a pre-test phase to ensure their relevance, understandability, and accuracy. Accompanying instructions were also provided to assist participants in navigating and completing the survey effectively. In the end, the survey strategy successfully yielded a total of 356 responses. This sample size is considered satisfactory for the purposes of this study, both in terms of representing the target population adequately and providing a robust data set for the subsequent PLS-SEM analysis (J. F. Hair & Alamer, 2022).

3.5 QUESTIONNAIRE DESIGN

This study utilizes a structured, self-completed online questionnaire, featuring multiple items measured on a 5-point Likert scale (Zainudin Awang et al., 2016). These items are crafted to assess distinct aspects of the Innovative Work Behavior of SMEs employees. Respondents will express their level of concurrence with each statement, with options extending from "Strongly Disagree" (1) to "Strongly Agree" (5). Employing a Likert scale approach enables the numerical representation of opinions, simplifying the process of data examination and statistical interpretation.

3.5.1 QUESTIONNAIRE SECTIONS:

The structure of the questionnaire for this study is thoughtfully designed to gather comprehensive data, divided into two distinct sections. The initial section is dedicated to collecting demographic data from the participants, which includes details such as age, gender, job title, industry sector, department, and years of experience. This demographic information plays a critical role in ensuring that the sample is representative and provides valuable context for analyzing the findings. The subsequent section of the questionnaire delves into the core variables of the study, with items meticulously derived from established research and tailored to meet the specific objectives of this research. These items are aimed at assessing

factors such as Perceived Usefulness, Perceived Ease of Use, Adoption Intention of IR 4.0 Government Support, Personal Innovativeness in Automation, Learning & Development, and Innovative Work Behavior. To provide a comprehensive view, the complete questionnaire, including both demographic and variable-related items, is presented in Annexure-A at the end of this research document.

3.5.1.1 VARIABLE ITEMS

- **Perceived Usefulness (PU):** For the Perceived Usefulness variable, participants are presented with four statements related to their perception of usefulness of technical skills for adoption of IR 4.0, as adopted from (Davis, 1989a). Participants express their perceptions on a 5-point Likert scale, indicating the extent to which they agree or disagree with each statement. These items aim to gauge how perception of usefulness of technical skills impact the Innovative Work Behavior among SMEs employees.
- **Personal Innovativeness in Automation (PIA):** For the Personal Innovativeness in Automation variable, participants responded to 6 questions, adopted from (Agarwal & Prasad, 1998) to assess their willingness and readiness to adopt new automation technologies. These items, rated on a 5-point Likert scale, measure the degree to which participants are open to experimenting with and implementing innovative technologies in their workplace. The aim is to understand how individual innovativeness influences their behavior and attitude towards technological changes, specifically in the context of Industry 4.0.
- **Government Support (GOV):** The Government Support variable involves three statements that reflect the participants' perceptions of the support provided by government bodies to SMEs in adopting new technologies. Respondents rate these statements on a 5-point Likert scale to indicate their agreement or disagreement. This variable seeks to capture the extent to which government initiatives, policies, and programs are perceived as effective in facilitating technological adoption and innovation within SMEs.
- **Learning & Development (LD):** In assessing the Learning & Development variable, participants are presented with four questionnaire items, adopted from (Margaryan et al., 2022) that explore the quality, relevance, and effectiveness of learning and development programs in their organization. These items are rated on a 5-point Likert scale and are designed to assess how well these programs equip employees with the skills and knowledge required for Industry 4.0 technologies and how they impact innovative work behaviors.
- **Adoption Intention of IR4.0 (IRA):** For the Adoption Intention of IR4.0 variable, participants evaluate the five statements that measure their willingness or intent to adopt and engage with Industry

4.0 technologies as adopted from (Davis, 1989a). The responses, gathered on a 5-point Likert scale, aim to gauge the readiness and enthusiasm of employees in manufacturing SMEs to embrace these new technological advancements and integrate them into their work practices.

- **Perceived Ease of Use (PEOU):** The Perceived Ease of Use variable is assessed through four questions, taken from (Davis, 1989a), that examine the participants' views on the ease and effortlessness of using new technical skills and technologies. Rated on a 5-point Likert scale, these items aim to determine how the perceived simplicity and user-friendliness of new technologies influence employees' attitudes towards adoption and their innovative behaviors within the workplace.
- **Innovative Work Behavior in SMEs (SIWB):** In evaluating the Innovative Work Behavior of SMEs Employees (SIWB), participants respond to six questions designed to assess their engagement in innovative activities within their organization, as adopted from the (Janssen, 2000). These items, rated on a 5-point Likert scale, aim to capture the extent to which employees are involved in creative problem-solving, idea generation, and implementation of novel solutions in their workplace. The goal is to understand the factors that foster or hinder innovative behaviors among employees, particularly in the context of adapting to Industry 4.0 technologies and practices. This variable is crucial in determining how various factors like learning and development, personal innovativeness, and perceived usefulness of technology translate into tangible innovative actions in the workplace.

3.5.2 FACE VALIDITY OF QUESTIONNAIRE:

Before administering the questionnaire to participants, face validity is ensured through expert review and pilot testing. Experts in the field of Manufacturing SMEs and research methodology evaluate the questionnaire to verify whether the items appropriately capture the intended constructs and research objectives. Moreover, a pilot study is conducted with a small sample of participants to assess the clarity, comprehensibility, and relevance of the variable items. Feedback from the pilot study helps refine and finalize the questionnaire, ensuring its face validity and reliability for data collection (Jalilvand & Samiei, 2012).

3.6 DATA ANALYSIS PROCESSES

This study will employ a combination of descriptive statistics and the Partial Least Squares Structural Equation Modeling (PLS-SEM) method for data analysis. Initially, descriptive statistics, including measures such as mean, standard deviation, skewness, and kurtosis, will be utilized to offer a comprehensive overview of the data and assess its normality. This approach aims to gain insights into the data distribution and identify any potential issues requiring attention. Then the PLS-SEM method will be applied to examine the relationships among variables in the dataset and to evaluate the research hypotheses. PLS-SEM, a statistical technique frequently employed in the social sciences, particularly

when dealing with intricate and multidimensional data, will be instrumental in drawing meaningful conclusions. A more in-depth exposition of these methodologies is provided in the subsequent subsections.

3.6.1 DESCRIPTIVE STATISTICS

Descriptive statistics play as a method to succinctly characterize and comprehend a dataset by employing informative coefficients. These statistics are applicable to both populations and samples, encompassing measures of central tendency (e.g., mean, median, and mode) and measures of variability (e.g., standard deviation, variance, and minimum and maximum values), along with indicators of data normality (Kurtosis and Skewness). By furnishing a concise overview of the data, descriptive statistics facilitate researchers in discerning the relationships between dependent and independent variables. In essence, they offer a valuable tool for comprehending and summarizing a dataset (Zikmund et al., 2013).

Descriptive statistics can be categorized into three main groups: measures of central tendency, measures of variability, and measure of data normality. Measures of central tendency focus on identifying the average or central values within a dataset, while measures of variability assess the spread or dispersion of the data. These metrics are often conveyed through charts, diagrams, and written descriptions to facilitate a comprehensive understanding of the evaluated data. Central tendency measures, including the mean, median, and mode, elucidate the central position of a distribution in a dataset by analyzing the frequency of each data point. In contrast, measures of variability, also referred to as measures of spread, offer insights into how dispersed the data is within a set. For example, while measures of central tendency provide an average for a dataset, they may not necessarily unveil the extent of dispersion within the dataset (Kallner, 2018).

3.6.2 STRUCTURAL EQUATION MODELLING

Structural Equation Modeling (SEM) stands out as a statistical approach enabling researchers to explore the connections between observed variables and latent variables. While sharing similarities with conventional techniques such as correlation, regression, and analysis of variance, SEM distinguishes itself by providing heightened flexibility and comprehensiveness. In contrast to traditional methods, SEM involves researchers explicitly defining a model that encapsulates their hypotheses rather than relying on a predetermined model. One of SEM's strengths lies in its capacity to incorporate both observed and unobserved variables, facilitating the simultaneous examination of multiple interconnected equations to evaluate parameter estimations. Undoubtedly, SEM considers as a potent tool for scrutinizing relationships between variables. Nevertheless, its effectiveness is contingent upon meticulous model specification and robust theoretical underpinning, a requirement that surpasses the demands of traditional methods.

As posited by (J. F. Hair et al., 2017), (SEM) emerges as a sophisticated multivariate analysis technique employed for scrutinizing relationships between independent and dependent variables. The methodology encompasses two primary approaches: covariance-based SEM (CB-SEM) and partial least squares SEM (PLS-SEM). Executable through software platforms like AMOS and LISREL, CB-SEM estimates the variance-covariance matrix of the data. In contrast, PLS-SEM, operationalized through tools like SmartPLS and PLSGraph, elucidates the variance of an unobserved dependent variable. While CB-SEM and PLS-SEM exhibit variances in their methodologies, it is imperative to refrain from viewing them as competitors; rather, they should be regarded as complementary tools applicable in distinct contexts. Mainly, CB-SEM and PLS-SEM demonstrate strengths and weaknesses in different domains (Hair et al., 2019), as shown in Table 3.1. Consequently, scholars are advised to judiciously select the methodology aligning with the specifics of their research questions and data.

Table 3.1: CB-SEM vs PLS-SEM

Attributes	CB-SEM	PLS-SEM
Research Objectives	Confirming or Validating theories	Developing or expanding upon current theories or perspectives on prediction
Goodness-of-fit	Supported	Complex to analyze
Sample size	Larger sample sizes	Comparatively smaller sample sizes
Distributional assumptions	Unable to meet the required assumptions in non-normally distributed data	Enhanced robustness when assuming non-normally distributed data
Complex model	Supported	Improved Performance
Secondary data	Require increased emphasis for analysis	Highly adaptable for analysis
Statistical power	Not well-suited for causal research	Well-suited for causal research

Source: (Joseph F. Hair et al., 2019)

In this study, the SmartPLS is utilized to assess PLS-SEM method to analyse the gathered data for various reasons, aligning well with the nature of this research. These reasons include:

- Presenting a formidable statistical approach, Partial Least Squares Structural Equation Modeling (PLS-SEM) proves particularly adept when handling smaller sample sizes featuring numerous

constructs and indicators within the model (Hair et al., 2017, 2019). In contrast to simultaneous computation, PLS-SEM excels by individually computing relationships among manifest and latent variables, making it especially applicable for small sample scenarios. The technique employs distinct partial least squares regressions to derive partial regression relations within both the measurement and structural models. It is crucial to note that while PLS-SEM demonstrates efficacy with smaller sample sizes, the appropriateness of such samples hinges on the specific nature of the research being undertaken (Hair et al., 2012).

- Predominantly selected for social science investigations, PLS-SEM stands out for its absence of distributional assumptions, presenting a distinguished advantage in the analysis of non-normal data. This compelling attribute provides a strong rationale for the adoption of PLS-SEM in research endeavors (Hair, Hult, Ringle, Sarstedt, et al., 2021).
- The proliferation of secondary data, a valuable resource for examining real-world phenomena, has expanded significantly. PLS-SEM emerges as a particularly apt choice for causal studies utilizing secondary data, given its capacity to seamlessly incorporate the interplay between theoretical frameworks and empirical observations (Hair, Hult, Ringle, Sarstedt, et al., 2021). The accessibility of secondary data from diverse sources such as corporate databases, online platforms, customer tracking systems, national statistical bureaus, and publicly available survey data, has facilitated the seamless integration of theory and data. This proves especially efficacious in predictive and causal-predictive modeling domains. Leveraging its emphasis on prediction, PLS-SEM proves well-suited for advancing research in this nuanced landscape (Hair et al., 2017).
- From the vantage point of measurement theory, PLS-SEM proves invaluable in handling secondary data. Notably, one of its merits in this context lies in its flexibility to accommodate single-item and formative measures, a feature particularly advantageous in archival research settings. Here, measures often assume the form of artifacts embedded in company databases, encompassing financial ratios and other fixed factors integral to firms (Hair et al., 2012; Hair, Hult, Ringle, Sarstedt, et al., 2021). This flexibility becomes paramount, considering that measures derived from secondary data sources typically lack the meticulous design and explicit refinement commonly associated with survey measures intended for confirmatory analyses (Hair et al., 2020).
- Praised for its superior statistical power, PLS-SEM emerges as a go-to choice, especially in experimental studies grappling with theories that are not yet fully crystallized (Hair et al., 2012). The heightened statistical power intrinsic to PLS-SEM holds significant sway, amplifying its

prowess in discerning meaningful relationships among variables when they do exist. This competitive advantage positions it favourably against CB-SEM, where lower statistical power may pose challenges in comparable scenarios (Hair et al., 2017, 2019).

- Putting less weight on the notion of model fit than CB-SEM, PLS-SEM nonetheless sees a number of scholars advocating for the incorporation of model fit assessments (Hair et al., 2019). Yet, caution is necessary for researchers contemplating the integration of model fit assessments within the scope of PLS-SEM (Hair et al., 2012, 2019).

3.6.3 PARTIAL LEAST SQUARES STRUCTURAL EQUATION MODELLING (PLS-SEM)

Partial least squares structural equation modeling (PLS-SEM) is a statistical approach empowering researchers to assess hypotheses and address research inquiries through the modeling of latent constructs and their interconnections. Notably advantageous in dissecting intricate path models featuring latent variables, PLS-SEM has been on a trajectory of increasing popularity. However, it remains categorized as an evolving methodology, prompting ongoing investigations by researchers seeking optimal practices in its application (Hair et al., 2019). Accordingly, it becomes imperative for scholars to cultivate a profound understanding of PLS-SEM and employ it judiciously in their studies.

The PLS-SEM approach, a constituent of structural equation modeling rooted in component-based methodology, stands out among methodologists and practitioners for its myriad advantages in practical applications. Widely embraced in management research, it has steadily garnered sustained attention in the applied research landscape within the management domain. The efficacy of PLS models hinges on their ability to articulately capture the relationships between latent constructs (Hair et al., 2017). But, evaluating the calibre of a PLS model necessitates a meticulous process, encompassing the scrutiny of measurement models and an assessment of the structural model. PLS-SEM encompasses two types of measurement models: the formative measurement model and the reflective measurement model (Hair et al., 2012, 2017, 2019).

3.6.3.1 MEASUREMENT MODEL

Conducting the PLS-SEM requires the incorporation of both a structural model and a measurement model. The measurement model, referred to as the outer model, establishes the relationship between indicators and their underlying latent variables. When employing PLS-SEM, it becomes crucial to pinpoint suitable observed variables (indicators) for conceptualizing the given notion. This modeling approach proves beneficial for addressing latent constructs that cannot be directly measured, necessitating a measurement model comprising one or more observed variables. In the sphere of PLS-SEM, two types of measurement models exist: formative measurement models and reflective measurement models (Hair

et al., 2012, 2017, 2019). This study focuses on the reflective measurement model, and the ensuing discussion elucidates the characteristics inherent in such models.

3.6.3.2 REFLECTIVE MEASUREMENT MODEL

Reflective measurement items are conceptualized as manifestations or "effects" of latent variables, indicating that these latent variables generate or shape the measurement items. All reflective measures operate under the assumption of a shared underlying concept, which is the latent variable. When there are changes in latent variables, reflective measures exhibit corresponding changes, a phenomenon known as internal consistency. Consequently, positive correlations among all reflective measures are expected (Hair et al., 2019).

The designation of measurement items as reflective hinges on their high correlation and interchangeability. Thus, it becomes imperative to meticulously assess their reliability and validity. For instance, latent constructs may comprise multiple measured variables within a dataset, necessitating a thorough examination and reporting of outer loadings, composite reliability, average variance extracted (AVE), and discriminant validity for these measured variables. Within reflective measures, causal directions emanate from the blue-colored latent constructs to the yellow-colored measurement items (Hair et al., 2017, 2019).

It is noteworthy that SmartPLS defaults to considering reflective measurement items as constituting the model, with arrows pointing away from the blue-colored latent variables. Scholars sometimes err by altering arrow directions when dealing with formative measures, potentially introducing analytical errors. In cases where all measured items are reflective, as in the provided example, there is no need to alter the arrow direction. Being cognizant of this default assumption is crucial, and careful consideration of indicator nature is necessary when assuming the measurement model in SmartPLS (Hair et al., 2017; Hair, Hult, Ringle, Sarstedt, et al., 2021). In alignment with the nature of this study, a reflective measurement model is employed. The ensuing section outlines a step-by-step analysis of the reflective measurement model.

3.6.3.2.1 Indicator Reliability

During the application of PLS-SEM, it becomes imperative to assess the reliability of the indicators. In the PLS-SEM context, reflective measurement items are identified by single-headed arrows that extend from latent variables to the measuring items. The coefficients representing this relationship are termed outer loadings. The conventional recommendation is for outer loadings to exceed 0.70, signifying that constructs account for a minimum of 50% of the variance in the indicator, thereby indicating satisfactory indicator reliability (J. F. Hair et al., 2017; Joseph F. Hair et al., 2021).

3.6.3.2.2 Construct Reliability

To assess the reflective measurement model, the subsequent step involves estimating construct reliability, with a common method being the utilization of composite reliability. This approach is particularly well-suited for the PLS-SEM method, as it doesn't assume equal indicator loadings and doesn't favor any specific item based on particular reliability assessments of the outer models (Hair et al., 2019; Hair, Hult, Ringle, Sarstedt, et al., 2021).

Comparatively, Cronbach's alpha gauges the internal consistency of all constructs, employing a minimum threshold of 0.70. However, it tends to yield smaller values compared to composite reliability. This discrepancy arises because Cronbach's alpha treats all indicators equally, while composite reliability adjusts weights based on individual loadings of indicators for the target construct. Consequently, composite reliability is considered a more precise measure of reliability than Cronbach's alpha (Ringle et al., 2020). Although Cronbach's alpha is perceived as conservative, composite reliability is robust, often surpassing the reliability scores obtained through these methods (Hair et al., 2019; Ringle et al., 2020).

Elevated values of both Cronbach's alpha and composite reliability generally indicate a higher level of item reliability. According to (J. F. Hair et al., 2017; Sarstedt et al., 2017), values ranging from 0.60 to 0.70 are deemed adequate for experimental studies, while those between 0.70 and 0.90 are considered adequate to excellent. However, values exceeding 0.95 may signal issues such as redundancy, potentially compromising construct validity. Furthermore, excessively high reliability values may hint at unwanted reliability, such as straightening, leading to inflated correlations among items and inaccurate results (Hair et al., 2019; Sarstedt et al., 2021).

3.6.3.2.3 Construct Validity

To assure the validity of constructs, it is essential to execute both convergent and discriminant validity procedures. These are the two analytical approaches employed for assessing construct validity:

3.6.3.2.3.1 Convergent Validity

The Average Variance Extracted (AVE) is a measure indicating the extent of convergent validity, with values ideally exceeding 0.50. AVE assesses how effectively specific indicators are interconnected in representing the variable they aim to measure. Its computation involves analyzing indicator reliability to determine the AVE of the latent variable. Adequate convergence is achieved when outer loading values surpass 0.70, capturing 50% of the variance. AVE values of 50% or higher signify that over half of the variance in the measuring items of the construct falls within this threshold (Hair et al., 2019; Ringle et al., 2020; Sarstedt et al., 2021).

3.6.3.2.3.2 Discriminant Validity

The Heterotrait-Monotrait ratio of correlation (HTMT) criterion, as introduced by (Henseler et al., 2015), stands out as a widely employed and advanced technique for evaluating discriminant validity. This method involves comparing the mean correlations between indicators within variables to the mean correlations for indicators measuring a single variable. A high HTMT value suggests potential issues with discriminant validity. (Joseph F. Hair et al., 2019) propose using a threshold value of 0.90 for constructs with high correlations to assess discriminant validity. If HTMT values exceed 0.90 in such instances, it raises concerns about the lack of discriminant validity (Hair et al., 2019; Sarstedt et al., 2021).

(Henseler et al., 2015) suggest that, when the theoretically expected differences between constructs are more pronounced, using lower threshold values, such as 0.85, may be more appropriate for evaluating discriminant validity. A reliable method to assess the significance of HTMT values involves bootstrapping and comparing them to context-specific threshold values at or below 1.00. Determining the appropriate threshold value should align with the study's nature, and scholars can calculate the 95% confidence interval of the HTMT, checking if the upper bound falls below 0.90 or 0.85 (Hair et al., 2019).

3.6.4 STRUCTURAL MODEL

The comprehensive PLS-SEM methodology integrates assessments of both the structural and measurement models. Following a thorough evaluation of the measurement model, attention shifts to the examination of the structural model. This inner model encompasses the connections between latent variables, representing hypothetical relationships. The latent variables are categorized into independent predictor variables and dependent response variables. Notably, a response variable within the structural model can be influenced by multiple predictors, and the removal of a predictor may impact the response variable (Joseph F. Hair et al., 2019).

As outlined by (J. F. Hair et al., 2017), an additional pivotal step in the PLS-SEM approach involves scrutinizing the relationships between variables, commonly referred to as causal relationships. This step aims to assess the theoretical structure between variables, examining the robustness and significance levels of these relationships. Essentially, this approach validates the theoretical framework by statistically testing the structural model relationships, drawing on insights from prior research. The structural model plays a central role in analyzing the interrelationships between constructs (Hair et al., 2017, 2019).

In alignment with the nature of this study, the structural model is employed, and four techniques of structural model analysis are applied. The ensuing section delineates a step-by-step analysis of the structural model.

3.6.4.1 COLLINEARITY

To ensure the precise evaluation of structural relationships, it is crucial to examine collinearity, as its presence can introduce bias to regression results. This scrutiny involves computing Variance Inflation Factor (VIF) values using latent variable scores from predictors in a partial regression. VIF scores exceeding 5 may indicate the existence of collinearity among predictors. However, collinearity can also manifest at VIF values between 3 and 5. To mitigate any issues related to collinearity, it is advisable to aim for VIF values that are close to or below 3 (Hair et al., 2017, 2019; Ringle et al., 2020).

3.6.4.2 PATH COEFFICIENTS

The assessment of path coefficients between latent variables within PLS-SEM is a pivotal phase in scrutinizing the structural model. For an accurate computation of path models, it is imperative to consider the algebraic sign, magnitude, and significance of each path. Path models exhibiting signs conflicting with theoretically proposed hypotheses do not support assumed hypothetical relationships (Akter et al., 2022; Hizam, Akter, et al., 2021; Hizam et al., 2023). The magnitude of path models indicates the strength of relationships between latent variables. Many experts posit that path coefficient scores exceeding 0.10 signify a substantive impact on the path model. Additionally, the significance of path coefficients should be appraised using methods like bootstrapping, with a preferred significance level of at least 0.05 (Hair et al., 2011, 2019; Hair, Hult, Ringle, Sarstedt, et al., 2021; Ringle et al., 2020).

3.6.4.3 COEFFICIENT OF DETERMINATION

A crucial metric for assessing the structural model within partial least squares (PLS) is the coefficient of determination (R^2) applied to endogenous latent variables. R^2 represents the proportion of explanatory power in latent variables to the variance in their response variables. To ensure a satisfactory level of explained variance, it is preferable for R^2 values to be relatively high. In partial least squares (PLS), the coefficient of determination (R^2) holds significance as a key measure for assessing the structural model. R^2 reflects the proportion of explanatory power of endogenous latent variables to the variance of their response variables. Higher R^2 values indicate a more substantial level of explained variance. Under the guidelines set forth by Cohen in 1988, the R^2 value, or the coefficient of determination, is interpreted as a measure of the strength of a model. R^2 values less than 0.02 are viewed as very weak, indicating that the model does not explain much of the variance of the dependent variable. R^2 values that fall between 0.02 and 0.13 are classified as weak, showing a slight explanatory power of the model. Those within the range of 0.13 to 0.26 are regarded as moderate, suggesting a reasonable amount of variance being accounted for. Finally, R^2 values of 0.26 and above are considered substantial, demonstrating that the model has a strong explanatory power regarding the variance of the dependent variable (Cohen, 1988a).

3.6.4.4 EFFECT SIZE f^2

The assessment of effect sizes is valuable for pinpointing weak relationships within a structural model. Practitioners commonly compute effect sizes of path models utilizing Cohen's f^2 (Cohen, 1988b). This metric measures the impact of exogenous latent variables on an endogenous latent variable. It is posited that an increase in f^2 within path models corresponds to a reduction in the amount of non-explanatory power latent variables possess. Effect sizes are considered adequate when f^2 values reach 0.02 for exogenous latent variables influencing an endogenous latent variable (Hair et al., 2019; Sarstedt et al., 2021). The essential criteria for interpreting f^2 values are as follows: small effect for values at 0.02, medium effect for values equal to or greater than 0.15, and large effect for values equal to or exceeding 0.35.

3.6.5 COMPARISON OF PLS-SEM WITH CB-SEM

This study uses Partial Least Squares Structural Equation Modeling (PLS-SEM) instead of Covariance-Based SEM (CB-SEM), based on the nature of the research questions and the characteristics of the data. CB-SEM is generally used for confirming well-established theories. It requires a large sample size, normally distributed data, and emphasizes how well the proposed model fits the data. While this approach is valuable for testing mature theoretical frameworks, it is less suitable for exploratory studies or situations where models are still being developed. PLS-SEM, on the other hand, is more appropriate for research focused on exploring new relationships or developing theory. It works well with smaller sample sizes, does not assume that data follow a normal distribution, and is more flexible in handling complex models. According to Hair et al. (2011, 2017), PLS-SEM is especially useful in applied research areas such as business and management, where prediction and understanding practical relationships are often more important than confirming a specific model structure.

In this study, the research aims to understand how different factors influence SME innovative work behavior in the Klang Valley, which is still a developing area of research. Because the theoretical model is not yet fully established and the data did not meet the strict statistical requirements of CB-SEM, PLS-SEM was the more practical and reliable choice. It also allowed for the measurement of both the reliability of survey items and the testing of relationships between variables in a single analysis process. Moreover, PLS-SEM is effective when models include both types of variables, those that are measured directly (reflective) and those that combine indicators to form a concept (formative). This is particularly useful in studies involving organizational behavior, where abstract constructs like performance or innovation are not easily measured. As emphasized by Hair et al. (2019), PLS-SEM offers a robust approach for generating useful insights in situations where prediction and theory-building are the main goals.

3.7 PILOT STUDY

(Bell et al., 2018) delineated the concept of a pilot study as an initial examination involving a small cohort of representative participants. According to (Sekaran & Bougie, 2016a), the pilot study plays a critical role in addressing issues related to study quality, ensuring transparency in survey data, and mitigating language barriers. This becomes particularly crucial in the context of online surveys, where researchers lack the opportunity to clarify ambiguities in the main study (Bell et al., 2018).

Typically, the sample size of a pilot study is smaller than that of the main study. In the present thesis, the determination of the sample size was guided by recommendations from existing literature on pilot studies (Sekaran & Bougie, 2016a). Employing an online survey questionnaire, this study aimed to swiftly engage with respondents, elicit and analyze their opinions, and identify any confusing elements in the questionnaire. The survey targeted a convenient sample of Manufacturing SMEs in the Klang Valley. The researcher effectively communicated the research's purpose and objectives, fostering an environment for respondents to seek clarification on any aspects of the study.

3.7.1 ANALYSES OF THE PILOT STUDY

The initial stage of the investigation incorporated a pilot study with a limited sample size, totaling 30 participants, in contrast to the larger main study. This preliminary data was collected via an online survey tool and subsequently encoded using SPSS software for the early examination of demographic patterns. To further examine the reliability and validity of the constructs, SmartPLS v3 was employed. The subsequent sections provide a detailed account of the analytical processes applied to the pilot study data.

3.7.1.1 INDICATOR RELIABILITY

The preliminary results of the pilot study indicate that all indicators showed outer loading values above 0.70, indicating a strong association with the underlying latent variable being studied (J. F. Hair & Alamer, 2022). These variables play a substantial role in the construct being evaluated, as illustrated in Table 3.2.

Table 3.2: Outer Loadings

Variables	Items	Outer loadings
Personal Innovativeness of Automation (PIA)	PIA1	0.815
	PIA2	0.709
	PIA3	0.702
	PIA4	0.729
	PIA5	0.724

	PIA6	0.738
Government Support	GOV1	0.726
	GOV2	0.85
	GOV3	0.801
Adoption Intention of IR4.0	IR1	0.874
	IR2	0.853
	IR3	0.868
	IR4	0.795
	IR5	0.802
Perceived Ease of Use	PEOU1	0.801
	PEOU2	0.751
	PEOU3	0.845
	PEOU4	0.811
Perceived Usefulness	PU1	0.731
	PU2	0.887
	PU3	0.825
	PU4	0.771
Innovative Work Behavior in SMEs	SIWB1	0.843
	SIWB2	0.766
	SIWB3	0.747
	SIWB4	0.852
	SIWB5	0.841
	SIWB6	0.834
Learning & Development	LD1	0.729
	LD2	0.869

	LD3	0.825
	LD4	0.712

3.7.1.2 CONSTRUCT RELIABILITY

In this research, the evaluation of construct dependability was conducted using Cronbach's alpha and composite reliability measures. The results from these metrics were favorable, confirming the dependability of the constructs in use. Indicative of the constructs' internal consistency, the Cronbach's alpha and composite reliability scores surpassed the 0.70 threshold (J. F. Hair et al., 2021). This suggests that the elements of the construct are coherent in measuring a common underlying theme, thereby verifying their dependability. Detailed information on the overall construct reliability can be found in Table 3.3.

Table 3.3: Construct Reliability

Variables	Cronbach's Alpha	Composite Reliability
Personal Innovativeness in Automation (PIA)	0.894	0.907
Government Support (GOVT)	0.902	0.909
Innovative Work Behavior of SMEs Employees (SIWB)	0.809	0.819
Adoption Intention of IR4.0 (IRA)	0.914	0.93
Perceived Usefulness (PU)	0.931	0.943
Perceived Ease of Use (PEOU)	0.872	0.881
Learning & Development (LD)	0.792	0.811

3.7.1.3 CONVERGENT VALIDITY

The outcomes of the pilot test pertaining to convergent validity revealed a robust correlation between the indicator and latent variables, characterized by an AVE value surpassing 0.50 (J. F. Hair et al., 2017). This underscores the efficacy of the indicator variables in accurately gauging the underlying construct of interest in the context of this research. A comprehensive overview of the convergent validity results is provided in Table 3.4.

Table 3.4: Convergent Validity (AVE)

Variables	Average Variance Extracted (AVE)
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Personal Innovativeness in Automation (PIA)	0.667
Government Support (GOVT)	0.709
Innovative Work Behavior of SMEs Employees (SIWB)	0.687
Adoption Intention of IR4.0 (IRA)	0.574
Perceived Usefulness (PU)	0.614
Perceived Ease of Use (PEOU)	0.728
Learning & Development (LD)	0.619

3.7.1.4 DISCRIMINANT VALIDITY

The preliminary evaluation of discriminant validity confirmed that the indicators successfully identify distinct underlying constructs. This was validated by the hierarchical threshold criteria for HTMT (Heterotrait-Monotrait) analysis. The validation is further strengthened by all HTMT values being below the 0.85 mark, which indicates that the indicators are measuring different constructs and not simply evaluating the same construct in varied ways (Sarstedt, Hair, et al., 2022). For an in-depth look at the results of discriminant reliability, please refer to Table 3.5.

Table 3.5: Discriminant Validity (HTMT)

	PIA	GOVT	IRA	PEOU	PU	SIWB	LD
PIA							
GOVT	0.719						
IRA	0.098	0.561					
PEOU	0.099	0.459	0.785				
PU	0.119	0.247	0.098	0.228			
SIWB	0.698	0.708	0.222	0.156	0.768		
LD	0.345	0.220	0.115	0.234	0.095	0.176	

3.8 CHAPTER SUMMARY

This chapter provides an in-depth exploration of the research methodology and data analysis procedures employed in the study. The research onion model is introduced, elucidating the various layers involved.

The chapter investigates into the specifics of data collection, covering sampling techniques, survey questionnaire design, sampling location, target respondents, and sampling elements. The chosen data collection method is outlined, highlighting the appropriateness of an online survey strategy. Additionally, the chapter outlines two distinct approaches for data analysis: descriptive analysis and PLS-SEM analysis. It elucidates the quantitative research approach, leveraging structural equation modelling to derive pertinent study findings. Notably, the chapter extensively discusses the pilot study, showcasing results that validate the reliability and validity of all constructs. This not only establishes a solid foundation for the main data analysis but also sets the stage for subsequent chapters, which will delve further into data analyses and unveil key findings from the main study. The summary fo chapter 3 is illustrated in Figure 3.2.

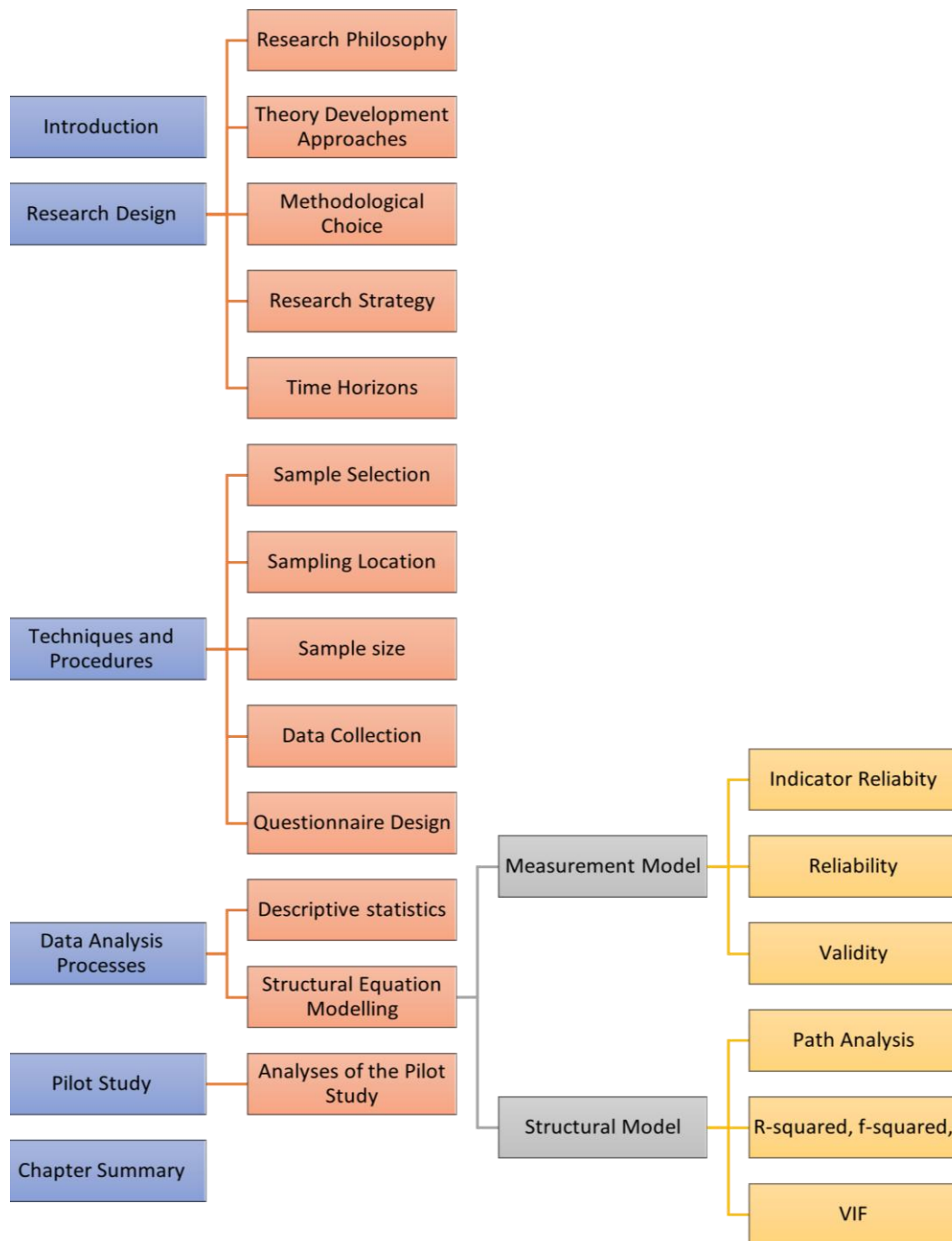


Figure 3.2 – Chapter 3 Summary

CHAPTER 4

4 RESULTS

4.1 INTRODUCTION

The chapter four outlines the results derived from the quantitative research methodology implemented in this study, which involved conducting a survey among manufacturing small and medium-sized enterprises (SMEs) in Malaysia. This survey garnered 356 responses. The initial step in data analysis was data coding, tailored to the collected information, followed by a refinement process to rectify any missing or inaccurate data and to ensure the normality of data. The comprehensive analysis was then performed on 356 valid data points. Demographic findings were scrutinized using SPSS Statistics Version 26. In contrast, SmartPLS Version 3 was employed for conducting the partial least squares structural equation modeling (PLS-SEM) analysis. This PLS-SEM analysis was divided into two primary phases: the first phase involved the measurement model analysis, focusing on indicator reliability (outer loadings), construct reliability (α , composite reliability), and construct validity (convergent and discriminant validity). The second phase concentrated on the structural model analysis, which included collinearity assessment (VIF), evaluation of path coefficients, coefficient of determination (R^2), and effect sizes (f-square) for hypothesis testing. The chapter concludes by providing a succinct summary of these findings and an encapsulated overview of the data analysis procedure.

4.2 PRIMARY DATA ASSESSMENT

The initial phase of data analysis, commonly referred to as preliminary data assessment, is crucial for gaining insights into the dataset's unique attributes and spotting potential anomalies or trends. The primary objective of this phase is to establish a basic understanding of the dataset and tackle any significant issues prior to engaging in more detailed analysis. This approach aligns with (Smith, 2012) perspective on the importance of foundational data comprehension. The process involves several key steps, such as identifying missing data, pinpointing outliers, and evaluating data normality. It is an iterative process, as highlighted by (George, D., & Mallery, 2013), allowing for continuous re-evaluation to resolve any issues and delve deeper into the dataset. Thorough documentation of this preliminary phase is vital for ensuring data traceability, setting the context for future analysis, and guaranteeing the data's accurate application for its intended purpose. In this study, researcher employs the SPSS software to carry out the preliminary data assessment through various steps, including an in-depth exploration of common method bias (CMB) and other pertinent tests. CMB, as discussed by (Podsakoff et al., 2003), is a notable

concern in research methodologies, where the data collection approach can introduce biases, potentially leading to exaggerated correlations between variables.

4.2.1 MISSING DATA

Missing data, also referred to as incomplete data, is the phenomenon where certain values are absent from a dataset. This can occur for a variety of reasons, including non-responses, errors in data entry, or issues in measurement. The importance of addressing missing data is underscored by (Bell et al., 2018), who note that it can lead to skewed or biased conclusions if not properly managed. The strategy for handling missing data should be carefully chosen, taking into consideration the specific research question, the extent and pattern of the missing data, and assumptions regarding the nature of the data's absence, as advised by (Zikmund et al., 2013).

In this study, the researcher adopted an online questionnaire method, which was designed to be both comprehensive and meticulous in gathering data. This approach ensured that all participants provided complete responses, leading to the collection of a robust dataset with 356 fully completed questionnaires. The thoroughness of this data collection methodology played a critical role in avoiding any instances of missing data, thereby bolstering the precision and dependability of the study's results. The effective use of the online questionnaire method was key in achieving a complete dataset, facilitating an exhaustive analysis and significantly contributing to the overall credibility and validity of the research findings.

4.2.2 OUTLIERS

Outliers are atypical data points that markedly differ from other observations in a dataset. Characterized by their significantly higher or lower values, these points stand apart from the bulk of the data, potentially due to reasons like measurement or data entry errors, or being genuine extreme observations. (Sarstedt & Mooi, 2019) emphasize that outliers can have a substantial impact on statistical analyses, possibly leading to skewed results and inaccurate conclusions. To identify outliers in a multivariate context, the Mahalanobis distance method is often employed. This technique measures the distance of each data point from the center of the data distribution, accounting for the correlations between variables.

The Mahalanobis distance method is a statistical tool used to identify outliers in multivariate datasets. It operates by measuring the distance between a data point and the overall distribution of points, while considering the correlations among variables. This approach, as described by (George, D., & Mallery, 2013), tags an observation as an outlier if its Mahalanobis distance surpasses a predetermined threshold. This threshold is usually set based on a Chi-squared distribution with degrees of freedom equal to the number of variables in the dataset minus one, often using the critical value for $p=0.05$ as a guideline (Kallner, 2018; Zikmund et al., 2013).

This method is particularly valuable for identifying outliers in correlated multivariate datasets, providing insight into the strength of the outlier through the calculation of the Mahalanobis distance, which identifies extreme cases (Bougie & Sekaran, 2019). However, the Mahalanobis distance method assumes normal data distribution and known covariance matrix. When these assumptions are not met, robust Mahalanobis distance methods are recommended. Visualizing the data and assessing Mahalanobis distance against a scatter plot matrix aid in identifying data points that deviate significantly from the data's center (Sarstedt & Mooi, 2019). While outliers are often present in large datasets, they may not exert substantial influence on the data's conclusions. In this study, multivariate outliers were retained as they were not found to significantly impact the results, supporting their inclusion in the analysis.

The employment of Partial Least Squares Structural Equation Modeling (PLS-SEM) in this research offers a significant advantage due to its inherent robustness against non-normal data distributions and outliers, as outlined by (Joseph F. Hair et al., 2021). Unlike other statistical methods, PLS-SEM does not require stringent checks for data normality or the exclusion of outliers. This characteristic makes PLS-SEM particularly effective for analyzing complex models, even with relatively small sample sizes. In this research, the approach towards handling multivariate outliers deviated from conventional methods, opting for a more inclusive strategy. The focus shifted to identifying overarching trends and key influential points in the dataset. This meticulous approach entailed a thorough assessment, revealing that the presence of multivariate outliers did not significantly impact the overall results. This finding validated the decision to include these outliers in the analysis, ensuring a broader and more comprehensive understanding. The adoption of this inclusive methodology was instrumental in maintaining the dataset's integrity and wholeness. It also bolstered the thoroughness of the investigation, underpinning the study's conclusions with a more robust data analysis. This detailed method of scrutinizing the dataset ensured that the research outcomes were solidly based, encompassing a complete view of the data and all its inherent variations.

4.2.3 COMMON METHOD BIAS (CMB)

Common method bias means the potential bias that arises when the same method is used to collect data on both the predictor and criterion variables in a study (Podsakoff et al., 2003). This can result in overestimated or underestimated correlations between variables, thus affecting the study's accuracy and validity. In this research, several measures were implemented to counteract the potential effects of CMB. Initially, the survey was designed to allow respondents to express their views on each variable independently, thereby diminishing the possibility of systematic biases. Additionally, the questionnaire items were meticulously crafted for clarity, aiming to eliminate any biases that could arise from leading or

suggestive wording. Moreover, the use of an online survey method facilitated respondent anonymity, which helps in reducing social desirability bias, a factor that could otherwise influence the responses. Finally, the Harman's single-factor test was conducted to assess the extent of common method variance. The data were subjected to exploratory factor analysis to determine if a single factor accounted for a substantial portion of the variance in the variables. The results indicated that no single factor explained the majority of the variance, which suggested that CMB was not a significant concern in this study. The results of Harman's single-factor test indicated (see Annexure A) that the first component extracted accounted for 36.923% of the total variance, with subsequent components explaining additional proportions of variance. The cumulative variance explained by the first component was 36.923%, indicating that it did not account for a majority of the variance in the data. This finding suggests that common method bias (CMB) was not a major concern in this study, as a single factor did not dominate the variance across the variables (Khan et al., 2020).

4.3 DEMOGRAPHIC RESULTS

In the context of this study, the demographic results are instrumental in shaping an understanding of SME Innovative Work Behavior in Malaysia's manufacturing SME industry. These demographics provide essential context, offering insights into the characteristics of the respondents. Examining factors such as gender, age, position in the company, years of experience, department, and industry classification, allows for a comprehensive understanding of the diverse backgrounds and perspectives present in the survey. This demographic information is critical, not merely as statistical data but as a foundation for ensuring that the survey captures a broad spectrum of experiences and viewpoints. It enables an assessment of the representativeness of the sample and provides an understanding of how these characteristics might influence innovative work behavior within the sector. The demographic results, therefore, are pivotal in setting the stage for a nuanced exploration of the factors driving innovation in SMEs, crucial for the development of targeted strategies and interventions in the manufacturing industry.

4.3.1 GENDER

The survey shows a predominant male representation, with 62% of the respondents being male (221 individuals) and 38% female (135 individuals). This gender distribution suggests a male-dominant perspective in the SME sector of Malaysia's manufacturing industry, as illustrated in Figure 4.1.

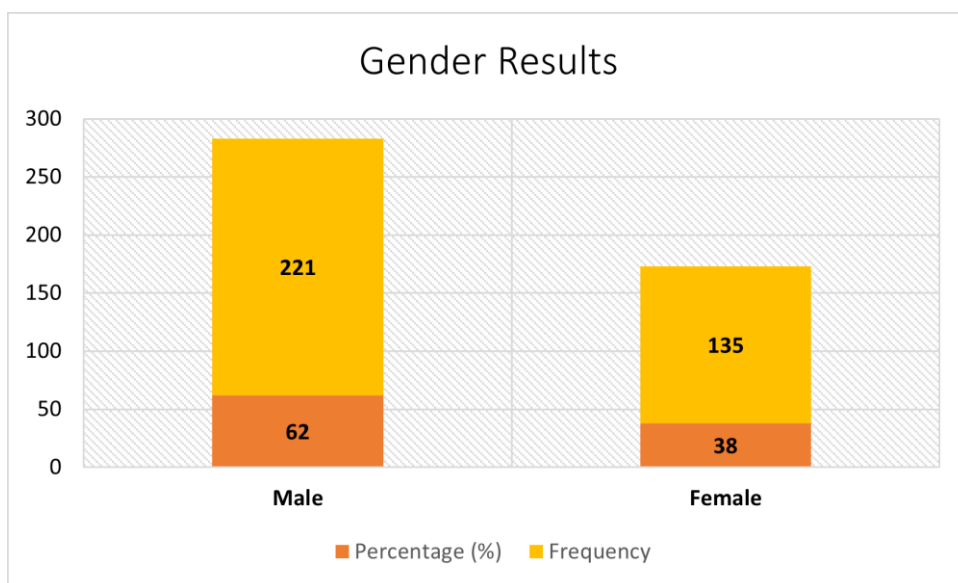


Figure 4.1: Gender

4.3.2 AGE GROUP

The age distribution in the survey, as Figure 4.2, reveals a significant representation of respondents in their late twenties to early forties, reflecting a workforce that is largely in the early to middle stages of their careers. Specifically, the largest group consists of individuals aged 30-40, who make up 35% of the

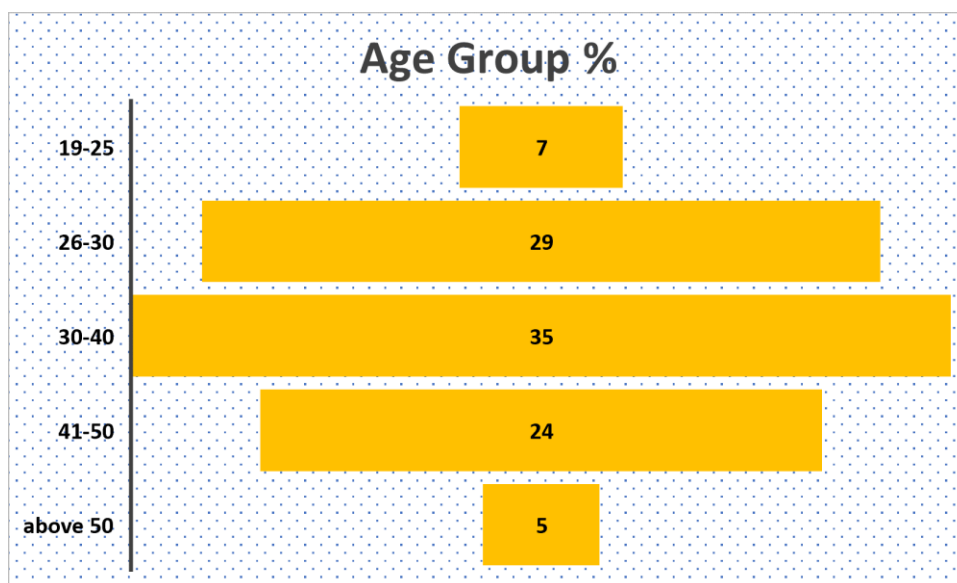


Figure 4.2: Age Group

respondents, equating to 125 individuals. This is followed by those in the 26-30 age range, representing 29% (103 individuals) of the sample. The 41-50 age group also has a notable presence, comprising 24% of the respondents (85 individuals). In contrast, the youngest (19-25 years) and the oldest (above 50 years) age groups are less represented, accounting for just 7% (25 individuals) and 5% (18 individuals) of the participants, respectively.

4.3.3 POSITION IN COMPANY

The survey results regarding the position of respondents within their companies reveal a diverse range of job roles, providing a comprehensive insight into the company hierarchies. The largest groups are Non-Executives and Executives/Supervisors, each representing about 24% of the respondents. This indicates a significant portion of the survey's insights comes from those in operational or supervisory roles. Middle Management is also well represented, accounting for 21% of the participants. This presence of mid-level management suggests that the survey captures the perspectives of those with a balance of on-ground experience and administrative responsibilities. On the higher end of the company hierarchy, Top Management and Business Owners/Directors are less prevalent in the survey, making up 15% and 12% of the respondents, respectively, as illustrated in Figure 4.3.

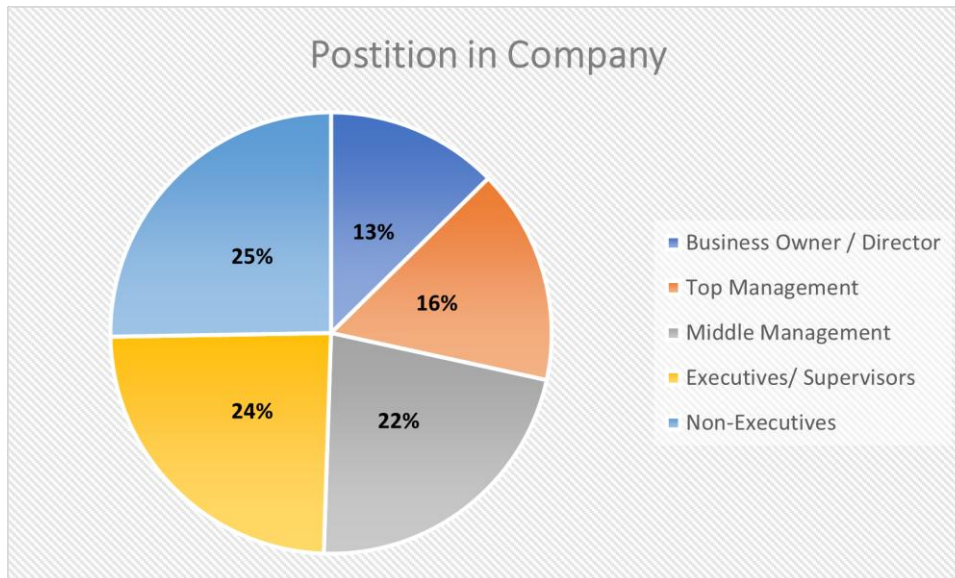


Figure 4.3: Position ion Company

4.3.4 WORK EXPERIENCE

The survey results regarding the respondents' work experience in their organizations reveal a diverse range of tenure, providing insights into the workforce's experience levels in the SME sector of Malaysia's manufacturing industry as depicted in Figure 4.4. The most represented group is individuals with 7-10 years of experience, accounting for 31% of the respondents. This indicates a substantial portion of the survey population is comprised of moderately experienced professionals, likely possessing a deep understanding of their industry and potentially holding positions of significant responsibility. Following this, the survey includes a notable number of individuals with 3-6 years and less than 3 years of experience, representing 23% and 20% of the respondents, respectively. These groups likely consist of

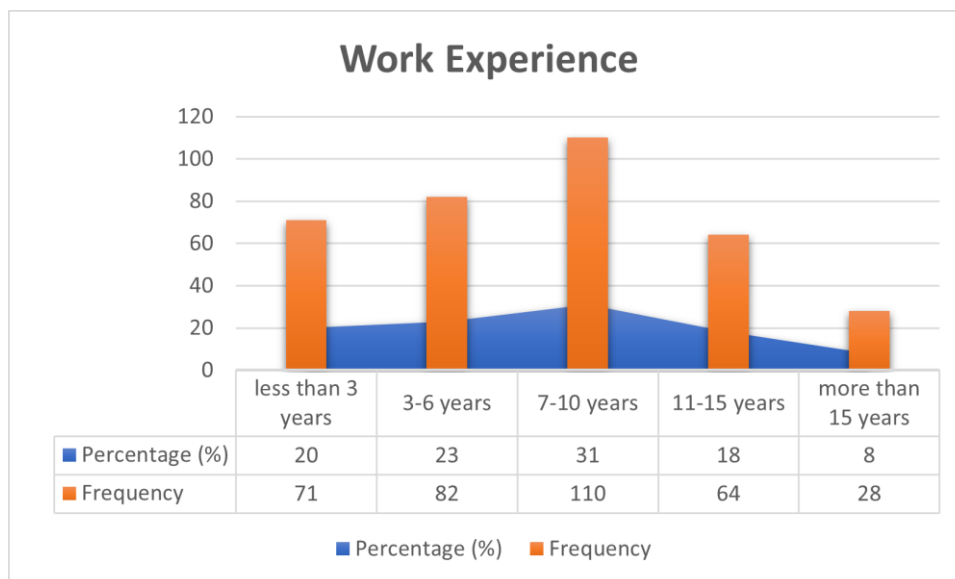


Figure 4.4: Work Experience

early-career professionals who are still accumulating industry knowledge and experience. Their perspectives could provide fresh insights into innovation and work behavior, reflecting more recent trends and industry changes. Conversely, those with more extended tenures, such as 11-15 years and more than 15 years of experience, are less common in the survey, making up 18% and 8% of the participants, respectively. While smaller in number, these individuals bring a wealth of experience and potentially a more long-term perspective on the evolution of innovative practices and work behaviors in the industry. Overall, the spread across different levels of work experience ensures a comprehensive understanding of innovative work behavior from multiple career stages. This diversity is particularly valuable for understanding how perceptions and implementations of innovation might evolve with increasing professional experience in the SME manufacturing sector.

4.3.5 DEPARTMENT

The survey results in Figure 4.5 regarding departmental affiliations of the respondents reflect a diverse representation across various functional areas within companies, offering a multifaceted view of the organizational landscape. The Production department emerges as the most represented group, accounting for 34% of the respondents. This significant presence of individuals from the Production department is indicative of the emphasis on manufacturing processes and could provide valuable insights into the practical aspects of innovative work behavior in the manufacturing sector. Other departments such as Management and Operation also have a notable representation, each comprising about 19% and 18% of the survey population, respectively. The presence of respondents from these departments suggests that the survey captures perspectives related to strategic planning, operational efficiency, and day-to-day management. Furthermore, the Engineering department, representing 16% of the respondents, and the

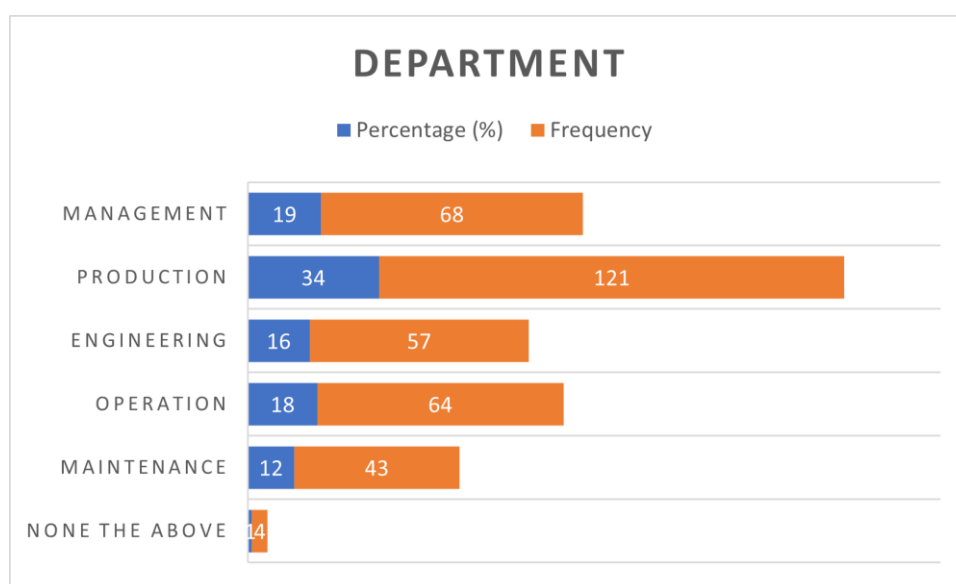


Figure 4.5: Department

Maintenance department, accounting for 12%, contribute insights from technical and infrastructural standpoints. These roles are essential in understanding how innovation is applied and managed in more specialized areas of the business. Interestingly, a small percentage (1%) of the respondents do not align with any of the listed departments, indicating a presence of roles or functions outside the conventional departmental structures. This could include individuals in more unique or cross-functional roles, providing an additional layer of diversity to the responses.

4.3.6 COMPANY'S INDUSTRY

As per the Figure 4.6, the survey's findings regarding the company's industry classification highlight a significant emphasis on the manufacturing sector. A notable 43% of the respondents are from the Manufacturing industry, underscoring the study's strong focus on this sector. This substantial representation is crucial, as it provides in-depth insights into the innovative work behaviors and practices within the core manufacturing domain, which is a key area of interest in the context of SMEs in Malaysia. Additionally, the Manufacturing Supporting Industry is also well-represented, with 27% of the respondents. This indicates that the survey captures perspectives not just from primary manufacturers but also from businesses that support and complement the manufacturing process. This could include a range of services and products that aid the manufacturing sector, providing a more comprehensive view of the ecosystem. The Services sector comprises 18% of the participants, offering a different angle on innovation, likely more focused on customer service, technology, and non-manufacturing processes. This diversification is important for understanding how innovation is perceived and implemented in service-oriented environments compared to more traditional manufacturing settings. Lastly, the category of Others – General accounts for 12% of the responses. This segment might include a variety of industries

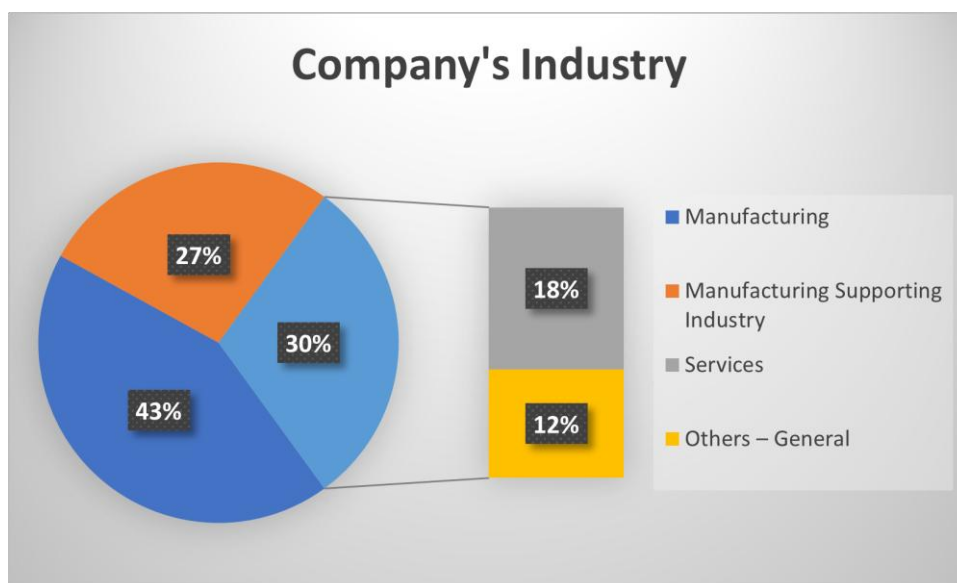


Figure 4.6: Company's Industry

outside the main focus areas, adding to the breadth of the survey data by bringing in additional perspectives from various other sectors.

4.4 PARTIAL LEAST SQUARES STRUCTURAL EQUATION MODELLING (PLS-SEM)

Partial Least Squares Structural Equation Modeling (PLS-SEM) serves as a statistical method employed in fields like social sciences and business to examine intricate relationships between observable variables and latent constructs. Diverging from traditional Structural Equation Modeling (SEM) that emphasizes covariance-based methods, PLS-SEM operates on a variance-based approach. This technique is especially apt for scenarios involving small sample sizes, data that does not adhere to a normal distribution, or when the theoretical framework underpinning the model is not extensively established. (Hair et al., 2006; Hair & Alamer, 2022; Sarstedt et al., 2021).

PLS-SEM is highly valued by researchers and practitioners for its adaptability and versatility. This method is especially beneficial in scenarios involving numerous latent variables, intricate relationships, and the presence of formative indicators (J. F. Hair et al., 2010). Additionally, PLS-SEM offers the advantage of concurrently testing measurement and structural models, enhancing efficiency and saving time. It also supports the analysis of non-linear relationships, enabling researchers to investigate complex real-world phenomena that may not be adequately addressed by conventional linear approaches (Sarstedt, Radomir, et al., 2022).

In this research, PLS-SEM proves to be a valuable tool for forecasting outcomes and analyzing the interplay among various factors being studied. It facilitates the creation and validation of measurement models, enabling precise measurement of latent constructs like attitudes, perceptions, or intentions, and elucidating their interrelations. PLS-SEM is adept at estimating both direct and indirect effects, which helps in pinpointing critical predictors and mediators that affect the outcome of interest (J. F. Hair et al., 2017; Sarstedt & Mooi, 2019). Additionally, its capability to manage both reflective and formative indicators enhances its applicability. Reflective indicators are typically used for measuring latent variables, viewing observed variables as manifestations of the underlying construct. In contrast, formative indicators consider observed variables as contributors to or creators of the latent construct. This dual capability of handling both types of indicators positions PLS-SEM as an ideal method for examining intricate causal relationships and accurately predicting outcomes (Sarstedt et al., 2022).

PLS-SEM encompasses two primary models: the measurement model and the structural model. The measurement model focuses on the linkages between latent constructs and their observable indicators, playing a critical role in confirming the reliability and validity of the constructs being analyzed. This model's primary purpose is to evaluate how effectively the observed variables represent the latent

constructs. Attention is given to analyzing the loadings of these indicators on the constructs and determining their significance, which reflects the robustness of these relationships. On the other hand, the structural model within PLS-SEM investigates into the dynamics between the latent constructs themselves. It is instrumental in uncovering the causal links and both direct and indirect effects among the constructs. The emphasis in this model is on calculating the path coefficients between the latent variables. These coefficients are key in illustrating the strength and direction of the relationships between the constructs, thereby providing insights into the underlying structural relationships in the research model. (Sarstedt et al., 2017). The stepwise analyses of the PLS-SEM model are explained below:

4.4.1 MEASUREMENT MODEL

The measurement model in PLS-SEM plays a pivotal role in verifying the reliability and validity of latent constructs and their associated observed indicators. This model allows researchers to assess the internal consistency of constructs using measures such as Construct Reliability (Cronbach's alpha) and Indicator Reliability (outer loading). Furthermore, it involves evaluating Composite Reliability and Convergent Validity, which together offer a comprehensive understanding of the measurement model's overall reliability and coherence. Another critical aspect is Discriminant Validity, which ensures that each construct is sufficiently distinct and not overly correlated with others.

The significance of the measurement model lies in its ability to lay a solid groundwork for further analysis. It ensures that the observed variables are accurate reflections of the latent constructs, thus providing researchers with reliable and valid measurements. These are essential for drawing meaningful interpretations and conclusions from PLS-SEM analyses. This reliability and validity are crucial for the integrity and credibility of the research findings. The subsequent sections detail the step-by-step analysis of the measurement model as applied in this research (Hair et al., 2017; Hair, Hult, Ringle, Sarstedt, et al., 2021; Sarstedt et al., 2017). The stepwise analyses of the measurement model used in this study are described following:

4.4.1.1 OUTER LOADING:

Indicator reliability, often referred to as outer loading, is a critical metric in PLS-SEM that quantifies how strongly each observed indicator is associated with its corresponding latent construct. This metric is indicative of the extent to which an indicator effectively captures or represents the construct it is intended to measure. In PLS-SEM analyses, outer loading values exceeding 0.70 are generally regarded as the benchmark for affirming a strong connection between observed indicators and latent variables. Nonetheless, more recent research (Hizam et al., 2023; Sentosa et al., 2012; Sentosa & Ming, 2012) proposes that indicators with outer loadings surpassing 0.50 may still be deemed reliable in reflecting the

latent construct. This perspective introduces a greater degree of flexibility in assessing indicator reliability and underscores the adaptability and robustness of the measurement model within PLS-SEM analyses.

In Table 4.1, the outer loadings results reflect the strength of the relationship between individual items and their respective latent constructs. For Personal Innovativeness of Automation (PIA), the items PIA1 through PIA6 show a progressive increase in loadings from 0.563 to 0.786, indicating that each item is a relatively good measure of the construct, with PIA5 and PIA6 being the most representative. Government Support items GOV1 and GOV2 exhibit very high loadings (0.877 and 0.893), demonstrating strong relationships with the construct, while GOV3 at 0.566 is somewhat weaker but still acceptable. The Adoption Intention of IR4.0 items range from 0.616 to 0.785, with the higher loadings suggesting a stronger association with the construct. Items measuring Perceived Ease of Use (PEOU) have high loadings between 0.787 and 0.892, suggesting a strong and consistent measurement of the construct. Perceived Usefulness (PU) items also show high loadings from 0.758 to 0.883, indicating a robust association with the construct. Innovative Work Behavior in SMEs (SIWB) items range from 0.719 to 0.81, with all items demonstrating strong loadings. Lastly, Learning & Development (LD) items display loadings from 0.686 to 0.825, with LD1 being the most strongly associated with the construct. Overall, the outer loadings suggest that the items are good indicators of their respective constructs, with most showing strong associations, thereby validating the measurement model of the PLS-SEM analysis.

Table 4.1: Outer Loadings

Variables	Items	Outer loadings
Personal Innovativeness of Automation (PIA)	PIA1	0.563
	PIA2	0.639
	PIA3	0.697
	PIA4	0.702
	PIA5	0.786
	PIA6	0.767
Government Support	GOV1	0.877
	GOV2	0.893
	GOV3	0.566
Adoption Intention of IR4.0	IR1	0.616
	IR2	0.657
	IR3	0.774
	IR4	0.744

	IR5	0.785
Perceived Ease of Use	PEOU1	0.787
	PEOU2	0.892
	PEOU3	0.881
	PEOU4	0.865
Perceived Usefulness	PU1	0.758
	PU2	0.883
	PU3	0.839
	PU4	0.862
Innovative Work Behavior in SMEs	SIWB1	0.719
	SIWB2	0.805
	SIWB3	0.81
	SIWB4	0.791
	SIWB5	0.75
	SIWB6	0.787
Learning & Development	LD1	0.825
	LD2	0.686
	LD3	0.699
	LD4	0.724

4.4.1.2 CONSTRUCT RELIABILITY (CRONBACH'S ALPHA)

Construct reliability, often measured using Cronbach's alpha, assesses the internal consistency and reliability of the latent constructs in the measurement model. It indicates the extent to which the observed indicators (items) consistently measure the underlying construct. Cronbach's alpha ranges from 0 to 1, with higher values indicating better reliability. Typically, a Cronbach's alpha value above 0.7 is considered acceptable, while values greater than 0.8 are preferred for stronger reliability (Sarstedt et al., 2017).

In this research, the results of reliability (Cronbach's Alpha) are presented in 4.2, the Cronbach's Alpha values serve as an indicator of internal consistency for various constructs, reflecting how well the set of items measures an underlying attribute. Personal Innovativeness in Automation (PIA) shows a Cronbach's Alpha of 0.785, indicative of a high degree of reliability among the items assessing individuals' propensity to embrace automation technologies. This suggests that the questions related to PIA are well-aligned and consistently capture the essence of this construct. The Government Support (GOVT)

construct has a Cronbach's Alpha of 0.737, which, while slightly lower, still falls within an acceptable range, implying that the survey items related to government incentives, policies, and support systems are relatively cohesive in measuring this aspect of the business environment. For the Adoption Intention of IR4.0 (IRA) construct, a Cronbach's Alpha of 0.765 is reported, denoting a solid internal consistency. This reflects that the items are reliably gauging the intent of businesses or individuals to adopt the principles and technologies associated with the Fourth Industrial Revolution. The construct of Perceived Ease of Use (PEOU) stands out with an Alpha of 0.88, indicating an excellent level of agreement among the items that measure how user-friendly and accessible respondents perceive technology to be. This high level of consistency assures that the PEOU construct is robustly captured by the survey items.

Similarly, Perceived Usefulness (PU) achieves a Cronbach's Alpha of 0.856, demonstrating that the items assessing how beneficial the technology is perceived to be in enhancing job performance are consistently measured across the sample. This high internal consistency is crucial, as PU is often a significant predictor of technology adoption and user satisfaction. The Innovative Work Behavior of SMEs employees (SIWB) construct also shows a strong internal consistency with an Alpha of 0.869. This implies that the survey items are very effective in measuring the innovative behaviors within the SME workforce consistently, which is central to understanding the dynamics of innovation in small and medium enterprises. Lastly, Learning & Development (LD) records a Cronbach's Alpha of 0.732, which is at the threshold of acceptability. It indicates that the items related to the learning and development opportunities within organizations are reasonably consistent, although there might be room for improvement in the alignment of these items. These Cronbach's Alpha results affirm the robustness and reliability of the measurement model, providing confidence in the ability of the observed variables to accurately measure the latent constructs in the PLS-SEM analysis.

Table 4.2 - Construct Reliability

Variables	Cronbach's Alpha
Personal Innovativeness in Automation (PIA)	0.785
Government Support (GOVT)	0.737
Innovative Work Behavior of SMEs Employees (SIWB)	0.765
Adoption Intention of IR4.0 (IRA)	0.88
Perceived Usefulness (PU)	0.856
Perceived Ease of Use (PEOU)	0.869

Learning & Development (LD)	0.732
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4.4.1.3 COMPOSITE RELIABILITY (CR)

Composite reliability is another measure of internal consistency, specifically focused on the overall reliability of the measurement model for a specific construct. It considers both the indicator reliabilities (outer loadings) and the error variances of the indicators associated with the construct. Composite reliability values above 0.7 indicate a reliable measurement model (Sarstedt et al., 2017). Table 4.3 presents the Composite Reliability results for each construct in the measurement model. The results for each construct show a strong level of composite reliability, all exceeding the commonly accepted threshold of 0.7, indicating that the latent variables are measured with a high degree of reliability.

Starting with Personal Innovativeness in Automation (PIA), the composite reliability score is 0.848, suggesting that the construct's indicators have a high internal consistency and that PIA is a stable construct within this data set. The Government Support (GOVT) construct follows with a composite reliability of 0.831, affirming that the scale used to measure the perceived support from government policies and initiatives is both consistent and reliable. The Adoption Intention of IR4.0 (IRA) shows a composite reliability of 0.841, pointing to a robust set of items that effectively capture the respondents' intention to adopt Industry 4.0 technologies. The constructs for Perceived Ease of Use (PEOU) and Perceived Usefulness (PU) stand out with particularly high composite reliability scores of 0.917 and 0.903, respectively. These scores are indicative of the strong internal consistency of the survey items for PEOU and PU, suggesting that the respondents' perceptions regarding the ease of use and usefulness of the technologies are captured in a reliable manner by the survey.

The Innovative Work Behavior of SMEs employees (SIWB) construct also demonstrates high reliability with a composite score of 0.902. This high score reflects the reliability of the items measuring how SME employees engage in innovative behaviors within their roles, providing confidence in the consistency of the respondents' answers. Lastly, Learning & Development (LD) has a composite reliability of 0.824, which, like the other constructs, denotes a reliable scale for assessing the impact of learning and development on employee performance and growth within the organization. In summary, the composite reliability scores of all the constructs in this study are robust, reflecting well-defined and reliable measures. These scores are critical for ensuring that the interpretations and conclusions drawn from the data are based on solid and consistent measurements across all constructs, providing a strong foundation for any subsequent analysis or discussion derived from this survey data. These Composite Reliability results reaffirm the ability of the observed variables to effectively measure their corresponding latent constructs in the PLS-SEM analysis.

Table 4.3 - Composite Reliability

Variables	Composite Reliability
Personal Innovativeness in Automation (PIA)	0.848
Government Support (GOVT)	0.831
Innovative Work Behavior of SMEs Employees (SIWB)	0.841
Adoption Intention of IR4.0 (IRA)	0.917
Perceived Usefulness (PU)	0.903
Perceived Ease of Use (PEOU)	0.902
Learning & Development (LD)	0.824

4.4.1.4 CONVERGENT VALIDITY (AVE):

Convergent validity evaluates the extent to which the observed indicators consistently and accurately measure the latent construct. It is assessed through the Average Variance Extracted (AVE), which represents the amount of variance in the indicators that can be explained by the underlying construct. AVE values should ideally be greater than 0.5, indicating that the construct explains more than 50% of the variance in its indicators (Sarstedt et al., 2021). The Average Variance Extracted (AVE) results in the Table 4.4 insight into the convergent validity of each construct in the survey, indicating how much variance in the indicators is accounted for by the latent construct. To establish adequate convergent validity, an AVE value of 0.5 or higher is typically desired, as it suggests that the construct explains more than half of the variance of its indicators.

In the results, Perceived Ease of Use (PEOU) stands out with the highest AVE value of 0.735, indicating a strong convergent validity and suggesting that a substantial proportion of the variance in the PEOU indicators can be attributed to the underlying latent construct. Perceived Usefulness (PU) also shows a strong AVE value of 0.7, reflecting well on the convergent validity of the construct and signifying that the PU indicators are predominantly influenced by the latent variable they intend to measure. Government Support (GOVT), with an AVE of 0.629, demonstrates that the indicators used to measure the construct capture a considerable amount of the variance attributed to government support, hence showing good convergent validity. Similarly, the Innovative Work Behavior of SMEs employees (SIWB) construct has an AVE of 0.605, indicating that the majority of the variance in the SIWB indicators is indeed due to the innovative work behavior construct.

The construct of Personal Innovativeness in Automation (PIA) presents an Average Variance Extracted (AVE) value of 0.485, which is slightly below the optimal threshold of 0.5 that is typically sought for strong convergent validity. Despite this, the value is close enough to the threshold to suggest that a moderate proportion of the variance in the observed indicators is indeed accounted for by the PIA construct, indicating an acceptable level of convergent validity. When this is coupled with the construct's high level of reliability, as evidenced by a Cronbach's Alpha and Composite Reliability both well above the 0.70 benchmark, the AVE value for PIA is within an acceptable range. High reliability scores compensate for the marginally lower AVE, allowing for some flexibility in the assessment of convergent validity. This is predicated on the understanding that the items measuring Personal Innovativeness in Automation are reliable and generally reflect the latent variable effectively, thereby affirming the construct's robustness and suitability for inclusion in subsequent analyses within the PLS-SEM framework.

The construct of Adoption Intention of IR4.0 (IRA) has an Average Variance Extracted (AVE) of 0.516, which surpasses the threshold of 0.5, commonly regarded as indicative of good convergent validity. This means that more than half of the variance in the indicators for IRA can be explained by the construct itself, reflecting that the indicators are substantially capturing the essence of the respondents' intentions to adopt Industry 4.0 technologies. Lastly, Learning & Development (LD) has an AVE of 0.541, which meets the threshold, indicating that the construct has an acceptable level of convergent validity, and a majority of the variance in its indicators is accounted for by the LD construct. These AVE results indicate the convergent validity of the measurement model, suggesting that the constructs effectively capture the variance in their corresponding observed variables in the PLS-SEM analysis.

Table 4.4 - Convergent Validity (AVE)

Variables	Average Variance Extracted (AVE)
Personal Innovativeness in Automation (PIA)	0.485
Government Support (GOVT)	0.629
Innovative Work Behavior of SMEs Employees (SIWB)	0.516
Adoption Intention of IR4.0 (IRA)	0.735
Perceived Usefulness (PU)	0.70
Perceived Ease of Use (PEOU)	0.605
Learning & Development (LD)	0.541

4.4.1.5 DISCRIMINANT VALIDITY (HTMT):

Discriminant validity ensures the distinctiveness of different constructs in the measurement model. It verifies that each construct measures a unique underlying concept and is not highly correlated with other constructs. The Heterotrait-Monotrait ratio (HTMT) is a recent method for assessing discriminant validity in PLS-SEM. It compares the average correlations of items belonging to different constructs (heterotrait) with those belonging to the same construct (monotrait). The HTMT ratio is calculated as the average heterotrait correlation divided by the average monotrait correlation. The ideal threshold for discriminant validity is less than 0.90, indicating that the constructs are more distinct from each other than they are within themselves (Sarstedt et al., 2021).

In the Table 4.5 for Discriminant Validity using the Heterotrait-Monotrait Ratio (HTMT), it is observed that all HTMT values are well below the threshold of 0.90, indicating a good discriminant validity among the constructs. For instance, the HTMT value between Personal Innovativeness in Automation (PIA) and Government Support (GOVT) is 0.414, which implies that these two constructs are distinct and measure separate dimensions within the study. Similarly, the HTMT value between PIA and Adoption Intention of IR4.0 (IRA) is 0.449, reaffirming that these constructs are uniquely captured by their respective indicators. The relationship between Perceived Ease of Use (PEOU) and other constructs like PIA (0.498), IRA (0.444), and Learning & Development (LD) (0.790) also demonstrates clear discriminant validity, as the correlations are sufficiently low to confirm that respondents view these constructs as different. Notably, PEOU's correlation with Perceived Usefulness (PU) is the highest observed in the table at 0.838, which is still below the cutoff, indicating that while related, they are perceived as distinct constructs by the respondents.

The HTMT value between Innovative Work Behavior of SMEs employees (SIWB) and IRA is 0.752, which is the highest among the HTMT values but still below the threshold, suggesting that while there's a strong relationship between these constructs, they are conceptually different. Moreover, SIWB's discriminant validity with LD (0.629) indicates a clear distinction in the respondents' perceptions of these constructs. Lastly, LD's HTMT values in relation to PIA (0.359), GOVT (0.138), and PU (0.665) further reinforce the discriminant validity among these constructs. These values support the conclusion that the constructs are empirically distinct and the survey items for each construct are not conflated with those of another, which is crucial for the integrity of the structural model within the PLS-SEM framework. In this table, all the HTMT ratios are less than the threshold value of 0.90, indicating strong discriminant validity. This suggests that the constructs are distinct from each other and are not highly correlated, validating the measurement model in the PLS-SEM analysis.

Table 4.5 - Discriminant Validity (HTMT)

	PIA	GOVT	IRA	PEOU	PU	SIWB	LD
PIA							
GOVT	0.414						
IRA	0.449	0.113					
PEOU	0.498	0.123	0.444				
PU	0.386	0.084	0.343	0.838			
SIWB	0.283	0.103	0.752	0.342	0.308		
LD	0.359	0.138	0.638	0.79	0.665	0.629	

4.4.2 STRUCTURAL MODEL ANALYSIS

The Partial Least Squares Structural Equation Modeling (PLS-SEM) approach integrates evaluations of both the measurement and structural models. The process begins with a thorough assessment of the measurement model, ensuring that the observed variables accurately represent their respective latent constructs. Upon satisfactory evaluation of the measurement model, focus shifts to the structural model, also known as the inner model. This model embodies the hypothesized relationships between the latent variables, delineating a network of causal pathways. Within this framework, the independent latent variables are categorized as predictor variables, and the dependent latent variables are identified as response variables. Notably, in the structural model, a single response variable may be influenced by several predictor variables, and the removal of a predictor can significantly alter the outcomes associated with the response variable, variable (Hair, Hult, Ringle, Sarstedt, et al., 2021).

The analysis of the structural model is tailored to align with the specific objectives and nuances of the study. In this research, a comprehensive approach is adopted, utilizing four distinct techniques for structural model analysis. Each technique contributes to a deeper understanding of the latent variable interactions and the strength and direction of the hypothesized relationships. The step-by-step process of this analysis is detailed in the subsequent sections, methodically unfolding the intricate causal relationships within the study's conceptual framework. This meticulous approach ensures a robust and thorough exploration of the structural model, providing valuable insights into the latent constructs and their interdependencies as defined in the research hypothesis.

4.4.2.1 COLLINEARITY

Accurate evaluation of structural relationships in statistical modeling, particularly in methods like PLS-SEM, necessitates the careful examination of collinearity among predictor variables, as it can

significantly bias regression outcomes. Collinearity is typically assessed using the Variance Inflation Factor (VIF), calculated from the latent variable scores in partial regression models. VIF values between 3 and 5 are indicative of potential collinearity concerns, suggesting a problematic level of correlation among predictors that could compromise the integrity of the model's results. To ensure a robust and reliable analysis, it is crucial to maintain VIF values as close to or below 3 as possible. Lower VIF values signify a reduced degree of multicollinearity, affirming that the predictor variables are sufficiently independent to provide clear and distinct contributions to the regression model. This approach enhances the precision and validity of the structural relationship assessment, ensuring that the findings are both credible and accurately reflective of the underlying data relationships (Hair et al., 2017).

In Table 4.6, the VIF results for the constructs in the PLS-SEM model indicate that multicollinearity does not pose a concern for the relationships under examination. All reported VIF values are significantly below the threshold of 5, which would indicate high multicollinearity. Specifically, the VIF values for Personal Innovativeness in Automation (PIA) with Government Support (GOVT) and Learning & Development (LD) stand at 1.213, showcasing their independence. The Government Support construct shows an even lower VIF of 1.004 when compared with the Innovative Work Behavior of SMEs employees (SIWB), further affirming negligible collinearity. The Adoption Intention of IR4.0 (IRA) with SIWB has a VIF of 1.301, which is comfortably below the threshold, while the Perceived Ease of Use (PEOU) records a moderate VIF of 2.233 with PIA and LD. Lastly, Perceived Usefulness (PU) presents a VIF of 2.057 with PIA. These values collectively suggest that each construct in the model operates with a high degree of independence, ensuring the structural integrity and reliability of the model's predictive capabilities.

Table 4.6 - Inner Collinearity Results

	PIA	GOVT	IRA	PEOU	PU	SIWB	LD
PIA			1.213				1.213
GOVT						1.004	
IRA						1.301	
PEOU			2.233				2.233
PU			2.057				2.057
SIWB							
LD						1.301	

4.4.2.2 PATH COEFFICIENTS

Path coefficients in Partial Least Squares Structural Equation Modeling (PLS-SEM) act as vital indicators, operating as standardized regression weights that measure the magnitude and trajectory of associations between latent constructs. These coefficients, when positive, reflect direct proportional relationships, and when negative, reveal inverse correlations between variables. A thorough examination of path coefficients is essential for the structural model's evaluation, with coefficients exceeding the benchmark of 0.10 generally regarded as exerting substantial influence within the model's architecture. For rigorous validation of these coefficients' significance, bootstrapping is the method of choice, seeking p-values of 0.05 or below to confirm statistical significance. This stringent assessment, as Hair et al. (2020) suggest, is crucial for affirming the validity of the model's hypothesized relationships and ensures that the PLS-SEM analysis rests on a foundation of statistically verified relationships.

In the realm of path analysis, the beta coefficient (β) serves as a critical indicator, providing a standardized measure of the magnitude and direction of influence that a predictor variable exerts on an outcome variable. It is a quantifier of the expected shift in the outcome variable for a single-unit increment in the predictor. The t-statistic (t) is then employed to gauge the statistical significance of the beta coefficient, determining the likelihood that the observed relationship between the variables is not a product of random variation. A t-statistic with a significant value underpins the inference that the relationship is indeed systematic and not merely coincidental. Complementarily, the p-value (p) quantifies the probability of observing the current results, or more extreme ones, under the assumption that no actual relationship exists between the variables in question. Conventionally, a p-value below the threshold of 0.05 is interpreted as robust evidence refuting the null hypothesis, thus affirming a statistically significant relationship between the predictor and the outcome. These intricate elements of path analysis are meticulously synthesized to present a clear and comprehensive depiction of the relationships within the structural model (Awang, 2015; Hair & Alamer, 2022; Hizam et al., 2022). The path analysis results are presented in Table 4.7.

According to the Hypothesis H1a states that Perceived Usefulness (PU) positively and directly influences the Adoption Intention (IRA). This hypothesis is accepted, indicated by a path coefficient of 0.131, a T statistic of 1.689, and a P value of 0.046. The results affirm that perceived usefulness significantly impacts the intention to adopt Industry 4.0 technologies in the manufacturing sector, albeit the effect size is modest.

Hypothesis H1b posits that Perceived Usefulness (PU) has a positive and direct influence on Learning & Development (LD). This hypothesis is accepted. With a path coefficient of 0.12, a T statistic of 1.842, and

a P value of 0.033, it suggests a significant, albeit modest, relationship between perceived usefulness and learning and development initiatives within the sector.

Hypothesis H2a suggests that Perceived Ease of Use (PEOU) positively and directly influences the Adoption Intention of IR4.0 (IRA). This hypothesis is accepted, evidenced by a path coefficient of 0.231, a T statistic of 2.826, and a P value of 0.002. The findings highlight the importance of ease of use in influencing the intention to adopt new technologies within the SME manufacturing-industry.

Hypothesis H2b states that Perceived Ease of Use (PEOU) has a positive and direct impact on Learning & Development (LD). This hypothesis is also accepted, demonstrating a strong relationship as indicated by a high path coefficient of 0.519, a T statistic of 8.848, and a P value of 0.000. This underscores the significant role of ease of use in enhancing learning and development efforts.

Hypothesis H3 asserts that Government Support (GOVT) positively and directly influences the Innovative Work Behavior of SMEs Employees (SIWB). However, this hypothesis is rejected, as indicated by a relatively low path coefficient of 0.063, a T statistic of 1.529, and a P value of 0.063. The findings suggest that government support may not play a significant role in influencing innovative work behaviour in the Malaysian SME manufacturing industry. The negative influence of government support towards SWIB can be a factor of the organization culture that hinder the initiatives of innovation (Kurniawan et al., 2021). Companies that receive the government benefits for innovation of development of technology may use this advantage as expenses in the firm that does not result in innovation creation (Jugend et al., 2020)

Hypothesis H4a proposes that Personal Innovativeness in Automation (PIA) positively and directly affects the Adoption Intention of IR4.0 (IRA). This hypothesis is accepted, with a path coefficient of 0.131, a T statistic of 2.29, and a P value of 0.011, affirming the significant influence of personal innovativeness on the intention to adopt Industry 4.0 technologies.

Hypothesis H4b suggests that Personal Innovativeness in Automation (PIA) positively and directly influences Learning & Development (LD). Despite the proposition, this hypothesis is rejected, as indicated by a low path coefficient of 0.028, a T statistic of 0.522, and a high P value of 0.301. This result suggests that personal innovativeness does not have a significant direct impact on learning and development within the sector.

Hypothesis H4c posits that Personal Innovativeness in Automation (PIA) influences the Innovative Work Behavior of SMEs Employees (SIWB) indirectly through Adoption Intention of IR4.0 (IRA). This indirect relationship is accepted, with a path coefficient of 0.063, a T statistic of 2.068, and a P value of 0.02, highlighting the significant role of adoption intention as a mediator.

Hypothesis H4d states that Personal Innovativeness in Automation (PIA) impacts the Innovative Work Behavior of SMEs Employees (SIWB) indirectly through Learning & Development (LD). Despite the initial hypothesis, this relationship is found to be insignificant, as evidenced by the low path coefficient of 0.007, a T statistic of 0.494, and a P value of 0.311. These results suggest that the indirect effect of personal innovativeness on innovative work behaviour through learning and development is not substantial within the context of the Malaysian manufacturing industry.

Hypothesis H5a asserts that Learning & Development (LD) positively and directly influences the Adoption Intention of IR4.0 (IRA). Accepted with a path coefficient of 0.235, a T statistic of 2.371, and a P value of 0.009, the results emphasize the strong influence of learning and development initiatives on the intention to adopt Industry 4.0 technologies.

Hypothesis H5b suggests that Learning & Development (LD) positively and directly impacts the Innovative Work Behavior of SMEs Employees (SIWB). This hypothesis is accepted, indicated by a path coefficient of 0.256, a T statistic of 3.25, and a P value of 0.001, affirming the critical role of learning and development in fostering innovative behaviors.

Hypothesis H6 posits that the Adoption Intention of IR4.0 (IRA) positively and directly influences the Innovative Work Behavior of SMEs Employees (SIWB). This relationship is strongly affirmed by the acceptance of the hypothesis, with a path coefficient of 0.486, a T statistic of 6.681, and a P value of 0.000. The results highlight the significant role of adoption intention in driving innovative work behavior in the sector.

Table 4.7 - Path Analysis

Hypotheses		Path Coeff. (β)	T Statistics	P Values	Decision
H1a	PU $\rightarrow$ IRA	0.131	1.689	0.046	Accepted
H1b	PU $\rightarrow$ LD	0.12	1.842	0.033	Accepted
H2a	PEOU $\rightarrow$ IRA	0.231	2.826	0.002	Accepted
H2b	PEOU $\rightarrow$ LD	0.519	8.848	0.000	Accepted
H3	GOVT $\rightarrow$ SIWB	0.063	1.529	0.063	Rejected

H4a	PIA → IRA	0.131	2.29	0.011	Accepted
H4b	PIA → LD	0.028	0.522	0.301	Rejected
H4c	PIA → IRA → SIWB	0.063	2.068	0.02	Accepted
H4d	PIA → LD → SIWB	0.007	0.494	0.311	Rejected
H5a	LD → IRA	0.235	2.371	0.009	Accepted
H5b	LD → SIWB	0.256	3.25	0.001	Accepted
H6	IRA → SIWB	0.486	6.681	0.000	Accepted

4.4.2.3 COEFFICIENT OF DETERMINATION

In partial least squares (PLS), the coefficient of determination (R^2) holds significance as a key measure for assessing the structural model. R^2 reflects the proportion of explanatory power of endogenous latent variables to the variance of their response variables. Higher R^2 values indicate a more substantial level of explained variance. Under the guidelines set forth by Cohen in 1988, the R^2 value, or the coefficient of determination, is interpreted as a measure of the strength of a model. R^2 values less than 0.02 are viewed as very weak, indicating that the model does not explain much of the variance of the dependent variable. R^2 values that fall between 0.02 and 0.13 are classified as weak, showing a slight explanatory power of the model. Those within the range of 0.13 to 0.26 are regarded as moderate, suggesting a reasonable amount of variance being accounted for. Finally, R^2 values of 0.26 and above are considered substantial, demonstrating that the model has a strong explanatory power regarding the variance of the dependent variable (Cohen, 1988a).

As per the Table 4.8, the R Square and Adjusted R Square values are crucial indicators in PLS-SEM, reflecting the proportion of variance in the dependent variables explained by the model. For the Adoption Intention of IR4.0 (IRA), the R Square value is 0.341, with an Adjusted R Square of 0.334. This indicates that approximately 34.1% of the variance in IRA is explained by the model, which slightly reduces to 33.4% when accounting for the number of predictors and sample size. The Innovative Work Behavior of SMEs employees (SIWB) demonstrates a higher R Square value of 0.449 and an Adjusted R Square of 0.444, suggesting that the model explains about 44.9% of the variance in SIWB. This proportion remains

largely consistent after adjustment. Learning & Development (LD) presents an R Square value of 0.406 and an Adjusted R Square of 0.401. This indicates that the model accounts for approximately 40.6% of the variance in LD, with a minimal reduction to 40.1% after adjustment for predictors and sample size. These values signify that the model is most effective in explaining the variance in Innovative Work Behavior of SMEs employees, followed by Learning & Development, and is somewhat less effective in explaining the variance in Adoption Intention of IR4.0. The closeness of the Adjusted R Square values to the R Square values for each construct underscores the robustness of the model's explanatory power against the influence of the number of predictors and sample size.

Table 4.8- R Square and R Square Adjusted

Variables	R Square	R Square Adjusted
IRA	0.341	0.334
LD	0.406	0.401
SIWB	0.449	0.444

4.4.2.4 EFFECT SIZE F^2

In PLS-SEM analysis, the f^2 metric is instrumental in gauging the predictive power of independent variables over a dependent latent variable, reflecting the relative impact of these predictors. Higher f^2 values signify a stronger explanatory influence on the observed variance in a latent variable. When integrated with R^2 , which quantifies the overall explained variance, f^2 values provide a nuanced understanding of the predictive strength within the model. Cohen's guidelines suggest that an f^2 value of 0.02 denotes a small yet significant effect, values of 0.15 or higher indicate a moderate effect, and those of 0.35 or greater signify a strong effect, thereby aiding in pinpointing potentially weak links in the structural model and deepening the understanding of the model's explanatory power (Cohen, 1988b; Hair & Alamer, 2022; Sarstedt, Hair, et al., 2022).

In Table 4.9, the impact of Government Support (GOVT) on Innovative Work Behavior of SMEs employees (SIWB) is minimal with an f^2 value of 0.008. Conversely, the Adoption Intention of IR4.0 (IRA) exhibits a strong influence on SIWB with an f^2 value of 0.284, indicating that IRA is a significant predictor of SIWB. Learning & Development (LD) also shows a notable effect on SIWB with an f^2 of 0.093. The Perceived Ease of Use (PEOU) demonstrates varying influences, with a small effect on IRA (f^2 of 0.047) and a large effect on LD (f^2 of 0.293). Personal Innovativeness in Automation (PIA) has a small impact on IRA (f^2 of 0.031) and a negligible one on LD (f^2 of 0.001), while Perceived Usefulness (PU) similarly shows a small effect on IRA (f^2 of 0.028) and a negligible one on LD (f^2 of 0.004). These

findings elucidate the varying strengths of relationships between the predictors and outcomes within the PLS-SEM model.

Table 4.9 - f-Square Values

Variables	IRA	LD	SIWB
GOVT			0.008
IRA			0.284
LD			0.093
PEOU	0.047	0.293	
PIA	0.031	0.001	
PU	0.028	0.004	
SIWB			

4.4.2.5 PLS-SEM FRAMEWORK

Figure 4.7 unfolds the intricacies of the PLS-SEM model with meticulous detail, illustrating the nuanced regression paths that link latent constructs to their observed indicators, and quantifying the relationships' strength through outer loadings. This depiction provides a granular view of each construct's reliability and the overall validity of the measurement model, captured through R-squared values that highlight the model's explanatory prowess. Complementing this, Figure 4.8 delves into the bootstrapping results crucial for hypothesis testing within the PLS-SEM framework, illuminating the statistical significance of the path coefficients with precision. By displaying t-statistics for each pathway, it furnishes empirical support for accepting or rejecting the formulated research hypotheses. Together, these visual analyses offer a holistic comprehension of the PLS-SEM analysis carried out in the study, underscoring the reliability and validity of the measurement model and affirming the significance of the structural relationships postulated. This rigorous methodological approach enables a thorough validation of the research model, yielding critical insights for the theoretical expansion and practical application in the field of study.

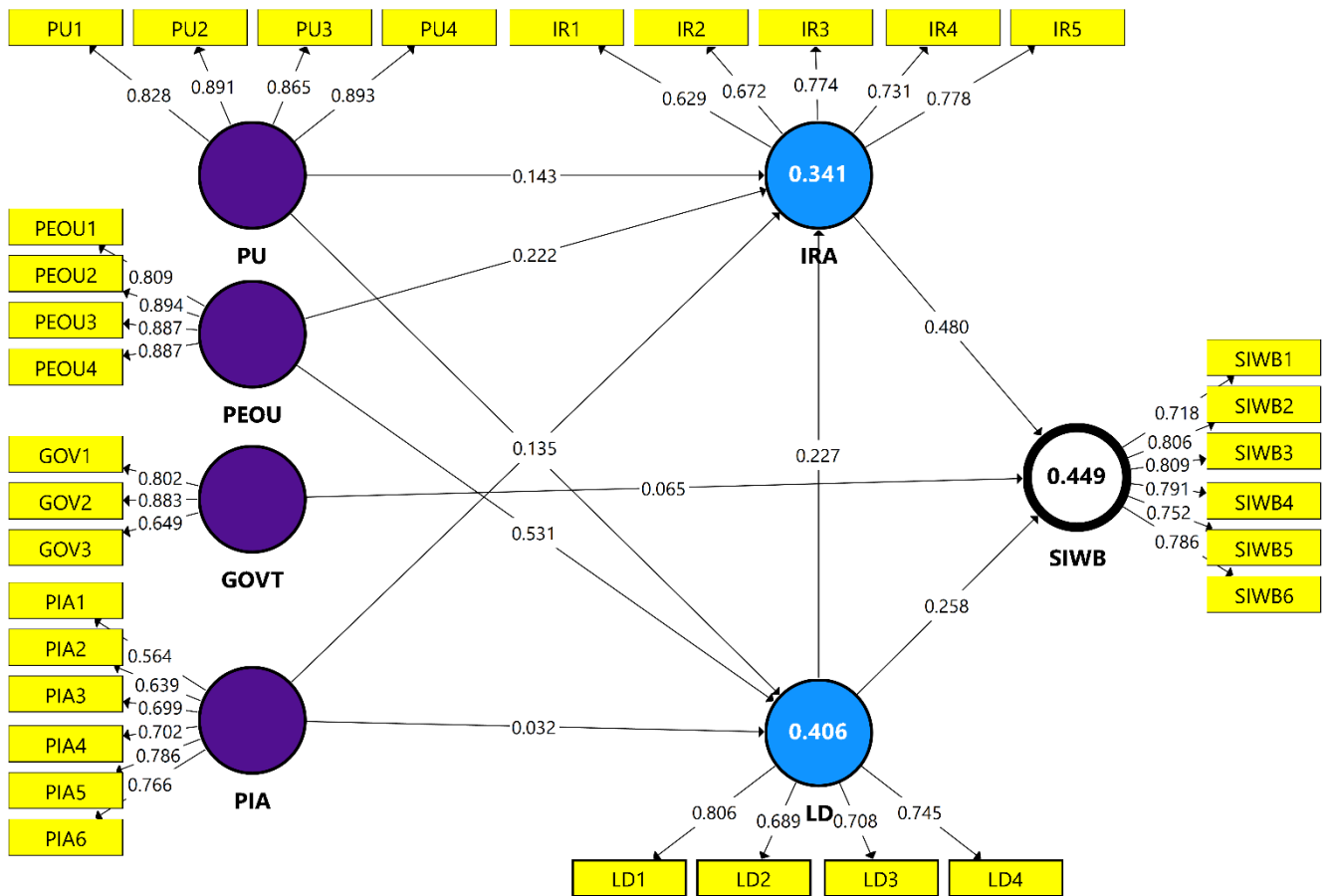


Figure 4.7 – PLS-SEM Algorithm

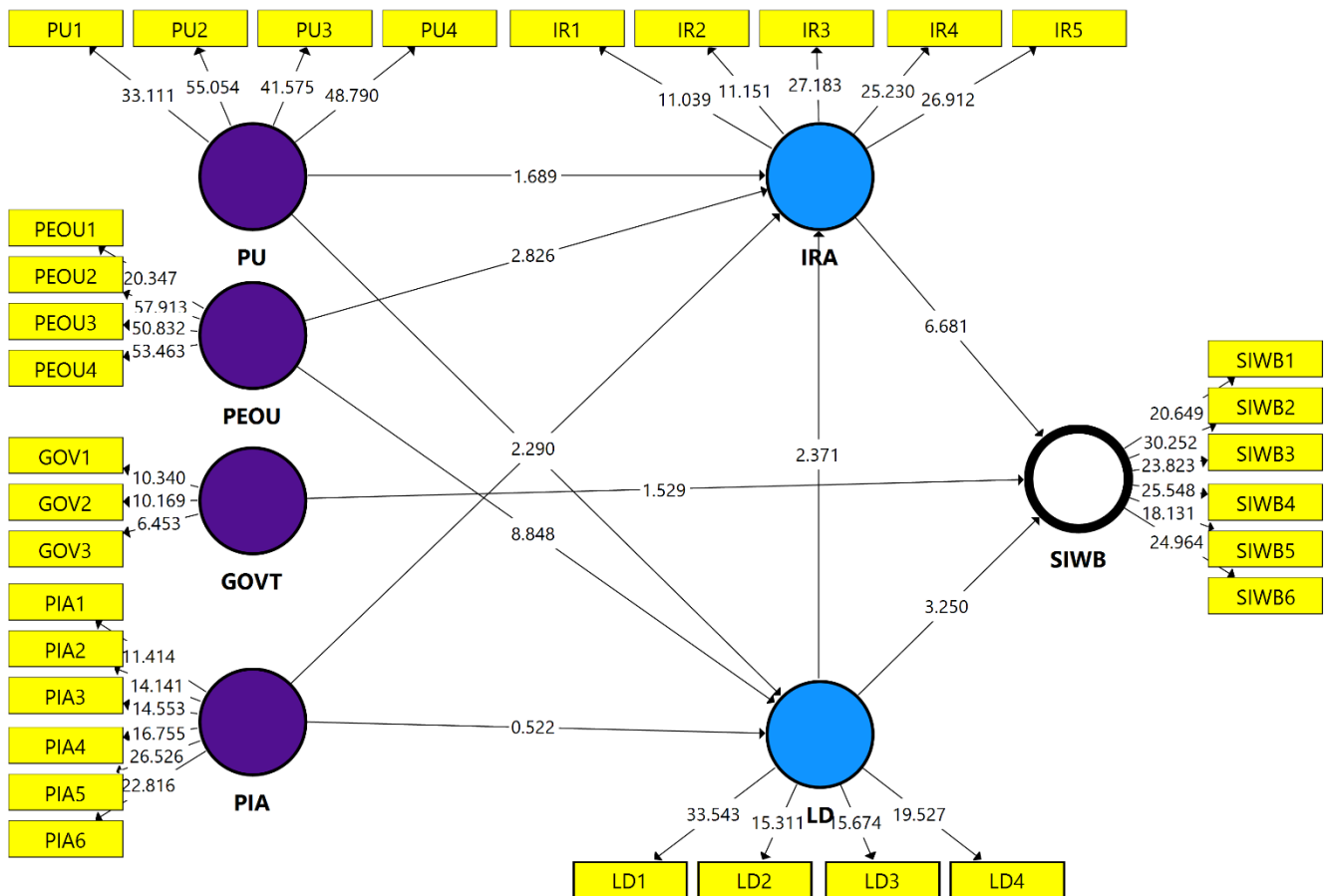


Figure 4.8 – PLS-SEM Bootstrapping Model

4.5 CHAPTER SUMMARY

Chapter 4 offers an in-depth examination through PLS-SEM analysis, delving into the innovative work behaviors of SMEs in Malaysia's manufacturing industry. The chapter begins with rigorous data preprocessing to validate the dataset's robustness, addressing any missing data, outliers, and potential common method biases that could skew results. Insightful demographic analyses shed light on the survey's participant structure, laying the groundwork for deeper understanding in subsequent analytical phases. Following the demographic analysis that sets the stage by profiling the survey participants, the chapter advances into the intricacies of PLS-SEM, systematically dissecting both the measurement model and the structural model. In the measurement model, reliability and validity are scrutinized through Cronbach's Alpha, Composite Reliability, and AVE values, while HTMT ratios confirm discriminant validity. Subsequently, the structural model is rigorously tested through path analysis, considering R^2 values for explanatory power and f^2 values for effect size, with VIF calculations ensuring no

multicollinearity, thus reinforcing the overall validity of the model. This sequential analysis meticulously maps out the contours of innovative behaviors in the sector, informed by empirical data.

CHAPTER 5

5 RESULTS

5.1 INTRODUCTION

Following the detailed exposition of survey data analysis in Chapter 04, Chapter 05 shifts the focus towards a thorough discussion and elaboration of these results, primarily in the context of their contribution to research and the advancement of knowledge. This chapter aims to weave the individual threads of data into a cohesive narrative that not only elucidates the findings but also places them within the broader spectrum of academic inquiry. The chapter initiates with an in-depth examination of the hypotheses results derived from the theoretical framework. Each hypothesis is dissected to explore its implications and relevance to the study's overarching objective. This meticulous analysis will provide an overarching view of each variable, delineating their individual and collective impacts on the research subject. As we investigate deeper, the discussion expands to present and debate the key findings in detail. This segment is pivotal, as it not only highlights the core outcomes of the research but also engages in a critical evaluation of these findings against the backdrop of existing literature and theories. The discourse here transcends mere data interpretation, venturing into the realms of theoretical implications and practical applications. In line with the objective of contributing to the field, this chapter also hunts into the practical implications of the study. It examines how the insights garnered can influence real-world applications, particularly focusing on the role of SEM (Structural Equation Modeling) analysis in predicting factors critical to Innovative Work Behavior in SMEs. This discussion is expected to provide valuable guidelines and strategies for practitioners and decision-makers in the relevant fields. Lastly, the chapter acknowledges the limitations inherent in the research process. These limitations are critically examined, providing a transparent and honest reflection of the study's scope. Building upon this, the chapter also outlines potential avenues for future research, suggesting how subsequent inquiries can build on the findings and insights of this study to further enrich the understanding of IWB factors in SMEs.

5.2 HYPOTHESIS DISCUSSION

The research conducted on the Manufacturing Sector in Malaysia holds significant importance due to its focus on understanding the complexities and dynamics of Industry 4.0 adoption. This study is pivotal as it unveils critical factors that influence this sector's transition towards more advanced and innovative practices. By analyzing a series of hypotheses, the research provides a nuanced view of the elements that are instrumental in shaping the future of manufacturing in Malaysia.

In total, twelve hypotheses were put forward in this study, examining various aspects of technology adoption and innovation within the manufacturing sector. Notably, nine of these hypotheses received empirical support, while three were rejected. This outcome indicates a complex interplay of factors that govern the adoption of Industry 4.0 technologies and innovative behaviors in small and medium-sized enterprises (SMEs). For instance, hypotheses related to Perceived Usefulness and Perceived Ease of Use were among those accepted, highlighting the significance of these perceptions in influencing adoption intentions and learning and development activities within the sector.

The R Square values obtained in this study further reinforce the strength and relevance of the accepted hypotheses. For Adoption Intention of IR4.0 (IRA), the R Square value was 0.341, and the adjusted R Square was 0.334, indicating a moderate level of explained variance in IRA by the model. Similarly, Learning & Development (LD) had an R Square of 0.406 and an adjusted R Square of 0.401, while Innovative Work Behavior of SMEs Employees (SIWB) demonstrated an R Square of 0.449 and an adjusted R Square of 0.444. These values suggest a substantial proportion of variance in the dependent variables explained by the independent variables, signifying a strong model fit.

According to Cohen's guidelines for interpreting R Square values, the results obtained in this study can be considered of moderate to high magnitude. This interpretation aligns with the common thresholds in social science research, where values around 0.3 are often viewed as moderate, and those nearing 0.5 are considered substantial. Therefore, the findings from this research not only provide empirical support for the majority of the proposed hypotheses but also exhibit a considerable degree of explanatory power in understanding the factors influencing the adoption and impact of Industry 4.0 in Malaysia's Manufacturing Sector. This research offers a comprehensive and insightful exploration into the factors affecting Malaysia's Manufacturing Sector in the context of Industry 4.0. The acceptance of a majority of the hypotheses and the robust R Square values achieved underscore the relevance and depth of the study, providing a valuable foundation for both academic inquiry and practical applications in the field.

In the exploration of various factors influencing the Manufacturing Sector in Malaysia, the study's analysis reveals insightful outcomes across a range of hypotheses. In this research, 9 out of 12 hypotheses were accepted, while 3 were rejected, as shown in Table 5.1, offering a comprehensive insight into the factors influencing the Manufacturing Sector in Malaysia. Perceived Usefulness (PU) positively impacted both Adoption Intention of IR4.0 (IRA) and Learning & Development (LD), as indicated by the acceptance of hypotheses H1a and H1b. Equally, Perceived Ease of Use (PEOU) was found to significantly influence IRA and LD, affirming hypotheses H2a and H2b. Contrary to expectations, Government Support (GOVT) did not show a significant effect on the Innovative Work Behavior of SMEs Employees (SIWB), leading to the rejection of hypothesis H3. The role of Personal Innovativeness

in Automation (PIA) showed a mixed influence; while directly impacting IRA positively (H4a), it did not significantly affect LD (H4b). However, its indirect effect on SIWB through IRA was notable (H4c), though not through LD (H4d). Learning & Development (LD) strongly influenced both IRA and SIWB, as seen in the acceptance of H5a and H5b. Finally, the direct positive influence of IRA on SIWB (H6) highlights the importance of adoption intention in fostering innovative behaviors. These results collectively provide a nuanced understanding of the dynamics driving the adoption of Industry 4.0 and innovation within the sector, setting a foundation for further detailed analysis.

5.3 THEORETICAL ALIGNMENT:

These findings align closely with the Technology Acceptance Model (TAM) by Davis (1989), which posits that Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) are foundational to users' intention to adopt new technologies. The empirical support for H1a, H1b, H2a, and H2b reinforces this model's central claims. The significant influence of PU and PEOU on both Adoption Intention (IRA) and Learning & Development (LD) echoes the findings of Chatterjee et al. (2021) and Salimon et al. (2023), who extended TAM in manufacturing and digital transformation contexts to demonstrate that user-centric perceptions directly shape behavioral intentions and learning engagement. In contrast, the rejection of H3 (Government Support → IWB) challenges simplistic assumptions that external institutional support directly translates to innovation. This resonates with the findings of Adam and Alarifi (2021) and Pu et al. (2021), who argue that the impact of government support on innovation is often indirect and moderated by internal capabilities, cultural context, and execution focus.

The role of Personal Innovativeness in Automation (PIA) as a significant driver of IRA (H4a) and indirect contributor to IWB (H4c) confirms the assertions by Ghosh et al. (2016) and Mustafa et al. (2021), who suggest that intrinsic innovation orientation among employees catalyzes technology-driven innovation. However, the non-significant paths from PIA to LD (H4b) and to SIWB via LD (H4d) suggest that innovative disposition does not necessarily translate into engagement with structured development, a finding that challenges traditional assumptions about linear learning behavior in SME contexts (Marouani & Nilsson, 2016). These results suggest the need for theoretical expansion beyond traditional TAM, possibly integrating elements of the Technology–Organization–Environment (TOE) framework or models of self-regulated learning (Margaryan et al., 2022) to fully capture the nuances in employee innovation behavior within SMEs under IR4.0 contexts.

Table 5.1 – Hypotheses Results

Hypothesis	Statement	Decision
H1a	Perceived Usefulness (PU) positively influences the Adoption Intention of IR4.0 (IRA).	Accepted
H1b	Perceived Usefulness (PU) positively influences Learning & Development (LD).	Accepted
H2a	Perceived Ease of Use (PEOU) positively influences the Adoption Intention of IR4.0 (IRA).	Accepted
H2b	Perceived Ease of Use (PEOU) positively influences Learning & Development (LD).	Accepted
H3	Government Support (GOVT) positively influences the Innovative Work Behavior of SMEs Employees (SIWB).	Rejected
H4a	Personal Innovativeness in Automation (PIA) positively influences the Adoption Intention of IR4.0 (IRA).	Accepted
H4b	Personal Innovativeness in Automation (PIA) positively influences Learning & Development (LD).	Rejected
H4c	Personal Innovativeness in Automation (PIA) influences the Innovative Work Behavior of SMEs Employees (SIWB) through IRA.	Accepted
H4d	Personal Innovativeness in Automation (PIA) influences the Innovative Work Behavior of SMEs Employees (SIWB) through LD.	Rejected
H5a	Learning & Development (LD) positively influences the Adoption Intention of IR4.0 (IRA).	Accepted
H5b	Learning & Development (LD) positively influences the Innovative Work Behavior of SMEs Employees (SIWB).	Accepted
H6	The Adoption Intention of IR4.0 (IRA) positively influences the Innovative Work Behavior of SMEs Employees (SIWB).	Accepted

5.3.1 HYPOTHESIS H1– PERCEIVED USEFULNESS (PU)

Perceived Usefulness (PU) is a crucial factor in technology acceptance models and plays a significant role in the context of technical skills in manufacturing SMEs. PU, in this context, refers to the degree to which employees in manufacturing SMEs believe that improving their technical skills will enhance their job performance. This belief can lead to a more positive attitude towards learning and adopting new technologies. In an industry characterized by rapid technological advancements, such as the manufacturing sector, the perception of the usefulness of acquiring and updating technical skills is vital for both individual performance and organizational competitiveness.

5.3.1.1 HYPOTHESIS 1A (PU → IRA)

In examining the role of Perceived Usefulness (PU) within the context of manufacturing SMEs, the analysis of Hypotheses H1a and H1b reveals insightful trends. Hypothesis H1a, which posits that PU

positively influences the Adoption Intention of IR4.0 (IRA), is substantiated with a path coefficient (β) of 0.131, a T statistic of 1.689, and a significance level (P value) of 0.046. These figures, while indicating a statistically significant relationship, suggest a moderate rather than a robust impact of PU on IRA. This outcome aligns with the foundational principles of the Technology Acceptance Model, where perceived usefulness is acknowledged as a critical determinant of technology adoption. However, the relatively modest beta value in this context implies that while PU is indeed influential, it is not the sole factor driving the adoption intention towards IR4.0 technologies. It hints at a complex decision-making process among SME employees, where the utility perception of new technology is one of several considerations. This finding echoes the assertions of prior research, such as the work of Venkatesh and Bala (2008), which emphasized the multifaceted nature of technology acceptance, especially in environments characterized by rapid technological change. In the study done on Malaysian dairy manufacturing industry confirms the Technology Acceptance Model (TAM) framework where PU is a critical driver of technology adoption intention but also highlights the role of other social and control factors (Saeedi, Juwaidah and Kelly, 2022).

5.3.1.2 HYPOTHESIS 1B (PU $\rightarrow$ LD)

Further, Hypothesis H1b, examining the impact of PU on Learning & Development (LD), presents a path coefficient (β) of 0.12, a T statistic of 1.842, and a P value of 0.033. This evidence supports a positive but again moderate influence of PU on LD initiatives. The acceptance of this hypothesis indicates that employees' perception of the usefulness of acquiring new skills has a significant, albeit not overwhelming, impact on their engagement with learning and development activities. This result can be interpreted within the broader framework of adult learning theories, which suggest that adult learners are predominantly goal-oriented and value learning that they perceive as immediately useful and beneficial to their job performance. The moderate strength of this relationship, as seen in the beta value, suggests that other motivational factors, possibly including organizational support, peer influence, or intrinsic motivation, also play crucial roles in shaping employees' attitudes towards learning and development.

This nuanced understanding of the factor's influencing LD is supported by research in the field of organizational learning and development, such as the studies by Noe and colleagues, which highlight the complexity of learning motivation in professional settings.

The findings from Hypotheses H1a and H1b collectively emphasize the significance of perceived usefulness in influencing both the adoption of new technologies and participation in learning and development activities in the manufacturing sector. However, the moderate nature of these impacts underlines the presence of other influential factors, requiring a comprehensive approach to

understanding and enhancing both technology adoption and employee development in this rapidly evolving sector.

5.3.2 HYPOTHESIS H2– PERCEIVED EASE OF USE (PEOU)

Perceived Ease of Use (PEOU) is a critical determinant in the adoption and effective utilization of technical skills, especially in the context of Industry 4.0 technologies within manufacturing SMEs. PEOU refers to the degree to which employees believe that using a particular technology will be free of effort. In an environment where technical skills are rapidly evolving and becoming increasingly complex, the perceived ease with which employees can learn and apply these skills becomes a vital factor. It not only influences their willingness to embrace new technologies but also affects their efficiency and productivity. A high level of PEOU typically leads to greater acceptance and more enthusiastic engagement with new technologies, as it reduces the cognitive and physical strain associated with learning and applying new skills.

5.3.2.1 HYPOTHESIS 2A (PEOU → IRA)

The analysis of Hypothesis H2a reveals a significant relationship between the Perceived Ease of Use of technical skills and the Adoption Intention of IR4.0 (IRA) in manufacturing SMEs. The path coefficient for this hypothesis stands at 0.231, accompanied by a T statistic of 2.826 and a P value of 0.002, indicating a strong and statistically significant influence. This result suggests that when employees perceive new technologies as user-friendly and easy to understand, their intention to adopt these technologies increases considerably. The importance of this finding is grounded in the Technology Acceptance Model, which posits ease of use as a fundamental driver of technology adoption. The literature review by (Nurqamarani, Sogiarto and Nurlaeli, 2021) identifies Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) as the most influential variables in TAM-based studies across SME contexts. This synthesis of TAM literature aims to highlight key factors affecting technology adoption in SMEs and explore model variations relevant to specific technology industries. In a manufacturing context, where Industry 4.0 technologies are often complex, the ease with which employees can assimilate and utilize these technologies becomes a critical factor in their widespread acceptance and implementation. This aligns with the findings of previous studies, such as those by Venkatesh and Davis (2000), which have consistently underscored the impact of ease of use on users' technology adoption decisions.

5.3.2.2 H2B: PEOU → LD

Similarly, Hypothesis H2b examines the impact of Perceived Ease of Use on Learning & Development (LD) initiatives within manufacturing SMEs. The results are compelling, with a path coefficient of 0.519, a T statistic of 8.848, and a P value of 0.000, demonstrating a very strong positive relationship. This high path coefficient is indicative of the significant role that ease of use plays in encouraging

employees' engagement in learning and development activities. The rationale behind this is rooted in adult learning theories, which emphasize the importance of accessible and straightforward learning experiences in motivating adult learners. In the specific context of manufacturing SMEs, where ongoing skill development is crucial to keep pace with technological advancements, the user-friendliness of new technologies can be a key factor in promoting effective learning and skill acquisition. This is supported by research in the field of educational technology and organizational learning, such as the studies by Agarwal and Prasad (1999), which highlight the influence of technology's ease of use on learning engagement and outcomes.

These results from Hypotheses H2a and H2b underscore the critical role of Perceived Ease of Use in influencing both the adoption of new technologies (IRA) and the engagement in learning and development activities (LD) in the manufacturing sector. The findings suggest that making new technologies more accessible and easier to use can have a substantial impact on their adoption and the effectiveness of related training and development programs. This has significant implications for technology designers, trainers, and organizational leaders in the manufacturing sector, highlighting the need to prioritize user-friendliness in both technology design and training programs.

5.3.3 HYPOTHESIS H3– GOVERNMENT SUPPORT (GOV)

Hypothesis H3, focusing on the impact of Government Support (GOVT) on the Innovative Work Behavior of SMEs Employees (SIWB), revealed intriguing findings. The path coefficient was relatively low at 0.063, and the T statistic of 1.529 combined with a P value of 0.063 steered to the rejection of this hypothesis. At first glance, these results suggest that government support, as perceived by employees within SMEs in the manufacturing sector, does not significantly influence their innovative work behavior.

The rejection of H3 may initially seem counterintuitive, especially considering the conventional wisdom that government initiatives and support play a crucial role in fostering innovation in the business sector. The Malaysian government support typically includes more financial incentives, policy frameworks, infrastructural support, and educational and training programs, all of which are traditionally seen as catalysts for innovation.

The justification for the rejection of the hypothesis regarding the impact of Government Support on Innovative Work Behavior (IWB) in SMEs can be better understood by analyzing the government's approach during the COVID-19 period (2020-2022). The Malaysian Federal Government's allocation of RM50 million in 2020, as detailed in the Penjana Programme Thrust 1, was primarily directed towards skill development and capacity-building programs (PMO, 2020). These initiatives were focused on Technical and Vocational Education and Training (TVET), enhancing the livelihood of the

B40 income group, and preparing Malaysia's Small and Medium Enterprises (SMEs) for the Fourth Industrial Revolution (IR4.0).

The execution of these strategies was managed by agencies such as Pertubuhan Keselamatan Sosial (PERKESO) and Human Resource Development Corporation (HRD Corp). Their programs, particularly the "Penajakerjaya" program, emphasized hiring incentives and entrepreneurial skills, targeting populations most impacted by the pandemic, including the B40 group (The Star, 2021a).

However, it is evident that the government's primary objective was to reduce the unemployment rate rather than directly encouraging innovation within SMEs. This approach, while critical in addressing the immediate economic and employment challenges posed by the pandemic, did not place a direct emphasis on fostering innovative work behavior among SME employees. The absence of innovation-centric initiatives during this period is a significant factor in understanding the rationale behind the rejection of the hypothesis. Additional economic analysis and context provided by (Syraaf, 2023) further supports this perspective.

The findings of this study illuminate a multifaceted relationship between government support and employee innovation behavior in SMEs, suggesting that while government initiatives provide necessary resources and a conducive environment for innovation, they may not directly result in innovative behavior at the employee level. This complexity can be attributed to various factors, such as the perceived relevance of government initiatives to employees' immediate work contexts, the effectiveness of communication and implementation at the grassroots level, and the cultural and organizational mediators that influence how government support is perceived and utilized by employees.

This nuanced understanding aligns with existing research indicating that the link between government support and innovation is not always linear. For instance, (Adam and Alarifi, 2021) argue that the effectiveness of government support in enhancing firm-level innovation varies significantly across different contexts and industries. Similarly (Islam et al., 2020; Pu et al., 2021) highlighted that public support's impact on firm innovation is often indirect and moderated by factors such as firm size, sector, and internal capabilities. These insights imply that for government support to effectively foster innovative behavior among SME employees, it must be closely aligned with the specific needs, cultures, and operational realities of these businesses. From a policy perspective, this suggests a need for government bodies to restructure and communicate their support mechanisms more effectively, ensuring they resonate with the end beneficiaries, namely, the employees in SMEs. This may involve collaborative approaches, where government agencies work in tandem with SMEs to co-create programs and initiatives that are directly aligned with the needs and contexts of these businesses and

their employees. Another finding on Industry 4.0 adoption in Malaysian manufacturing highlights that the current training often remains basic, focusing on digital tool usage rather than fostering a digital-first mindset. This lack of comprehensive learning and development programs risks SMEs failing to build internal capabilities necessary for effective IR4.0 adoption (Gen *et al.*, 2022). The paper stresses the importance of collaboration between firms and government to upskill current workers and prepare new entrants with the right educational foundation. Successful training programs funded by government but led by industry show promise in addressing skills gaps, which directly influence SMEs' readiness and intention to adopt IR4.0 technologies (Gen *et al.*, 2022).

For SMEs, these findings underscore the importance of actively communicating their workforce needs to the government and participating in policy development to ensure that funds are allocated effectively, focusing on developing technical skills within the workforce. It suggests that while external support is valuable, the primary drivers of innovation might lie within the organizational boundaries, including the intrinsic motivation and capabilities of employees. This approach requires a concerted effort to bridge the gap between government intentions and the practical, on-the-ground needs and realities of SMEs and their employees (Ishmukhametov *et al.*, 2022; Islam *et al.*, 2020; Marouani & Nilsson, 2016a; Pu *et al.*, 2021).

5.3.4 HYPOTHESIS H4– PERSONAL INNOVATIVENESS OF AUTOMATION (PIA)

Personal Innovativeness in Automation (PIA) within manufacturing SMEs in Malaysia is a pivotal concept, especially in the context of the rapid adoption of Industry 4.0 technologies. PIA in this realm refers to the propensity of employees to embrace and effectively utilize new automation technologies. This characteristic is crucial for the technological advancement and innovation in the manufacturing sector. In Malaysian SMEs, where there is a growing emphasis on enhancing productivity and competitiveness through automation, PIA is particularly significant. It embodies not just the capability to use new technologies but also reflects an open-mindedness and adaptability to technological changes.

High PIA among employees is essential as it can significantly influence the successful implementation of automation projects and mitigate resistance to change. In the broader economic landscape of Malaysia, which is moving towards more advanced manufacturing processes and facing stiff global competition, PIA is a key driver for innovation. It enables the workforce to not only adopt but also adapt new technologies to local business needs and challenges, thereby playing a critical role in maintaining the competitive edge of Malaysian manufacturing SMEs in the global market.

In this research focusing on the manufacturing SMEs in Malaysia, Personal Innovativeness in Automation (PIA) is central to understanding the adoption and effective use of new technologies. The study encompasses four hypotheses related to PIA, each examining different aspects of its impact. These hypotheses explore how PIA influences the Adoption Intention of IR4.0 (IRA), Learning & Development (LD), and the Innovative Work Behavior of SMEs Employees (SIWB). Specifically, Hypothesis H4a examines the direct influence of PIA on IRA, while H4b looks at its impact on LD.

Additionally, H4c and H4d investigate the indirect effects of PIA on SIWB through IRA and LD, respectively. This comprehensive approach underscores the multifaceted role of PIA in the technological and innovative dynamics within Malaysian manufacturing SMEs. It highlights not only the direct effects of personal innovation and development on technology adoption and learning but also its broader implications for fostering a culture of innovation and adaptability in the face of rapidly evolving industrial technologies.

5.3.4.1 HYPOTHESIS 4A (PIA → IRA)

Hypothesis H4a in the context of manufacturing SMEs in Malaysia investigated the influence of Personal Innovativeness in Automation (PIA) on the Adoption Intention of IR4.0 (IRA). The results from this hypothesis showed a path coefficient (β) of 0.131, accompanied by a T statistic of 2.29 and a P value of 0.011. Based on these statistical indicators, the hypothesis was accepted, suggesting a positive relationship between PIA and IRA, albeit with a moderate strength.

The acceptance of H4a points to a noteworthy but not dominant role of personal innovativeness in influencing employees' intentions to adopt Industry 4.0 technologies. The path coefficient, while indicating a significant relationship, is relatively modest. This implies that PIA is an important factor in shaping adoption intentions, but it operates within a complex array of other influences, such as organizational culture, perceived utility of the technology, and external environmental factors.

In the Malaysian manufacturing SME context, where technology adoption is crucial for maintaining competitive advantage and operational efficiency, understanding the nuances of how personal traits like innovativeness impact technology adoption decisions is vital. Employees who exhibit higher levels of personal innovativeness are more likely to be open to new technologies, experiment with them, and ultimately integrate them into their work practices. However, the moderate strength of this relationship suggests that there are additional factors at play in determining technology adoption intentions.

The significance of PIA in driving IRA is grounded in the broader literature on technology adoption and innovation management. Models such as the Technology Acceptance Model (TAM) and the Theory of Planned Behavior (TPB) have long posited that individual attitudes, experiences, and traits significantly influence the decision to accept and use new technologies. This finding corroborates those theories, highlighting the role of individual innovativeness in technological transitions. The study on UK SME's, personal innovativeness can be inferred as a factor that helps overcome these barriers by fostering awareness, willingness to experiment, and learning. SMEs with more innovative individuals are better positioned to navigate the complexity and uncertainty of IR4.0 adoption (Masood and Sonntag, 2020).

This result is particularly relevant in an era where technological advancements are rapid and often disruptive. For SMEs, which might not have the same resources as larger corporations to invest in

extensive training programs, harnessing the natural innovativeness of their employees can be a key strategy in facilitating the adoption of new technologies. It suggests that initiatives aimed at boosting PIA, such as fostering a culture of continuous learning, encouraging experimentation, and providing opportunities for employees to engage with new technologies, can have a positive impact on IRA. From a practical standpoint, this finding implies that Malaysian manufacturing SMEs might benefit from identifying and nurturing employees with high PIA, leveraging their propensity for innovation to drive technology adoption within the organization. This could involve targeted recruitment strategies, personalized professional development plans, and creating innovation-friendly work environments.

5.3.4.2 HYPOTHESIS 4B (PIA → LD)

Hypothesis H4b investigated the impact of Personal Innovativeness in Automation (PIA) on Learning & Development (LD) in the context of manufacturing SMEs in Malaysia. The statistical analysis presented a path coefficient (β) of 0.028, with a T statistic of 0.522 and a P value of 0.301. Based on these results, the hypothesis was rejected, indicating a negligible or non-significant direct relationship between PIA and LD activities. The rejection of H4b reveals an intriguing aspect of the relationship between individual innovativeness and formal learning and development initiatives. The low path coefficient suggests that personal innovativeness, as a trait, does not directly translate into increased engagement or effectiveness in structured learning and development programs. This outcome may seem counterintuitive initially, as one might expect more innovative individuals to be naturally inclined towards learning and development. However, this finding could be indicative of several underlying dynamics.

One possible explanation is that personal innovativeness might be more aligned with informal, experiential learning and on-the-job problem-solving rather than formalized training programs. Individuals with high PIA may prefer self-directed learning or learning by doing, which may not be captured within the conventional scope of LD programs. Additionally, the content and delivery of LD programs may not align well with the needs and learning styles of highly innovative individuals, thereby diminishing the apparent impact of PIA on LD. In the broader context of Malaysian manufacturing SMEs this finding has significant implications for how learning and development strategies are designed and implemented. It suggests a need for a more diverse and flexible approach to employee development, one that accommodates different learning styles and preferences, especially for those with higher levels of personal innovativeness. Personal innovativeness without sufficient organizational support and learning infrastructure may lead to trial-and-error approaches rather than systematic learning, which can increase risks and operational inefficiencies (Faiz Faiz and , Viet Le, 2024).

In light of these findings, it becomes imperative for organizations to reassess their training models,

particularly in the context of small and medium-sized enterprises (SMEs) in technology-driven sectors. Traditional, one-size-fits-all training approaches may no longer suffice, especially for employees who exhibit high levels of Personal Innovativeness in Automation (PIA). Instead, there's a growing need to embrace more dynamic, agile, and personalized forms of learning. Such methods should not only align with the innovative tendencies of certain employees but also cater to the diverse skill sets and learning preferences within the workforce. This shift is crucial in nurturing a culture of continuous learning and innovation.

Moreover, the importance of understanding employee characteristics when designing learning and development (L&D) initiatives cannot be overstated. For technology-driven SMEs, striking the right balance between structured training and flexible, innovation-friendly learning opportunities is key to leveraging their human capital effectively. This approach will enable these organizations to adapt swiftly to technological advancements and maintain a competitive edge.

The reason behind the necessity for such a strategic shift may stem from a skill mismatch prevalent in SMEs. This misalignment, particularly in the context of automation and technological adoption, is evident in the workforce's lack of initiative in acquiring new technological skills. Research conducted by (Bavaani Balakrishnan, Zakirah Othman, 2021) in 2021 highlighted a low enthusiasm for Industry 4.0 (IR4.0) adoption among Electrical and Electronics (E&E) SMEs. Additionally, a more recent study by (Shahzad et al., 2023b) focusing on SMEs registered with Malaysian Industrial Development Industry (MIDF) Berhad, pointed out that the challenge in adopting IR4.0 stems from its novelty and the inherent difficulties faced in integrating these technologies into existing operations. These studies underscore the critical gap in technology adoption and upgrade in SMEs, further emphasizing the need for L&D initiatives that are not only innovative and personalized but also focused on bridging these specific skill gaps.

The findings of (Marouani and Nilsson, 2016) shed light on the phenomenon of skill-biased technological change (SBTC) in Malaysia, attributing it to a lack of technological efficiency in the market. This concept of SBTC suggests a disparity in technological adoption and utilization, favoring those with specific skill sets. The labor market effects are evident through the shortage of skilled labor, leading to a preference for technologies that align with the available, predominantly unskilled labor force. This aligns with the argument presented by (Caselli and Coleman, 2006) who posited that countries abundant in skilled labor are more likely to adopt technologies that complement such skills, whereas countries with a predominance of unskilled labor lean towards technologies that suit their labor

profile. This phenomenon creates barriers to technology adoption and potentially hinders the efficient utilization of skilled labor.

This context is critical when examining the lack of Personal Innovativeness in Automation (PIA) and engagement in learning and development (L&D) within SMEs in Malaysia. According to Becker's theory of human capital, firms are more inclined to invest in technologies anticipating a future workforce that is skilled. However, in the Malaysian SME context, where the current skill set may be perceived as sufficient, there is a noticeable lag in the individual initiative to acquire new skills or engage in L&D. This inertia could be attributed to a belief that existing knowledge and skills are adequate for current job requirements, reducing the perceived need for further development or innovation.

The implications of this are significant for L&D strategies within Malaysian SMEs. It suggests a need for a paradigm shift in how L&D is approached, emphasizing the importance of aligning training programs with the existing skill profile while also fostering a culture that encourages continuous learning and skill upgrade. This could involve integrating more innovative and flexible L&D initiatives that not only cater to current skills but also incentivize learning in areas that are emerging as increasingly relevant in the context of technological advancements. Such a strategic shift in L&D could serve to bridge the gap between current skill sets and the evolving demands of the technological landscape, thereby enhancing the overall innovativeness and competitiveness of the workforce in Malaysian SMEs.

5.3.4.3 HYPOTHESIS 4C (PIA → IRA → SIWB)

Hypothesis H4c explored the indirect influence of Personal Innovativeness in Automation (PIA) on the Innovative Work Behavior of SMEs Employees (SIWB) through the Adoption Intention of IR4.0 (IRA). The statistical results indicated a significant relationship, with a path coefficient of 0.063, a T statistic of 2.068, and a P value of 0.02, leading to the acceptance of this hypothesis.

The acceptance of H4c suggests that the personal innovativeness of employees in the manufacturing sector in Malaysia indirectly influences their innovative work behavior, mediated by their intention to adopt Industry 4.0 technologies. The path coefficient, while not particularly high, indicates a meaningful relationship where PIA contributes to IRA, which in turn fosters SIWB. This finding is important as it highlights the cascading effect of personal traits on broader organizational outcomes.

Employees with higher PIA are more likely to show a positive intention towards adopting new technologies. This intention, fueled by an innovative mindset, translates into behaviors that are conducive to innovation at the workplace. The relationship suggests that personal innovativeness is a critical starting point that initiates a chain of reactions leading to actual innovative behavior in the

work context.

In the context of Malaysian manufacturing SMEs, where embracing IR4.0 technologies is crucial for maintaining competitiveness and innovation, this finding underscores the importance of nurturing an innovative mindset. It suggests that efforts to boost the adoption of new technologies should not solely focus on the technologies themselves but also on fostering the personal innovativeness of employees.

The result implies that management strategies and organizational policies should support an environment that encourages experimentation, risk-taking, and proactive engagement with new technologies. This environment can be cultivated through various means, such as offering opportunities for self-directed learning, encouraging participation in innovation-related activities, or creating platforms for sharing ideas

and experimentation. Moreover, this finding aligns with the broader literature on innovation management, which emphasizes the role of individual attributes in organizational innovation processes. It corroborates the idea that fostering a culture of innovation starts with the individual, whose personal traits and attitudes can significantly influence the overall innovative capacity of the organization.

5.3.4.4 HYPOTHESIS 4D (PIA → LD → SIWB)

Hypothesis H4d focused on exploring the indirect effect of Personal Innovativeness in Automation (PIA) on the Innovative Work Behavior of SMEs Employees (SIWB) through Learning & Development (LD). The statistical analysis showed a path coefficient (β) of 0.007, with a T statistic of 0.494 and a P value of

0.311. Based on these results, the hypothesis was rejected, indicating that the indirect relationship through LD is not significant in this context. The rejection of H4d suggests that while personal innovativeness might influence an individual's approach to learning and development, this does not necessarily translate into innovative work behavior. The low path coefficient and high P value indicate a very weak or nonexistent link between these constructs in the specific context of Malaysian manufacturing SMEs. This could imply several underlying dynamics at play.

A possible explanation is that the design and setup of Learning and Development programs may not be fully effective in turning personal creativity into actual innovations at work. Even though employees with a high PIA might participate in these training activities, the programs may not be well-suited to encourage innovative behaviors in their day-to-day job tasks. This issue could also stem from small and medium-sized enterprises (SMEs) facing challenges like insufficient technology infrastructure, a tendency to avoid risks, and resource shortages, which include financial limitations and limited access to the latest technologies.

Additionally, this finding could reflect a broader issue in how learning and development are perceived and utilized within the organizational culture. If LD initiatives are not closely integrated with real-world applications and opportunities for innovative expression, even the most innovative employees may not translate their learning experiences into innovative work behaviors.

This result has significant implications for how learning and development initiatives are designed and implemented in the manufacturing sector. It highlights the need for a more strategic alignment between LD programs and innovation goals within organizations. For effective translation of personal innovativeness into workplace innovation, LD initiatives should not only focus on skill enhancement but also foster a mindset of creativity, experimentation, and application of skills learned in novel ways.

Moreover, the finding suggests that Malaysian manufacturing SMEs might need to rethink their approach to employee development. It points towards the necessity of creating learning environments that are more dynamic, encourage experimentation, and are directly linked to innovative outcomes. This could involve incorporating project-based learning, real-world problem-solving scenarios, and opportunities for employees to experiment with new ideas and technologies within a supportive framework.

The rejection of Hypothesis H4d in this study underscores the complexity of the relationship between personal innovativeness, formal learning and development activities, and innovative work behavior. It challenges the assumption that personal innovativeness via LD programs will automatically lead to increased innovation in work behaviors. For Malaysian manufacturing SMEs, understanding this concept is key to creating comprehensive and cohesive strategies that promote innovation. These strategies should focus not only on improving individual skills and characteristics but also on transforming the strategic objectives or business models of the SMEs. If there's no clear link to the organization's goals, turning these personal qualities into concrete, innovative results at work may prove challenging.

5.3.5 HYPOTHESIS 5 – LEARNING & DEVELOPMENT (LD)

In the dynamic landscape of the manufacturing sector, particularly within Small and Medium-sized Enterprises (SMEs) in Malaysia, the role of Learning and Development (LD) assumes a pivotal position. As these enterprises navigate the challenges and opportunities presented by Industry 4.0, LD emerges not just as a tool for skill enhancement, but as a strategic asset crucial for organizational growth and innovation. The integration of advanced technologies, evolving market demands, and the constant need for competitive differentiation have placed LD at the heart of organizational

transformation efforts. The advent of Industry 4.0 has revolutionized manufacturing processes, introducing a range of new technologies such as the Internet of Things (IoT), artificial intelligence (AI), robotics, and big data analytics. Adapting to these technological changes requires a workforce that is not only technically proficient but also adaptable and continually evolving. LD plays a critical role in this context by providing employees with the necessary training and development opportunities to acquire and update their skills. It is through effective LD initiatives that SMEs can ensure their workforce remains relevant and capable of leveraging new technologies.

Aligning LD initiatives with the requirements of Industry 4.0 is crucial. This involves not just imparting technical knowledge but also developing skills like adaptability, digital literacy, and innovative thinking. Emphasizing these areas in LD programs ensures that employees are not only able to operate new technologies but can also play an active role in the organization's digital transformation journey.

Empowering the workforce through effective LD means moving beyond traditional training methods. It involves embracing new learning modalities like e-learning, virtual simulations, and blended learning approaches that provide flexibility and cater to diverse learning preferences. It also means fostering a learning culture where continuous improvement, experimentation, and knowledge sharing are valued and encouraged.

In the context of this research, the exploration of Learning and Development within Malaysian manufacturing SMEs is not just an academic exercise, but a critical investigation into the factors that drive technological adaptation and innovation in the workplace. Specifically, hypotheses such as H5a and H5b delve into the direct impacts of LD on both the Adoption Intention of IR4.0 (IRA) and the Innovative Work Behavior of SMEs Employees (SIWB). These hypotheses aim to empirically establish the connections between a well-developed LD framework and key organizational outcomes in the era of Industry 4.0. By examining these hypotheses, the research seeks to uncover the extent to which LD initiatives can influence employees' willingness to embrace new technologies and engage in innovative behaviors, thereby providing valuable insights for both academic understanding and practical application in the dynamic sector of manufacturing SMEs in Malaysia.

5.3.5.1 HYPOTHESIS 5A (LD → IRA):

This hypothesis posited that Learning & Development (LD) positively influences the Adoption Intention of IR4.0 (IRA) within manufacturing SMEs in Malaysia. The statistical analysis revealed a path coefficient (β) of 0.235, accompanied by a T statistic of 2.371 and a P value of 0.009, leading to the acceptance of this hypothesis. These results indicate a significant and positive relationship, suggesting that learning and development initiatives substantially contribute to the intention to adopt

Industry 4.0 technologies.

The acceptance of H5a suggests that when employees engage in learning and development activities, particularly those geared towards new technologies, their likelihood to adopt these technologies increases. The relatively strong beta value signifies that LD is a key factor influencing IRA, though not the only one. This aligns with the broader understanding of adult learning theories and organizational behavior, where development opportunities are seen as critical in equipping employees with the necessary skills and confidence to embrace new technologies.

In the context of Malaysian manufacturing SMEs, this finding is particularly relevant. As these businesses face increasing pressure to modernize and integrate advanced technologies to remain competitive, the role of LD becomes pivotal. Effective LD programs not only impart necessary technical skills but also help in reducing apprehensions towards new technologies, thereby fostering a culture of innovation and openness to change. Organizational readiness is often built through learning and development efforts that enhance employees' skills and the firm's absorptive capacity for new technology. This underscores that learning and development, by improving readiness and competencies, play a crucial role in shaping SMEs' intention to adopt IR4.0 (Shahzad *et al.*, 2023).

The significance of this relationship is further underscored by the rapid technological evolution characterizing Industry 4.0. As technologies continue to advance at an unprecedented rate, continuous learning and development become essential for keeping pace with these changes. Moreover, LD initiatives can play a crucial role in bridging skill gaps that may hinder the adoption of new technologies, thereby facilitating a smoother transition into more automated, digitalized production processes.

For practitioners and policymakers within the Malaysian manufacturing sector, these findings highlight the need to invest in robust learning and development frameworks. Such investment should not only focus on the technical aspects of new technologies but also address the softer skills required to adapt to and leverage these technologies effectively. Additionally, these results suggest that LD programs should be designed in a way that they directly correlate with the specific technological needs of the industry, thereby making the learning experience more relevant and impactful for the employees.

This positive correlation between LD and IRA resonates with the global trend of upskilling workforces to meet the demands of the Fourth Industrial Revolution. As more countries and sectors acknowledge the critical role of human capital in driving technological advancement, the emphasis on continuous, targeted, and effective learning and development becomes increasingly paramount.

5.3.5.2 HYPOTHESIS 5B (LD → SIWB)

Hypothesis H5b examined the relationship between Learning & Development (LD) and the Innovative Work Behavior of SMEs Employees (SIWB) in the manufacturing sector of Malaysia. The statistical outcome for this hypothesis was compelling: a path coefficient (β) of 0.256, with a T statistic of 3.25 and a P value of 0.001, clearly leading to its acceptance. These figures indicate a strong and positive influence of LD activities on the innovative behavior of employees.

The strong beta value in H5b underscores the significant role that learning and development initiatives play in fostering innovative behaviors among employees. This result suggests that when employees are engaged in effective LD programs, they are not only better equipped with the necessary skills but are also more likely to exhibit innovative behaviors in the workplace. The same effect was shown among the teachers in Malaysia on IWB (Johari, Abdul Wahat and Zaremohzzabieh, 2021). The connection between LD and SIWB can be attributed to several factors. Firstly, well-designed LD programs can enhance employees' skills and knowledge, which are essential for innovation. Secondly, such programs often encourage critical thinking and problem-solving, which are crucial for innovative behavior.

In the context of Malaysian manufacturing SMEs, where innovation is key to maintaining competitiveness in a rapidly evolving industrial landscape, the impact of LD on innovative work behavior is particularly important. This finding indicates that investments in LD are not just cost centers but strategic tools that can drive innovation within the organization. The specific nature of the manufacturing sector, often characterized by complex processes and the need for continual adaptation to new technologies and market demands, makes the role of LD even more vital. The acceptance of H5b is consistent with the broader research in organizational behavior and human resource development, which has long emphasized the importance of continuous learning and development in fostering a culture of innovation. It aligns with the perspective that organizations which invest in developing their human capital are more likely to see a higher rate of innovative output. For Malaysian manufacturing SMEs, this implies that creating a learning-oriented organizational culture is a key factor in enhancing their innovative capacities.

Furthermore, the result of H5b has significant implications for policy and decision-makers in the manufacturing sector. It calls for a reevaluation of how learning and development activities are structured and delivered. There is a need for LD programs that are not only focused on skill enhancement but are also designed to encourage and support innovative thinking and behaviors. This involves integrating creativity and innovation into the curriculum of training programs and creating an organizational environment that supports and rewards innovative behaviors.

5.3.6 HYPOTHESIS H6 (IRA → SIWB):

Hypothesis H6 examined the direct influence of the Adoption Intention of IR4.0 (IRA) on the Innovative Work Behavior of SMEs Employees (SIWB) in the manufacturing sector of Malaysia. The statistical results for this hypothesis showed a strong relationship, with a path coefficient (β) of 0.486, a T statistic of 6.681, and a P value of 0.000. This led to the clear acceptance of the hypothesis, indicating a significant and positive impact of IRA on SIWB. The acceptance of H6 with a high beta value points to a robust relationship between the intention to adopt Industry 4.0 technologies and the manifestation of innovative work behaviors among employees. This significant relationship suggests that when employees in manufacturing SMEs intend to adopt new technologies, they are also more likely to engage in behaviors that are innovative, such as exploring new ways of working, problem-solving, and contributing creative ideas.

This finding aligns well with the broader literature on innovation and technology adoption, which often highlights the link between an individual's or group's intention to use new technologies and their innovative capacity (Shah, Shah and El-Gohary, 2022). The intention to adopt new technologies can be seen as a precursor to innovation, as it often involves openness to change, a willingness to experiment, and an eagerness to explore new possibilities, all of which are key ingredients for innovative behavior.

In the context of Malaysian manufacturing SMEs, where technological advancements are increasingly critical for competitiveness and growth, the strong influence of IRA on SIWB is particularly relevant. It underscores the importance of fostering a positive attitude towards the adoption of new technologies, as this can directly translate into more innovative practices within the organization. The result of H6 has substantial implications for how manufacturing SMEs approach the integration of Industry 4.0 technologies. It suggests that efforts to promote the adoption of these technologies should go hand in hand with strategies aimed at stimulating innovative behaviors. This could involve not just training and development focused on the technical aspects of new technologies but also initiatives that encourage creative thinking, risk-taking, and experimentation.

Moreover, the strong linkage between IRA and SIWB indicates that managerial strategies and organizational policies should focus on creating an environment that not only supports technological adoption but also actively encourages and rewards innovative behavior. This could be achieved through various means such as innovation-focused leadership, a culture that celebrates creativity, and systems that recognize and incentivize innovative contributions. In summary, the acceptance of Hypothesis H6 in this study highlights a critical pathway in the innovation process within Malaysian manufacturing SMEs. It shows that fostering an intention to adopt new technologies is not just about technological upgradation; it's also a catalyst for driving broader innovative behaviors within the

organization. For these SMEs, understanding and leveraging this connection could be key to achieving sustained innovation and maintaining a competitive edge in an increasingly technology-driven industry.

5.4 RESEARCH CONTRIBUTION

This research provides an in-depth exploration of the multifaceted factors influencing the adoption of Industry 4.0 technologies and the cultivation of innovative behaviors within manufacturing SMEs in Malaysia. By examining variables like Perceived Usefulness, Perceived Ease of Use, Government Support, Personal Innovativeness in Automation, and Learning & Development, the study offers a holistic view of the technological adoption process. It uncovers how these factors individually and interactively affect employees' intentions to adopt new technologies and engage in innovative work practices. This comprehensive approach addresses a significant gap in existing literature, as it moves beyond simplistic models to understand the complex interplay of multiple influences, thus providing a more nuanced and detailed understanding of the dynamics at play in technology adoption and innovation within the manufacturing sector. This research provides the research contribution through theoretical and practical context.

5.4.1 THEORETICAL CONTRIBUTIONS

5.4.1.1 EXPANSION OF TECHNOLOGY ACCEPTANCE MODELS:

The research makes a significant theoretical contribution by expanding the Technology Acceptance Model (TAM) within the context of Industry 4.0, particularly for manufacturing SMEs. Traditional TAM frameworks have primarily focused on the role of Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) in influencing users' attitudes and behavioral intentions toward technology. This research enriches this model by empirically testing and validating these constructs in the specific setting of Industry 4.0 adoption in particularly manufacturing SMEs. By establishing the connection between PU, PEOU, and the Adoption Intention of IR4.0 (IRA), as evidenced by the acceptance of hypotheses H1a and H2a, the study not only reaffirms the foundational principles of TAM but also contextualizes them within a modern industrial setting. This extension is crucial as it demonstrates the applicability of TAM in understanding the nuances of technology acceptance in an era characterized by rapid technological advancements. The research thus bridges a critical gap, offering a more comprehensive understanding of technology adoption dynamics within the manufacturing sector and adding depth to the existing body of TAM literature.

5.4.1.2 INSIGHTS INTO PERSONAL INNOVATIVENESS IN AUTOMATION (PIA):

The concept of Personal Innovativeness in Automation (PIA) receives a substantial theoretical enhancement through this research. PIA, as a construct, captures an individual's tendency to embrace

and utilize new technologies. The study's exploration of PIA, particularly through hypotheses H4a and H4c, sheds light on its direct and indirect impacts on technology adoption and innovative behavior in manufacturing SMEs. By demonstrating the influence of PIA on the Adoption Intention of IR4.0 (IRA) and its subsequent effect on Innovative Work Behavior of SMEs Employees (SIWB), the research contributes to a deeper understanding of how individual attributes affect organizational outcomes in the context of technological change. This provides a nuanced perspective on the role of personal traits in innovation and technology acceptance, extending beyond the traditional focus on external factors and organizational contexts. The findings enrich the theoretical discourse on individual differences in technology adoption, offering new insights into how personal innovativeness shapes technological and innovative dynamics within organizations.

5.4.1.3 UNDERSTANDING THE ROLE OF LEARNING & DEVELOPMENT (LD):

This research significantly contributes to the theoretical understanding of Learning & Development (LD) in organizational settings, especially in the context of technological transitions. By examining the impact of LD on both technology adoption (H5a) and innovative work behavior (H5b), the study underscores the strategic role of LD in organizational adaptation and innovation. This goes beyond the traditional view of LD as merely a tool for skill enhancement. The findings highlight LD as a critical driver of a culture conducive to innovation and technology adoption, aligning with and enriching theories in organizational learning and development. This perspective is particularly valuable in understanding how organizations can leverage LD to facilitate the adoption of new technologies and foster innovation, thereby providing a more integrated view of LD's role in organizational change.

5.4.1.4 NEW PERSPECTIVES ON GOVERNMENT SUPPORT IN INNOVATION:

The research challenges prevailing assumptions in the literature about the role of government support in driving organizational innovation, particularly within the context of SMEs. The rejection of hypothesis H3, which posited a positive influence of Government Support (GOVT) on the Innovative Work Behavior of SMEs Employees (SIWB), offers a new perspective on this relationship. It suggests that the impact of government initiatives on organizational innovation is more complex and less direct than traditionally assumed. This contributes to a critical reevaluation of the relationship between public policy and innovation, adding a new dimension to the discourse. It emphasizes the need for a more nuanced understanding of how government support interacts with other organizational and individual factors to influence innovation, thereby enriching the theoretical dialogue on public policy's role in fostering innovation within the business sector.

5.4.1.5 INTEGRATIVE APPROACH TO TECHNOLOGY ADOPTION AND INNOVATION:

The study adopts an integrative approach by considering multiple factors and their interrelations in the process of technology adoption and innovation in SMEs. This comprehensive framework captures the

complexity of these processes, contributing significantly to theoretical models in information systems, organizational behavior, and innovation management. By examining how different factors such as PU, PEOU, PIA, and LD interact to influence IRA and SIWB, the research provides a holistic view of technology adoption and innovation processes. This integrative perspective fills a crucial gap in existing literature, offering a more detailed and interconnected understanding of the factors that drive technology adoption and innovative behaviors in organizations, particularly within the manufacturing sector.

5.4.1.6 REVISITING ORGANIZATIONAL CHANGE AND INNOVATION THEORIES:

The research makes an important theoretical contribution to the fields of organizational change and innovation work behavior (IWB). By contextualizing these theories within the rapidly evolving landscape of Industry 4.0 in predominantly manufacturing SMEs, the study offers fresh insights into managing and facilitating change, particularly in adopting new technologies and fostering innovative work cultures. The findings contribute to a deeper theoretical understanding of change management and employees innovation behavior in the context of technological advancements, offering new perspectives on how organizations can navigate and manage the challenges and opportunities presented by digital transformation.

5.4.1.7 INTEGRATION WITH EXISTING THEORETICAL MODELS

This study builds directly on the Technology Acceptance Model (TAM) developed by Davis (1989), which posits that Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) are key antecedents of Behavioral Intention to use technology. The findings of this research support the validity of TAM in the context of Malaysian manufacturing SMEs adopting Industry 4.0 (IR4.0) technologies. PU and PEOU were found to significantly influence the Adoption Intention of IR4.0 (IRA), aligning with previous work by Venkatesh and Davis (2000), who extended TAM by incorporating variables such as job relevance and output quality. The significant path coefficients for both PU ($\beta = 0.131$ and $\beta = 0.231$ respectively) reinforce the robustness of TAM's core propositions even when applied in developing economy contexts where digital maturity remains uneven. Moreover, this research contributes to a nuanced understanding of TAM by incorporating Learning and Development (LD) and Personal Innovativeness in Automation (PIA), factors typically outside TAM's traditional structure. The inclusion and partial significance of PIA reflects an alignment with the Unified Theory of Acceptance and Use of Technology (UTAUT) and Diffusion of Innovations (DoI) theory (Rogers, 1995), where individual predispositions and innovation characteristics are deemed vital in adoption behaviorchap2. The observed indirect impact of PIA on Innovative Work Behavior (SIWB) through IRA suggests that TAM can be effectively expanded by integrating psychological traits, as also proposed in contemporary extensions like TAM3 and TOE-TAM frameworks (Gresham, 2020;

Chatterjee et al., 2021).

By demonstrating that LD significantly influences both IRA and SIWB, this study also intersects with organizational learning theory (Nonaka, 2009; Ferreira et al., 2015), where continuous skill development and knowledge transfer are pivotal to sustaining innovation. The importance of LD in supporting behavioral intention and innovative outcomes emphasizes that effective adoption of digital technologies in SMEs is not only a matter of usability but also of capacity-building and organizational readiness, a finding consistent with earlier works by Tam & Gray (2016) and Khalil et al. (2011). Importantly, the study also challenges the simplistic assumption that external support mechanisms, such as Government Support (GOVT), are sufficient to trigger innovation. The rejection of the hypothesis linking GOVT directly to SIWB (H3) aligns with literature that cautions against over-reliance on institutional support without internal absorptive capacity (Adam & Alarifi, 2021; Pu et al., 2021). These findings highlight a gap between macro-level policy support and micro-level innovation behavior in SMEs, particularly when top-down interventions lack alignment with firm-specific needs or are not perceived as immediately relevant by employees.

5.4.1.8 CONTRIBUTION TO CONTEXTUAL THEORY BUILDING IN SME INNOVATION

A significant theoretical contribution of this study lies in its context-specific expansion of innovation and technology adoption frameworks for SMEs operating in emerging economies, especially in the post-pandemic digital recovery phase. While TAM, UTAUT, and DoI are widely validated in developed markets, their generalizability to under-resourced, skill-constrained environments has often been questioned (Na & Kang, 2019; Shahzad et al., 2023). This study addresses this gap by empirically testing these constructs in the Malaysian manufacturing SME sector, where readiness levels, innovation intensity, and workforce digital literacy are often lower than in larger enterprises or more advanced economies. The rejection of H4b and H4d (PIA's influence on LD and its mediated effect on SIWB via LD) suggests that personal innovativeness alone is insufficient to drive upskilling or innovation unless supported by structured learning mechanisms and organizational scaffolding. This insight advances theoretical models by asserting the criticality of organizational intermediaries (like LD) in converting individual intent into innovative action, a concept not fully captured in classical TAM or DoI models but hinted at in learning-centric frameworks such as those by Therin (2003) and Tam & Gray (2021).

In addition, the study enriches understanding of behavioral innovation in SMEs by demonstrating how the presence of perceived ease and usefulness of digital skills contributes not just to adoption, but to broader innovative work behavior. Unlike conventional studies that isolate IWB as an outcome of

HRM practices or leadership styles (Alnajjar & Hashim, 2020; Helmy et al., 2023), this study places IWB within a technological adoption continuum, influenced by learning processes and psychological traits. This perspective provides a novel bridge between behavioral innovation theories and digital transformation literature, allowing for more holistic SME innovation models tailored to resource-constrained settings. Finally, this research reaffirms that bottom-up innovation, driven by employee-level perception, readiness, and self-initiated behavior, is indispensable in SMEs facing fast-evolving technological pressures. While top-down factors like policy and funding remain useful, the study confirms that internal behavioral and perceptual variables are more predictive of actual innovative output, supporting earlier theoretical claims by Ferreira et al. (2015) and Luksyte et al. (2018) on the primacy of knowledge workers in digital transformation success.

5.4.2 PRACTICAL CONTRIBUTION

5.4.2.1 GUIDING TECHNOLOGY ADOPTION STRATEGIES

In the context of manufacturing SMEs in Malaysia, the concepts of Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) are pivotal, especially when considering the usefulness and convenience of technical skills associated with Industry 4.0 technologies. The research offers strategic insights into technology adoption that are invaluable for manufacturing SMEs in Malaysia. The emphasis on factors like Perceived Usefulness (PU), Perceived Ease of Use (PEOU) and Personal Innovativeness in Automation (PIA) provides a nuanced understanding of what drives employees to embrace new technologies. For SMEs, this means developing technology integration strategies that go beyond the technical aspects of new systems to address how these technologies are perceived by the workforce. It suggests a need for comprehensive communication strategies that highlight the practical benefits and ease of use of new technologies. Additionally, the findings can guide SMEs in importance of employees' innovation behavior and perception in selecting or designing technology solutions that are user-friendly and directly address the needs of their employees. This approach not only ensures a smoother integration of new technologies but also enhances the likelihood of these technologies being effectively utilized, thereby maximizing the investment in technological resources.

5.4.2.2 ROADMAP FOR INDUSTRY 4.0 IMPLEMENTATION

To operationalize these insights, Malaysian SMEs should adopt a phased and context-sensitive roadmap for Industry 4.0 implementation. This journey can begin with a digital readiness assessment to evaluate existing technological capabilities, infrastructure, and workforce skills. Following this, SMEs should prioritize targeted workforce development, focusing on practical upskilling in automation, data analytics, and system integration through short courses, vocational partnerships, and hands-on training. Instead of attempting broad digital overhauls, businesses are encouraged to implement fit-for-purpose technologies that directly address specific pain points, such as using IoT for inventory tracking or automating repetitive

manufacturing tasks. Leveraging available government support, such as digitalization grants and automation subsidies, is also essential, and SMEs should appoint internal leads to manage these opportunities. In regions with limited infrastructure, collaboration between SMEs, through shared digital platforms, joint procurement, or innovation clusters, can help reduce costs and enhance adoption. Finally, a strong focus on change management is required: leadership must foster a culture that supports innovation by communicating clear goals, rewarding early adopters, and encouraging experimentation. These practical steps provide a structured foundation for SMEs to navigate the transition into Industry 4.0 in a strategic, employee-centered, and sustainable manner.

5.4.2.3 ENHANCING LEARNING & DEVELOPMENT PROGRAMS

The study's findings on Learning & Development (LD) are critical for SMEs aiming to foster a workforce capable of navigating the challenges of Industry 4.0. It highlights the necessity of LD programs that are not just focused on imparting technical skills but are also aligned with fostering innovation. This involves developing training initiatives that encourage creative problem-solving, adaptability, and the application of skills in innovative ways. For SMEs, this means investing in training programs that are closely aligned with the organization's technological and innovative goals. It also suggests the importance of continuous learning opportunities that allow employees to stay abreast of the latest technological trends and apply their learning in real-world scenarios. By doing so, SMEs can ensure that their workforce is not only technically proficient but also primed to contribute to the company's innovative endeavors.

5.4.2.4 FOSTERING PERSONAL INNOVATIVENESS IN WORKFORCE

The research underscores the significance of Personal Innovativeness in Automation (PIA) within the workforce, particularly in the context of adopting new technologies. With limited resources, SMEs rely heavily on their employees to drive innovation, underlining the need to understand the key factors that stimulate employee innovativeness (Maden Eyiusta & Esen, 2025). For SMEs, this translates into the need to create an organizational environment that nurtures and values innovativeness. This could involve implementing policies and practices that encourage risk-taking, experimentation, and proactive engagement with new technologies. SMEs could focus on identifying and nurturing innovators within their teams, providing them with the resources and autonomy to explore new ideas. SMEs can foster personal innovativeness by cultivating an organizational culture that values and supports innovation. This includes empowering leadership, rewarding creative efforts, encouraging continuous learning, and ensuring psychological safety. Such an environment not only motivates employees to embrace new technologies but also enhances the organization's overall innovative capacity.

5.4.2.5 REEVALUATING THE ROLE OF GOVERNMENT SUPPORT

The rejection of the hypothesis regarding the impact of Government Support (GOVT) on Innovative Work Behavior (SIWB) challenges SMEs to reevaluate the role of external aid in driving innovation. This finding suggests that while government initiatives can provide valuable resources, the key to sustainable innovation lies within the organization's internal capabilities and culture. For SMEs, this means focusing on building a robust internal ecosystem that supports innovation, rather than relying solely on external support. It also indicates a need for closer collaboration between government bodies and SMEs to ensure that support programs are effectively aligned with the specific needs and challenges of these businesses. This could lead to more targeted and impactful government policies and initiatives that truly cater to fostering innovation within the SME sector.

5.4.2.6 INFLUENCING POLICY AND DECISION-MAKING

The insights garnered from this study have significant implications for policy-making, particularly in the context of supporting SMEs' technological and innovative growth. Policymakers can leverage these findings to develop more nuanced and effective strategies that cater to the unique needs of SMEs in their digital transformation journey. Government agencies such as SME Corp Malaysia, MDEC, and MITI should transition from broad, one-size-fits-all programs to customized innovation schemes that reflect the unique needs of different industries and business maturity levels. Reduce overreliance on grants and subsidies; instead, create **mentorship ecosystems** by connecting SMEs with industry leaders, universities, and innovation hubs (e.g. SIRIM, MRANTI). Improve coordination between agencies (e.g., HRD Corp, SME Corp, MIDA, and MOSTI) to strengthen Institutional Coordination to align around a common **national innovation strategy** for SMEs. The study highlights the need for policies that go beyond financial incentives and infrastructural support to include initiatives that build capacity, foster a culture of innovation, and ensure that SMEs have the necessary tools and knowledge to effectively implement and benefit from new technologies.

5.4.2.7 DEVELOPMENT OF CUSTOMIZED AND FLEXIBLE LEARNING MODULES

To enhance the effectiveness of Learning and Development (L&D) initiatives within Malaysian manufacturing SMEs, it is crucial to design programs that are both customized and flexible, tailored specifically to meet the diverse needs and innovation profiles of the workforce. This approach should prioritize modular courses, on-demand learning resources, and hands-on projects that simulate real-world challenges, particularly in automation and technological applications. Such customization facilitates a deeper engagement by catering to individual learning styles and innovation inclinations, especially for employees demonstrating high Personal Innovativeness in Automation (PIA). By adopting a learner-centric design, these programs not only support the development of relevant skills

but also encourage a culture of continuous learning and adaptation to technological advancements, thereby addressing the critical skill mismatches prevalent in the sector.

5.4.2.8 STRATEGIC INTEGRATION OF L&D WITH TECHNOLOGICAL TRENDS AND BUSINESS GOALS

Aligning L&D initiatives with the strategic objectives of the organization and the latest technological trends is another pivotal contribution. This strategic integration necessitates a dynamic approach to skill development, where L&D activities are continuously updated to reflect emerging technologies and market demands. Conducting regular skills gap analyses to identify and address current and future learning needs is fundamental to this process. Such alignment ensures that the workforce remains at the forefront of technological advancements, enabling SMEs to navigate the complexities of skill-biased technological change effectively. Moreover, by embedding L&D within the strategic framework, organizations can foster a proactive culture of innovation and skill acquisition, crucial for sustaining competitiveness and driving growth in an increasingly digital economy.

5.4.2.9 IMPLEMENTATION OF INCENTIVE MECHANISMS FOR ENHANCING LEARNING MOTIVATION

The introduction of incentive mechanisms to motivate employees towards continuous learning and innovation represents a significant step forward in enhancing the efficacy of L&D programs. These mechanisms could range from recognition and awards for innovative contributions to career advancement opportunities and financial rewards linked to the successful completion of training milestones or the implementation of innovative solutions. Such incentives not only underscore the value placed on continuous professional development and innovation by the organization but also directly address the inertia often associated with the acquisition of new skills, particularly in the context of automation and technological upgrades. By embedding these incentives into the fabric of L&D strategies, SMEs can cultivate an organizational culture that prioritizes and rewards learning and innovation, thereby enhancing the overall dynamism and responsiveness of their workforce to technological shifts.

5.4.2.10 ENHANCING EMPLOYEE ENGAGEMENT AND MOTIVATION

The findings of this research provide SMEs with insights on how to enhance employee engagement and motivation, particularly in the context of technological changes and innovation. Understanding the factors that drive technology adoption and innovative behavior helps SMEs tailor their internal strategies to better meet the needs and expectations of their employees. By aligning technological initiatives with employees' personal and professional growth aspirations, organizations can foster a more engaged and motivated workforce. This can involve recognizing and rewarding innovative ideas,

creating a supportive environment for experimenting with new technologies, and ensuring that employees feel valued and integral to the company's technological journey.

5.4.2.11 PREPARING FOR FUTURE TECHNOLOGICAL SHIFTS

The study offers essential insights for Small and Medium-sized Enterprises (SMEs) aiming to navigate the complexities of future technological shifts. A common challenge for many SME owners lies in their limited understanding of how to transition their operations towards automation. Leveraging the technical skills and knowledge of their employees, including their perceived usefulness (PU), perceived ease of use (PEOU), and Personal Innovativeness in Automation (PIA), could mitigate concerns related to the potential risks, uncertainties, and disruptions of implementing new technologies.

Through a thorough analysis of the factors that influence technology adoption and innovation, the study provides SMEs with a framework to anticipate and prepare for changes in the technological environment. SME needs to examine into the human resources management practices in the organization where policy should encourage employees' innovative behaviors in SMEs through a supportive organizational climate for innovation. Adopting a proactive stance towards technology adoption is indispensable for maintaining a competitive edge in an ever-changing marketplace. By harnessing these insights, SMEs can formulate forward-thinking strategies that cater to immediate technological needs while simultaneously building the capacity and resilience required to embrace future advancements. This strategic foresight is vital for SMEs to ensure long-term sustainability and success in a digital and technologically advanced business landscape.

5.4.2.12 IMPROVING COMPETITIVE ADVANTAGE

In a market increasingly defined by technological capabilities, the insights from this research empower SMEs to enhance their competitive advantage. Understanding the nuances of technology adoption and innovation enables SMEs to optimize their operations, refine their products and services, and position themselves more strategically in the market. This could translate into improved efficiency, better customer experiences, and the ability to innovate continually. By effectively applying the findings of this research, SMEs can differentiate themselves, offering unique value propositions that stem from advanced technological capabilities and innovative approaches.

5.4.2.13 CONTEXTUALIZING INNOVATION WITHIN THE MALAYSIAN SME ENVIRONMENT

While the findings of this study are grounded in widely accepted theoretical models, their interpretation must be contextualized within Malaysia's unique socio-economic and policy environment. Malaysian SMEs face uneven levels of digital readiness, with firms in urban centers like Selangor and Kuala Lumpur advancing faster than those in less industrialized states such as Sabah or Kelantan. This regional

disparity impacts not only the pace of Industry 4.0 adoption but also the accessibility of workforce training and government incentives. Government programs such as Industry4WRD and TVET have laid important groundwork, but challenges in awareness, execution, and alignment with SME needs persist. Moreover, the cultural emphasis on job stability and hierarchy in many Malaysian firms may moderate employees' willingness to experiment with new technologies or take initiative, thereby influencing the strength of Innovative Work Behavior. These local realities underscore that while constructs like perceived usefulness and ease of use are influential, their outcomes are filtered through Malaysia's institutional, economic, and socio-cultural layers. Understanding this interplay is crucial for interpreting the true drivers and barriers to innovation among SMEs in the Malaysian context.

5.4.2.14 SECTORAL DIFFERENCES IN INNOVATION ADOPTION AND WORK BEHAVIOR

The Malaysian manufacturing sector is composed of highly diverse sub-sectors, each with unique operational models, resource availability, and technological demands. For instance, electronics and high-tech manufacturing SMEs tend to be more exposed to global supply chain expectations and therefore show higher urgency in adopting automation, data analytics, and robotics. These firms are typically innovation-driven and more aligned with Industry 4.0 readiness frameworks. In contrast, traditional sectors such as food processing, furniture, and metalworking often face capital constraints, lower digital literacy, and more conservative operational cultures, which can moderate both technology adoption and the emergence of Innovative Work Behavior (IWB). Additionally, compliance-driven industries like pharmaceuticals or automotive parts manufacturing may prioritize precision and documentation, influencing how innovation is structured and rewarded. These distinctions highlight that a one-size-fits-all approach to digital transformation and innovation strategies is insufficient. Policymakers and SME leaders must adapt their interventions to the sector-specific realities of their operations, ensuring that innovation support is aligned with the context, culture, and capabilities of each sub-sector.

5.4.2.15 BRIDGING THE GAP BETWEEN RESEARCH AND PRACTICE

Lastly, this research bridges the gap between academic research and practical application in the field of technology adoption and innovation. It provides a grounded, evidence-based framework that SMEs can apply in their technology and innovation strategies. This bridging is crucial, as it ensures that academic findings are not just theoretical but are also applicable and beneficial in real-world settings. The study, therefore, serves as a valuable resource for SMEs looking for research-backed strategies to navigate the complexities of Industry 4.0 and foster a culture of innovation within their organizations.

5.5 CONCLUSION

The research undertaken within the milieu of Malaysian SMEs, with a focus on manufacturing

industry integration of Industry 4.0 technologies and the promotion of innovative work behaviors, culminates in a series of significant findings and implications that extend the boundaries of current understanding in this field. Central to this investigation was the evaluation of various hypotheses surrounding critical factors such as Perceived Usefulness (PU), Perceived Ease of Use (PEOU), Government Support (GOVT), Personal Innovativeness in Automation (PIA), and the efficacy of Learning & Development (LD) initiatives. The R Square values derived from this study, particularly concerning the Adoption Intention of IR4.0 (IRA), Learning & Development (LD) efficacy, and the innovative work behavior among SME employees (SIWB), were illuminative. These metrics showcased notable variations in IRA, LD, and SIWB, as accounted for by the proposed model, underscoring the theoretical rigor and applicability of the framework adopted in this research.

A pivotal revelation of this study was the pronounced influence of Learning & Development (LD) strategies on both the inclination towards adopting IR4.0 technologies and the manifestation of innovative work behaviors within the organizational context. This finding accentuates the indispensable role of sophisticated L&D frameworks in not only facilitating the assimilation of emerging technologies but also in fostering an organizational ethos of innovation. The research distinguished itself through its holistic examination of the confluence of factors that drive technology adoption and innovation within SMEs. By amalgamating insights from technology acceptance models with variables like personal innovativeness and the scope of learning and development, the study carved out a nuanced understanding of the intricacies that govern technological adaptation and innovation processes within the SME sector. This comprehensive analytical approach represents a substantial contribution to the extant body of knowledge.

Crucially, this research offers pragmatic guidance for SMEs navigating the intricacies of Industry 4.0 technology adoption. The insights gleaned, particularly regarding the pivotal role of L&D and the impact of employee perceptions (PU and PEOU), furnish SMEs with pragmatic strategies to bolster their technological acumen and innovative capacities. This is of paramount importance in a contemporary landscape where technological agility and the ability to innovate are quintessential for sustaining a competitive edge. However, it was observed that in instances where Personal Innovativeness in Automation, as facilitated through Learning and Development, does not translate into enhanced innovative work behavior, a disconnect emerges. This gap primarily arises from the delayed adoption of cutting-edge technologies by SMEs resulting in the slow pace of L&D initiatives in morphing into tangible innovations within factory settings. Consequently, the skills and competencies developed by employees through L&D programs often remain underutilized, hindering the fluid integration of these newfound capabilities into the operational dynamics of the enterprises.

This observation signals a critical area for strategic intervention, aiming to synchronize the pace of skill acquisition with the adoption of advanced technological frameworks, thereby ensuring that L&D investments are fully capitalized within the operational ambit of Malaysian SMEs.

This research offers a detailed and holistic exploration of the dynamics influencing technology adoption and innovation within the context of Malaysian manufacturing SMEs. Through its rigorous analysis, it underscores the critical need for a comprehensive understanding and strategic management of both internal and external factors that are pivotal for thriving in the era of Industry 4.0. The study's findings not only contribute valuable theoretical insights but also deliver actionable guidance for SMEs striving to improve operational efficiencies, cultivate environments conducive to innovation, and remain competitive in an ever-changing marketplace. Consequently, this research acts as an indispensable tool for SMEs, policymakers, and the academic community, presenting a strategic framework to leverage technological advancements effectively. It embodies a foundational reference point that elucidates the pathways through which the modern business sector can fully exploit the opportunities presented by technological progress, ensuring sustainable growth and innovation in the digital age.

5.6 LIMITATION & RECOMMENDATION

In academic research, recognizing and addressing limitations is as crucial as highlighting findings and contributions. This study, focusing on technology adoption and innovation within manufacturing SMEs in Malaysia, provides significant insights into this domain. However, it is essential to acknowledge the inherent limitations that accompany the research process. These limitations stem from various factors, such as the study's scope, methodology, and the dynamic nature of the subject matter. Acknowledging these constraints not only enhances the credibility of the research but also paves the way for future studies to build upon and extend the work done. The following are key limitations, each elucidating areas that future research could address to deepen and broaden the understanding of technology adoption and innovation in the manufacturing sector.

- **Leadership Influence on Innovative Work Behavior:** While this study investigated the influence of individual and organizational factors on innovative work behavior (IWB), it did not explore how leadership styles impact employees' willingness to innovate in the context of Industry 4.0. Future research could focus on examining the role of transformational, transactional, and ambidextrous leadership in shaping IWB among employees in manufacturing SMEs. Leadership can act as a critical enabler or barrier in fostering a culture of innovation. For instance, transformational leaders may inspire higher engagement and experimentation, while transactional leaders may focus on structured outcomes that limit creative thinking. By incorporating leadership as a mediating or

moderating variable, researchers can gain deeper insights into how strategic vision, communication, and motivational practices influence technology adoption and innovation performance. Qualitative studies or mixed-method approaches involving in-depth interviews with managers and employees could be employed to uncover how leadership behavior translates into actual innovation-supportive practices. Understanding this dynamic will help organizations develop leadership development programs tailored to Industry 4.0 readiness and ensure that employee innovativeness is not only encouraged but sustained through effective leadership engagement.

- **Regional Disparities in Innovation Readiness:** Given the diverse economic and infrastructural profiles of Malaysia's regions, future studies should explore how regional differences impact the adoption of Industry 4.0 technologies and the emergence of innovative work behavior among SMEs. Current findings indicate that SMEs in urbanized and industrially advanced areas such as Selangor and Penang are more likely to implement digital technologies, while those in less developed regions like Sabah or Kelantan face structural limitations in infrastructure, digital literacy, and access to government incentives. Future research could adopt a comparative regional study design to assess variations in awareness, access to training, government program reach, and cultural attitudes towards innovation. Such studies could use cluster sampling to gather data across regions and examine how contextual factors, such as regional policy enforcement, local workforce readiness, or connectivity, affect innovation adoption outcomes. This research could also assess whether national digitalization policies are equitably benefiting SMEs across all regions. The insights gained could guide the design of more inclusive and geographically sensitive policy interventions, ensuring that digital transformation and innovation growth are not confined to major urban centers but are equitably distributed across Malaysia's SME landscape.
- **Geographic Limitation:** The study's focus on Malaysian manufacturing SMEs may limit its applicability to other regions. Cultural, economic, and technological landscapes vary significantly across countries, and what holds in Malaysia might not be true elsewhere. This geographic specificity means the findings might not be directly transferrable to SMEs operating in different cultural or economic contexts. Future research should consider a more diverse geographic scope to enhance the generalizability of the findings.
- **Demographic role in IWB:** As this research focused on assessing the impact of latent variables on Innovative Work Behavior (IWB), future studies could expand the model by incorporating demographic factors such as gender, age group, industry sector, job level, and years of experience. Exploring these demographic dimensions may offer deeper insights into how different employee

profiles influence or moderate the relationship between key constructs and IWB. This would enhance the robustness of the model and provide a more nuanced understanding of innovation behavior across diverse workforce segments.

- **Industry-Specific Focus:** Concentrating solely on the manufacturing sector limits the study's applicability to other industries that might interact with technology differently. Industries vary in their technological infrastructure, adoption rates, and innovation processes. A broader industry focus in future research would provide a more holistic understanding of technology adoption and innovation across various sectors.
- **Cross-Sectional Nature:** The cross-sectional design of the study captures data at a single point, which might not accurately reflect the dynamic nature of technology adoption and innovation over time. This design limits the ability to infer causality or track changes and trends. Longitudinal research could offer more comprehensive insights into how these factors evolve and interact over time.
- **Quantitative Approach:** The primarily quantitative methodology may overlook the nuanced experiences and perceptions of individuals. Qualitative data can provide deeper insights into personal attitudes, beliefs, and the contextual factors influencing behavior. Future studies could benefit from a mixed-methods approach to capture both quantitative data and rich, qualitative insights.
- **Limited Range of Variables:** The study may not account for all possible variables influencing technology adoption and innovation. Factors such as organizational structure, leadership style, external market conditions, and technological environment also play significant roles. Expanding the range of variables in future studies could provide a more comprehensive understanding.
- **Self-Report Bias:** Relying on self-reported data poses a risk of bias, such as social desirability or respondent misunderstanding. While valuable, self-reported information might not always accurately reflect actual behaviors or attitudes. Combining self-reported data with objective measures in future studies could mitigate these biases.
- **Sample Size and Diversity:** The sample size and diversity could limit the study's findings. A larger and more diverse sample would ensure that the findings are more representative of the broader population of SMEs. Future research should aim for a more extensive and diverse participant pool to enhance the robustness of the results.
- **Technological Landscape Changes:** The rapid evolution of the technological landscape means that the study's findings might quickly become outdated. What is relevant today in terms of technology adoption and innovation might not hold in the near future. Continuous research is needed to keep pace with these rapid changes.

- **Overlooked External Factors:** External factors such as economic trends, regulatory changes, and competitive pressures might significantly influence technology adoption and innovation but are not deeply explored in this study. Future research should include these external elements to provide a more holistic view.
- **Generalizability to Larger Firms:** The study's focus on SMEs raises questions about its applicability to larger firms, which may have different resources, organizational structures, and strategic priorities. The dynamics of technology adoption and innovation in larger organizations could differ significantly from those in SMEs. Research that includes larger firms would help in understanding these differences.

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ANNEXTURE - A

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.932	31.038	31.038	9.932	31.038	31.038
2	2.934	9.169	40.207			
3	2.651	8.284	48.491			
4	1.446	4.518	53.009			
5	1.412	4.412	57.421			
6	1.256	3.923	61.345			
7	1.152	3.599	64.943			
8	1.097	3.427	68.371			
9	0.900	2.811	71.182			
10	0.799	2.497	73.678			
11	0.744	2.325	76.004			
12	0.628	1.962	77.966			
13	0.610	1.908	79.873			
14	0.571	1.786	81.659			
15	0.549	1.715	83.374			
16	0.520	1.624	84.998			
17	0.453	1.415	86.413			
18	0.432	1.351	87.763			
19	0.420	1.313	89.076			
20	0.405	1.266	90.342			
21	0.387	1.209	91.552			
22	0.351	1.098	92.650			
23	0.327	1.023	93.673			
24	0.305	0.952	94.625			
25	0.277	0.864	95.489			
26	0.266	0.830	96.319			
27	0.235	0.734	97.053			
28	0.217	0.677	97.730			
29	0.202	0.630	98.360			
30	0.190	0.593	98.953			
31	0.170	0.531	99.485			
32	0.165	0.515	100.000			

Extraction Method: Principal Component Analysis.

ANNEXTURE - B

Questionnaire Survey

Survey on Innovative Work Behavior in Manufacturing SMEs in Malaysia

Study Particulars and Informed Consent

About the Study & Author

Research Title: Fostering Innovation in Malaysian Manufacturing SMEs Through Exploring the Drivers of Innovative Work Behavior in the Industry 4.0 Era

Dear Participant,

I invite you to participate in a survey conducted as part of a research study for the Doctor of Business Administration (DBA) program at the University of Wales Trinity Saint David. This survey aims to explore the factors influencing Innovative Work Behavior (IWB) among employees in the manufacturing sector of Small and Medium Enterprises (SMEs) in Malaysia, particularly in relation to the adoption and integration of Industry 4.0 technologies. Your valuable insights will play a crucial role in understanding the dynamics of technological adoption and innovation within SMEs, contributing significantly to the advancement of knowledge in this field.

Your participation in this survey is entirely voluntary, and all responses will be treated with the utmost confidentiality. No identifying information will be collected, ensuring anonymity and data protection.

Before proceeding to the survey, we kindly request you to read the following consent statement carefully. By continuing with the survey, you indicate your informed consent to participate in this research.

Thank you for your willingness to contribute to this study.

Sincerely,

Rohini a/p N Alagappar

Doctor of Business Administration Candidate

University of Wales Trinity Saint David

Consent Statement for Participation in Research

Title of Study: Fostering Innovation in Malaysian Manufacturing SMEs Through Exploring the Drivers of Innovative Work Behavior in the Industry 4.0 Era

Researcher: Rohini a/p N Alagappar

Institution: University of Wales Trinity Saint David

Study Context:

This survey is being conducted as part of a research study undertaken by Rohini a/p N Alagappar, a doctoral candidate in the Doctor of Business Administration (DBA) program at the University of Wales Trinity Saint David. The study is focused on exploring Innovative Work Behavior (IWB) among employees in the manufacturing sector of Small and Medium Enterprises (SMEs) in Malaysia, with a specific emphasis on the adoption of Industry 4.0 technologies.

Purpose of the Research:

This study is conducted to understand the dynamics of Innovative Work Behavior (IWB) among employees in Small and Medium Enterprises (SMEs) within Malaysia's manufacturing sector, particularly in relation to the adoption of Industry 4.0 technologies. Your participation will contribute valuable insights into how technological changes are influencing work behavior and innovation in SMEs.

What Participation Involves:

As a participant in this study, you will be asked to complete a questionnaire that should take approximately 7-10 minutes. The questionnaire includes questions about your perceptions of technology use, innovation at your workplace, and the impact of various factors on work behavior within the context of Industry 4.0.

Confidentiality:

Please be assured that your responses will be kept strictly confidential. All data collected will be anonymized, and no individual participant will be identifiable in any reports or publications resulting from this study.

Voluntary Participation:

Your participation in this study is completely voluntary. You are free to withdraw at any time without any penalty. If you decide not to participate or to withdraw from the study, it will not affect your current or future relations with University of Wales Trinity Saint David.

Consent:

By proceeding to the questionnaire, you acknowledge that you have read and understood this consent form, and agree to participate in this research study conducted by Rohini a/p N Alagappan from University of Wales Trinity Saint David.

If you have any questions about the study, you are welcome to contact the researcher at EMAIL.

Thank you for your valuable contribution to this research.

QUESTIONNAIRE

SECTION A: Respondents Demographic:

Please tick (/) your answer in the given box.

GENDER	
Male	
Female	
AGE GROUP:	
19-25	
26-30	
31-40	
41-50	
Above 50	
POSITION IN COMPANY	
Business Owner	
Top Management	
Middle Management	
Executive and Supervisor	
Non-Executives	

WORK EXPERIENCE	
Less than 3 years	
3-6 years	
7-10 years	
11-15 years	
More than 15 years	
DEPARTMENT	
Management	
Production	
Engineering	
Maintenance	
Operations	
None of above	
INDUSTRY	
Manufacturing	
Manufacturing Supporting Industry	
Services	

Others	
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SECTION B

Please mark “x” the most appropriate number(s) range to represent the level of agreement for each statement. **The scales start from 1 Strongly Disagree to 5 Strongly Agree.**

Strongly Disagree	1	2	3	4	5	Strongly Agree
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Perceived Usefulness (PU):

Perceived Usefulness (PU) is a crucial factor in technology acceptance models and plays a significant role in the context of technical skills in manufacturing SMEs. PU, in this context, refers to the degree to which employees in manufacturing SMEs believe that improving their technical skills will enhance their job performance.

Perceived Usefulness (PU)		1	2	3	4	5
1	I believe that having technical skills relevant to IR4.0 will enhance my productivity at work.					
2	The use of IR4.0 technologies will improve the quality of work in my job.					
3	I find that technical skills in IR4.0 are useful in achieving my work goals.					
4	Mastering technical skills for IR4.0 technologies will contribute to my job performance.					

Perceived Ease of Use (PEOU):

Perceived Ease of Use (PEOU) is a critical determinant in the adoption and effective utilization of technical skills, especially in the context of Industry 4.0 technologies within manufacturing SMEs. PEOU refers to the degree to which employees believe that using a particular technology will be free of effort.

Perceived Ease of Use (PEOU)		1	2	3	4	5
1	I find it easy to understand and learn the technical skills required for IR4.0 technologies.					
2	It is clear and straightforward for me to apply technical skills related to IR4.0 in my work.					
3	I believe that the technical skills needed for IR4.0 technologies can be mastered without much difficulty.					
4	Learning and using technical skills for IR4.0 technologies is not overly complex for me.					

Adoption Intention of IR 4.0 (IRA)

Adoption Intention of IR 4.0 (IRA) refers to an individual's inclination or readiness to embrace and utilize Industry 4.0 technologies within their manufacturing role. It captures their willingness to adopt these advanced technologies for improving work processes and outcomes.

Adoption Intention of IR 4.0 (IRA)		1	2	3	4	5
1	I intend to use IR4.0 technologies in my work processes in the near future.					
2	I plan to actively learn and apply IR4.0 technologies as part of my job.					
3	I am willing to undergo training to use IR4.0 technologies effectively in my work.					

4	I foresee myself regularly using IR4.0 technologies in my job role.					
5	Adopting IR4.0 technologies is something I am considering seriously for my professional development.					

Government Support (GOV)

Government Support (GOV) refers to the initiatives, policies, and financial incentives provided by government entities specifically aimed at encouraging the adoption and integration of Industry 4.0 technologies within the manufacturing sector.

Government Support (GOV)		1	2	3	4	5
1	I believe that government initiatives for IR4.0 are sufficient to support its adoption in our industry.					
2	The support and resources provided by the government make it easier for our SME to adopt IR4.0 technologies.					
3	Government policies are effective in encouraging the use of IR4.0 technologies in the manufacturing sector.					

Personal Innovativeness in Automation:

Personal Innovativeness in Automation refers to an individual's propensity to embrace and effectively utilize advanced automation technologies within the manufacturing industry, demonstrating a forward-thinking approach to technical skill development and application.

Personal Innovativeness in Automation		1	2	3	4	5
1	I am proficient in using advanced automation technologies independently in my role.					

2	I believe I possess sufficient knowledge to effectively utilize automation technologies.					
3	I actively seek opportunities to experiment with new automation techniques in the manufacturing process.					
4	I am eager to explore and test new automation technologies in my work environment.					
5	I am open to and not hesitant about trying out innovative automation techniques.					
6	I am often among the first to implement new automation techniques in my work.					

Learning & Development (LD)

Learning & Development (LD) refers to the structured initiatives and activities undertaken to enhance the technical and professional skills of employees in the manufacturing sector, particularly in relation to Industry 4.0 technologies.

Learning & Development (LD)		1	2	3	4	5
1	I consistently keep abreast of the latest technological and professional developments pertinent to the manufacturing sector.					
2	I actively seek and incorporate feedback on my work to refine my technical skills and enhance my professional expertise.					
3	I regularly participate in specialized training courses and workshops to advance my technical competencies in manufacturing.					

4	I engage in collaborative efforts with colleagues and industry peers to share knowledge and develop advanced manufacturing skills.					
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Innovative Work Behavior in SME (SIWB)

Innovative Work Behavior in SMEs (SIWB) refers to the actions and initiatives taken by employees in small and medium-sized manufacturing enterprises to develop, introduce, and apply novel ideas, processes, or products that contribute to the organization's technological and operational advancement.

Innovative Work Behavior in SME (SIWB)		1	2	3	4	5
1	I actively create new ideas to address challenging issues in my work.					
2	I continually explore new working methods, techniques, or tools to enhance manufacturing processes.					
3	I am adept at generating original solutions to problems encountered in my manufacturing role.					
4	I effectively mobilize support for innovative ideas among key organizational members.					
5	I systematically introduce innovative ideas in the workplace and evaluate their utility to improve our processes.					
6	I am skilled at transforming innovative ideas into practical and useful applications within my work environment.					

Thank You for your time and cooperation.