

Navigating Skills Disruption Challenge Amid Industrial 4.0 to Small Medium Enterprises in the Food Manufacturing Sector

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This paper explores the skills disruption phenomenon faced by Small and Medium Enterprises (SMEs) in the food manufacturing sectors during the adoption of Industry 4.0 technologies. A semi-structured interview was implemented involved five SME owners, with at least five years experiences in managing SME. Data were thematically analysed and the result; eight skills disruption challenges faced by SMEs in food manufacturing sector, these include skills in marketing strategies, equipment and maintenance, business practice, workforce and training, financial challenges, business operation, time and health as well as management challenges. Provisioning challenges enable SME to better prioritise investments in workforce training and advanced machinery thereby improving production efficiency and product quality. Policymakers could establish supportive policy frameworks that facilitate industry 4.0 adoption among SMEs, while training providers are positioned as key enablers in addressing the skill gaps by designing and delivering targeted training programs tailored to the specific needs of the SME workforce. This research highlights the human skills dimension from the perspectives of SME owners, aligning with the Sustainable Development Goals (SDG), particularly those related to decent work and innovation.

Keywords: skills disruption; food manufacturing SMEs; Industry 4.0; SDG 8; TVET

I. INTRODUCTION

SMEs play a vital role in driving country's economic growth. However, the continued reliance on conventional production method may hinder their competitiveness, particularly in term production efficiency, quantity, and quality. The food industry is highly competitive and continuously evolving, driven by consumers' increasing demands for higher product quality, enhanced safety, extended shelf life, greater product variety, and more environmentally sustainable production method. In this context, the adoption of technologies associated with the IR4.0 presents both opportunities and challenges. The extent which manufacturing organisations can adapt to this technological advancement determine whether IR4.0 becomes a catalyst

for growth or potential threat to their sustainability (Mohd Makhbul *et al.*, 2018).

Most scholars agree that IR4.0 has reshaped the skills landscape for SMEs. Each writer focuses on a different part of the challenge. Zhai *et al.* (2022) stress the pressure on both skilled and semi-skilled workers. Ling *et al.* (2020) highlight the changing nature of jobs. They show how tasks are moving away from routine work toward data-driven and complex responsibilities. Horváth and Szabó (2019) point to gaps in the education system. They warn that without reform the next generation of workers will not be ready for a digital economy. Isa *et al.* (2015) provide another angle. They note that the outlook and confidence of SME owners shape whether new technologies are adopted in practice.

Recent studies highlighted that many employees in SMEs lack the necessary skills required for their roles and

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are often underqualified for their current positions (Anuar, 2016). With the adoption of IR4.0 technologies such as cloud computing, big data, and artificial intelligence, roles in high-tech manufacturing increasing demands advanced and future-oriented skills sets (Zhai *et al.*, 2022). SMEs especially in this study context, continue to face limitations in both exposure and mastery of these technologies in their production processes. Taken together, these studies show that skills disruption under IR4.0 is not simple. It cuts across employees, education, and leadership. The issue is layered and complex. Yet there is still little understanding of how SMEs in developing contexts such as Malaysia are coping with these realities. They face limited resources, uneven infrastructure, and weak access to training. This study seeks to fill that gap.

II. MATERIALS AND METHOD

To conduct this study, researcher used a qualitative approach, gathering crucial data through semi-structured interviews. Using semi-structured interviews, the qualitative study enables the investigator to offer a clear, rich picture of participants' perspectives on a topic (Creswell, 2012).

Additionally, researcher's observations provided valuable insights into the specific environment and actual behaviours, rather than relying solely on self-reported actions or opinions. In this study, the researcher chooses a case study as the research design, to guide the researcher towards obtaining the right information and data. The aim of this study is to navigate skills disruption challenge amid Industrial 4.0 to Small Medium Enterprises in the food manufacturing sector. Research question was formed to get answer to the research problems, which is: i) What are the challenges regarding skills disruption experienced by SMEs in the food manufacturing sector amid IR4.0?

A. Research Location

This study investigates skills disruption challenges among SMEs in the food manufacturing sector, using Parit Raja as a localised case study. Situated within the Batu Pahat district of Johor, along the strategic Malaysia-Singapore economic corridor. Parit Raja has experienced rapid growth in recent years. This socioeconomic transformation is largely driven

by the establishment of key academic and vocational institutions, including Universiti Tun Hussein Onn Malaysia (UTHM), MARA High Skills College (KKTm) Sri Gading, and the Ministry of Health Training Institute (ILKKM) Batu Pahat. Together, these institutions have established the town as an emerging educational and technical training hub, fostering local enterprise development and innovation. Notably, Parit Raja is renowned for its thriving snack chip manufacturing industry, which has progressively adopted advanced technologies such as automated cutting, slicing, and frying systems (Mohamad *et al.*, 2023). To capture authentic workplace dynamics and ensure robust empirical validity and reliability, primary data were collected directly at the SMEs' operational sites.

B. Research Participants

Purposive sampling is used to obtain information from a group of specifically selected samples that have specific expertise and meet the criteria and coincide with the study's goals. It is often used in qualitative research as it is able to explore answers in more detail from respondents through research questions (Creswell, 2007). Babbie (2002) stated that, purposive sampling involves the intentional selection of study participants, guided by the researcher's judgment to choose a sample that is most valuable, suitable, and aligns with the study's objectives. According to Patton (1990), there are no rules for determining the size of participants the total number of study participants in qualitative studies as size is not a major issue. Rather the quality of the study sample selected is a determinant of the quality of the study data. The potential of each respondent's case to provide a good theoretical understanding of the aspect being studied is more important than the number of respondents. Study participants were selected in small numbers in order to obtain focused and in-depth information. This targeted approach allows for the inclusion of participants who can provide valuable insights into the specific challenges being investigated. Therefore, the study will involve five SME owners from Parit Raja who were selected based on their availability for interviews. Each owner had at least one year of experience in managing a business and their enterprises met the official national definition of an SME. Participants also agreed to take part in the study and share their views.

This careful selection ensured that the participants could offer meaningful insights into how SMEs deal with skills challenges under IR4.0. It aims to coordinate findings with associated variables (See Table 1).

Table 1. Demographic Profile of SME owners

Age	Gender	Education	Experiences
29	Female	Bachelor's degree	2 Years
27	Male	Malaysian Skills Certificate	10 Years
49	Female	Malaysian Skills Certificate	7 Years
36	Male	Bachelor's degree	3 Years
30	Female	Bachelor's degree	5 Years

C. Data Collection

Primary qualitative data were collected through semi-structured interviews with five SME owners, who were purposively selected based on their managerial roles and extensive industry experience. As noted by Robson (2011), semi-structured interviews serve as an effective standalone data collection method in social science research. This approach combined predetermined core questions with open-ended prompts, allowing participants to reflect deeply on operational challenges while enabling the researcher to probe emerging themes and gather contextualised insights.

Before conducting the interview, a framework was prepared. The research process was planned with consideration for the busy routines of SME owners. The first step involved seeking permission and informed consent, followed by confirming their agreement to participate and deciding on suitable locations for the study. To guide the process, a checklist was prepared and interview protocols were drafted. These protocols were tried out in a pilot study and refined to make them clearer and more effective. Before the formal interviews began, participants were contacted in advance by phone. These conversations introduced the purpose of the study and explained how the interviews would be carried out. With this groundwork in place, the dates for observation and interviews were then confirmed.

The semi-structured interview protocol was framed around four distinct question categories; introductory, transitional, key, and closing—adapted from Krueger and Casey (2002). Introductory questions established rapport

and familiarised participants with the study context, while transitional questions guided the conversation toward core research themes. Key questions investigated participants' experiences, perceptions, and challenges concerning technology adoption, innovation, and resource constraints within SMEs. Finally, closing questions enabled participants to synthesise their thoughts and offer supplementary insights.

The validity of research will be evaluated by assessing how well an account appears to fairly and accurately represent the collected data (Lacey & Luff, 2009a). Therefore, to ensure the validity and credibility of the instruments, the interview questions underwent expert validation. Three subject matter experts were consulted: one academic specialising in qualitative research methodologies, one industry experts in the food manufacturing sector, and one technology advisor with expertise in IR4.0 applications in SMEs. Their feedback was used to refine the questions for clarity, relevance, and alignment with the study objectives.

Interview were conducted in person at locations convenient to the participants and were audio-recorded with their consent. In addition to audio recording, field notes were taken to capture non-verbal cues, contextual details, and immediate reflections during the sessions. These supplementary notes played a crucial role in enriching the interpretation of the data during the transcription and analysis stages.

Additionally, a pilot study was conducted with an SME owner in Simpang Renggam, Johor, to refine the validity, clarity, and overall flow of the interview instrument. In accordance with Clark and Creswell (2011), this preliminary session sought to evaluate question complexity, sentence structure, interview duration, and potential ambiguities. The pilot interview commenced with an overview of the research objectives and participant background questions; key insights were noted manually, and the entire session was audio-recorded and transcribed verbatim

D. Data Analysis

The extensive amount of text resulting from interviews or observational data must be described and condensed (Lacey & Luff, 2009). Accordingly, data obtained from the semi-structured interviews were transcribed in order to simplify

and strengthen the subsequent analysis. Using thematic analysis, the researcher derived themes from the interview and observation transcripts by coding the research findings with a pencil and paper technique. During data transcription, the researcher transferred the interview data into text format so it could be coded and used to create thematic categories. According to Strauss & Corbin (2008), coding is a technique that enables the researcher to incorporate lines or statements into groups that have similar meanings. The extensive amount of text resulting from interviews data was described and condensed to extract meaningful insights. The Riverside Transcription application, Zotero software and Lucidspark were used to help researcher manage the data collections.

IV. RESEARCH FINDINGS

To address the research question, " What are the challenges regarding skills disruption experienced by SMEs in the food manufacturing sector amid IR4.0?", qualitative data was collected through a series of semi-structured interviews with 5 SME owners. The findings from these interviews are being analysed using thematic analysis. Table 2 presents the detailed results of the initial open coding derived from the interview data for this specific research question, highlighting the challenges and insights related to skills disruption.

Table 2. Open Code for The Skills Disruption Challenges

No	Open code (Initial)	Reference
1.	Dough flattening machine	SO (1) I-30/05/24
2.	Dough cutting machine	
3.	Dough flattening machine	
4.	Onion peeling machine	
5.	Used of Microsoft Excel	SO (2) I-02/06/24
6.	Marketing through social media	
7.	Marketing through contacts	
8.	Marketing through WhatsApp application status	
9.	On-stove cooking	
10.	Pressure cooker	
11.	Promoting through Facebook application	
12.	Promoting through friends	

13.	No record of money transaction	SO (3) I-03/06/24
14.	Chili grinding machine.	
15.	Dough flattening machine.	
16.	Marketing with a product contact number	
17.	Ledger-based transactions	SO (4) I-05/06/24
18.	Chest chiller	
19.	Small oven	
20.	Learning through Tiktok application	
21.	The neighbours help to promote	SO (5) I-05/06/24
22.	Manually packaging	
23.	Facebook marketing account	
24.	Marketing with a product contact number	
25.	Bread moulding machine.	
26.	Online business transaction	
27.	On-stove food preparation	
28.	Manual packaging	
29.	Promoting through Tiktok application	
30.	Loyvers tracking system usage	

From the initial 39 codes, 20 sub-themes emerged. These sub-themes provide a more detailed understanding of the data, as each sub-theme groups codes with similar meanings under a common category. Furthermore, the 20 sub-themes need to be broken down in more detail to create themes that align with the objectives of the research question. This detailed breakdown will help ensure that each sub-theme accurately reflects the aspects related to the skills disruption challenges. The division of sub-themes will be carried out according to the specific requirements of each theme, ensuring that all relevant codes are appropriately categorised. Table 3 below shows the sub-themes and themes that emerged.

Table 3. Formation of Sub-themes and Themes

Theme	Sub-theme	Code
Production Equipment	Food production machine	1, 2, 3, 4, 10, 14, 15, 18, 19, 25
	Manual Production	9, 22, 27, 28
Data Management	Ledger-based tracking	13, 17
	Digital tracking tools	5, 26, 30

Marketing and Promotion	Marketing through online	6, 8, 11, 20, 23, 29
	Non-online marketing	7, 12, 16, 21, 24

The 39 open codes that were initially filtered need to be categorised under specific sub-themes related to the main theme, "challenges regarding skills disruption." After a comprehensive analysis, 39 codes resulted in 20 sub-themes, which were carefully selected and structured into 8 main themes after all refinements. These themes directly address the second research question. Figure 1 offers a visual breakdown of themes and sub-themes pertaining the research question, providing a more detailed and comprehensive representation of the findings.



Figure 1. Overall Division of Themes and Sub-Themes

V. RESEARCH DISCUSSION

A. Theme 1: Marketing Strategies

Marketing strategies are critical for SMEs to navigate the competitive landscape, particularly in the context of skills shifts required to support IR4.0. SME owners face challenges in adjusting their marketing strategies due to rapid technological advancements and the demand for digital skills. Inconsistent IT system integration and data management standards further complicate this process (Bojan Jovanovski *et al.*, 2019). This theme encompasses

various sub-themes, including preferred methods and prioritising marketing over technology.

1. Preferred methods

The sub-theme of preferred methods reflects the dual approach SME owners take, balancing between manual and computerised systems. This challenge arises as many SME owners are accustomed to traditional methods and may lack the necessary digital skills to fully leverage modern marketing technologies. As a result, they often find themselves straddling both manual record-keeping and computer-based systems, leading to inefficiencies and a steeper learning curve in transitioning to digital marketing strategies.

2. Prioritising marketing over tech

The sub-theme of prioritising marketing over tech highlights the tendency of SME owners to focus more on marketing efforts rather than on adopting new technologies. This challenge arises because many SME owners perceive immediate returns and visibility from marketing initiatives, while the benefits of integrating advanced technologies may not be as apparent in the short term. Additionally, the shift in skills required to support IR4.0 often necessitates a substantial investment in learning and resources, which can be daunting for SME owners who are already stretched thin managing their day-to-day operations.

B. Theme 2: Equipment and Maintenance

Equipment and maintenance are crucial aspects for SMEs, especially as they navigate the demands of IR4.0. SME owners often face challenges in keeping up with the advanced technological requirements and maintenance needs of modern equipment. This is due to the insufficient or lack of capacity to test IR4.0-based solutions. (Bojan Jovanovski *et al.*, 2019) This theme addresses the difficulties in maintaining equipment reliability, which is essential for ensuring smooth and efficient business operations.

1. Machine reliability

The sub-theme of machine reliability highlights the frequent breakdowns and the need for SME owners to acquire repair skills. These challenges stem from the fact that many SME

owners are not traditionally trained in advanced machinery maintenance, making it difficult to support the sophisticated equipment required by IR4.0. As a result, SME owners often have to learn to repair their equipment independently, which can be time-consuming and challenging without proper training.

C. Theme 3: Business Practice

Business practices in SMEs often reflect the adaptation to new technological trends required by IR4.0. SME owners face challenges in shifting their operational methods and strategies to align with the digital era. As according to Anuar, A. R., (2016), Malaysian SMEs often prefer hiring low-cost labour for tasks like packaging over investing in advanced technology. This theme addresses two sub-themes which are, existing practice comfort and financial practices.

1. Existing practice comfort

The sub-theme of existing practice comfort illustrates the tendency of SME owners to stick with familiar and established business practices. This challenge arises because many SME owners feel comfortable with their current methods and are hesitant to adopt new technologies that require a shift in skills and routines. This resistance to change is often due to a lack of confidence in managing new systems, fear of disrupting existing operations, and a perception that current practices are sufficient to meet their business needs.

2. Financial practice

The sub-theme of financial practice refers to the challenges SME owners face when dealing with the allocation and management of funds in their business operations, especially when integrating new technologies for IR4.0. Many SME owners prioritise immediate financial needs and may not invest adequately in technology or skill development. This focus on short-term financial concerns can hinder the adoption of modern digital practices that require financial investment and expertise, contributing to the difficulty in managing the shift in skills required for IR4.0. Additionally, limited understanding of financial

management in the context of digital technologies can lead to resistance to change and slower adoption.

D. Theme 4: Workforce and Training

Workforce and training are critical themes for SMEs as they adapt to IR4.0. SME owners face significant challenges in ensuring their workforce possesses the necessary skills and training to operate advanced technologies and meet modern business demands. The adoption of IR 4.0 technologies demands workers to acquire new skills, creating new job roles (Zhai *et al.*, 2022). Under-skilled workers, however, may hinder productivity and the implementation of efficient technologies (Anuar, 2016). This theme includes sub-themes such as skill gaps, highlighting the difficulties in finding and training employees with the requisite expertise.

1. Skill gaps

The sub-theme of skill gaps underscores the difficulties SME owners encounter in bridging the gap between the current skill levels of their workforce and the skills required for IR4.0. This challenge is particularly pronounced as many employees may lack formal training or experience with advanced technologies, leading to inefficiencies and potential operational issues. SME owners often struggle to find qualified staff and must invest considerable time and resources into training to meet the demands of a technologically evolving business environment.

2. Staff shortage

The sub-theme of staff shortage highlights the challenges SME owners face in finding and retaining adequate workforce to meet business demands, particularly as they strive to integrate advanced technologies required by IR4.0. Many SMEs find it difficult to attract skilled workers with the expertise needed for new digital technologies, resulting in an overreliance on existing staff to manage multiple roles and functions. This shortage often leads to increased workload and burnout, hindering the capacity to adapt to modern business practices and technologies effectively.

3. Aging workforce

The sub-theme of aging workforce highlights the challenges faced by SME owners in managing employees with an older

demographic profile. This can create difficulties in acquiring the necessary skills for advanced technologies and adapting to the demands of IR4.0. As the workforce ages, there may be limited exposure to new digital skills and reluctance to adopt technological advancements, leading to inefficiencies in the business. This challenge affects the ability to integrate modern business practices and technologies and may limit overall business growth.

E. Theme 5: Financial Challenge

Financial challenges are a significant barrier for SMEs in supporting IR4.0. SME owners often struggle with securing the necessary funds to invest in new technologies and equipment required for modernisation. Muhamad *et al.*, (2020) stated that the cost becomes a critical factor for SMEs when deciding whether to upgrade their current IT infrastructure or establish a new one. This theme includes sub-themes such as loan application difficulties, funding limitations, financial barriers and cash management.

1. Loan application difficulties

The sub-theme of loan application difficulties emphasises the hurdles SME owners encounter when trying to secure loans. These challenges occur because financial institutions often require extensive documentation and proof of financial stability, which many SMEs struggle to provide. The process can be complicated and competitive, leaving many SME owners without the necessary funds to invest in equipment and training to support IR4.0.

2. Funding limitation

The sub-theme of funding limitation underscores the challenges that SMEs encounter in securing necessary financial support to invest in advanced technologies required for IR4.0. SME owners often hesitate to take out loans due to concerns about debt repayment, potential financial burden, and the impact on business operations. This hesitation can result in slower adoption of technologies due to limited capital investment, hindering the shift in skills necessary to embrace the requirements of IR4.0.

3. Financial barriers

The sub-theme of financial barriers highlights the challenges SMEs face when it comes to managing the financial aspects of modern business practices, particularly with the increasing cost of materials and goods. SMEs struggle to adapt to the rising prices of essential resources due to inflation and market conditions, which affects cash flow and overall business viability. This challenge impacts the ability of SME owners to allocate funds towards modernising their business and acquiring new skills for IR4.0.

4. Cash management

The sub-theme of cash management illustrates the difficulties that SME owners encounter in managing the flow of cash to ensure smooth business operations. Cash management becomes a significant challenge when SMEs struggle to control and allocate their financial resources efficiently. This challenge often hampers the ability to invest in new technologies and skills required for IR4.0, as cash flow can become a limiting factor in business expansion and modernisation.

F. Theme 6: Business Operation

Business operations encompass the day-to-day activities and logistics that SMEs must manage to run effectively. In the context of IR4.0, SME owners face challenges in modernising their operations to be more efficient and competitive. Jovanovski *et al.* (2019) stated that limited awareness of high-tech solutions and their potential benefits reduce their implementation in production processes. This theme includes sub-themes such as the lack of an official site, limited business scope and no-food manufacturing field.

1. Lack of official site

The sub-theme of lack of official site highlights the difficulties SME owners face when they do not have a dedicated business location. This challenge is significant because a lack of a permanent site can limit the ability to operate efficiently and professionally, making it harder to implement the technological advancements required by IR4.0. This can lead to dependence on temporary or shared spaces, which can hinder growth and stability.

2. Limited business scope

The sub-theme of limited business scope highlights the challenges SMEs encounter when managing a narrow range of operations or limiting business activities, especially in the context of transitioning into IR4.0. This limitation can impede the adoption of advanced technologies and diversification of product lines, restricting the ability of SME owners to explore new markets and opportunities. Consequently, the shift in skills required for modern business practices may be hindered, as owners may struggle to manage and integrate a broader scope of operations effectively.

3. Non-food manufacturing field

The sub-theme of non-food manufacturing field emphasises the challenges SME owners face when transitioning from a non-food manufacturing background into the complexities of adopting IR4.0 technologies. These owners often encounter difficulties in understanding and integrating advanced digital systems due to their original industry experience and educational background. Such challenges can impede the necessary skills shift, limiting the effectiveness of adopting modern business practices and technologies.

G. Theme 7: Time and Health

Time and health are critical concerns for SME owners, especially as they adapt to the demands of IR4.0. The pace of technology innovation today adds an extra layer of complexity to this ongoing issue (World Economic Forum, 2018). The challenges of balancing work and personal well-being become more pronounced with the increased pressure to acquire new skills and integrate advanced technologies. This theme includes sub-themes such as lack of time, health issues and no long-term plans.

1. Lack of time

The sub-theme of lack of time emphasises the struggles SME owners face in juggling multiple responsibilities, leaving little room for skill development and process optimisation. This challenge arises because the demands of daily operations can be overwhelming, making it difficult to allocate time for learning and implementing new

technologies essential for IR4.0. Consequently, the lack of time becomes a significant barrier to achieving the necessary skills shift and improving business efficiency.

2. Health issues

The sub-theme of health issues highlights the physical and mental challenges SME owners face as they navigate the demands of IR4.0. Health-related concerns can significantly impact the ability of SME owners to effectively manage their operations and acquire new skills. For instance, if an SME owner falls ill, their business operations may be interrupted, as they may not be able to perform essential tasks or supervise their employees. This can create difficulties in integrating advanced technologies and adapting to new business practices, further complicating the required skill shifts.

3. No long-term plan

The sub-theme of no long-term plan highlights the challenges that SME owners face in strategising for the future. SME owners may lack a long-term plan for business expansion, adoption of advanced technologies, or integration of Industry 4.0 (IR4.0) practices due to a variety of reasons. These challenges can hinder the effective management of their business operations and the necessary skills shift. Without a long-term plan, owners may find it difficult to invest in the required technology and skill development, which impacts their overall ability to adapt to IR4.0.

H. Theme 8: Management Challenge

Management challenges are a significant obstacle for SMEs, particularly in the context of adapting to IR4.0. SME owners often face difficulties in adjusting their management styles and structures to support the new skills and technologies required. According to Lee and Lee, (2022), policies addressing a company's strengths and weaknesses must be in place to ensure competitiveness in the IR4.0. This theme includes sub-themes such as leadership changes and specification not met.

1. *Leadership changes*

The sub-theme of leadership changes highlights the challenges that arise when there is a shift in leadership within an SME. These challenges are especially pronounced in the context of IR4.0, where new leaders may need to quickly adapt to advanced technologies and modern management practices. The transition can be difficult, as new leaders must balance learning these new skills while also maintaining business operations and managing existing staff.

2. *Specification not met*

This sub-theme pertains to the challenges that SME owners encounter when attempting to align with regulatory standards and specifications required by IR4.0. Many SME owners find it difficult to adapt their management structures and processes to meet these requirements, particularly in the context of integrating advanced technologies. Challenges such as outdated facilities, limited understanding of specific regulations, and a lack of compliance expertise can hinder the successful implementation of these standards. These difficulties often require a shift in management skills, and SME owners may struggle to adapt their operations to meet these evolving specifications.

VI. CONCLUSION

This study demonstrates that skills disruption among food manufacturing SMEs in the Industry 4.0 era extends beyond mere technical readiness, intersecting directly with financial capacity, organisational governance, and human capital development. Empirical evidence across seven critical operational domains management, marketing, equipment maintenance, business practices, workforce training, financial constraints, and time-and-health management reveals that digital transformation cannot succeed in isolation from broader firm capabilities.

To maintain market competitiveness, SMEs must pair continuous workforce upskilling with strategic financial management and collaborative resource sharing. At the macro level, policymakers in emerging markets must move beyond standalone training initiatives to deliver integrated

frameworks that align technical upskilling with accessible financing and digital infrastructure.

While bounded by a single-sector focus and a localised sample, this research provides essential empirical grounding for small-firm modernisation. Future research should leverage longitudinal, cross-sectoral frameworks to model long-term SME adaptability amid ongoing global technological shifts.

A. *Implication of Research*

Beyond hardware acquisition and digital adoption, Industry 4.0 implementation hinges on workforce adaptability. Enterprise leaders must align technology investments with practical, role-relevant upskilling. Balancing technological upgrades with targeted human capital development enhances operational efficiency, elevates product quality, and establishes long-term market competitiveness.

At the operational level, workplace automation causes immediate workflow disruption, often inducing role uncertainty and stress. However, structured upskilling transforms technological displacement into professional growth. Equipping workers with digital and operational competencies maintains their workplace relevance, drives shop-floor productivity, and fosters organisational commitment and self-efficacy.

At the governance level, institutional frameworks must integrate technological deployment with human capacity building. Policymakers should couple financial support for SMEs with mandated workforce development schemes. Synchronising capital assistance with skill acquisition ensures a smoother industrial transition while strengthening broader national competitiveness.

Finally, training providers play a critical role in mitigating sector-specific disruptions, rendering generic curricula ineffective. Co-designing programs focused on real-world industrial needs—such as digital literacy, machine operation, and system management—ensures immediate workplace application. Ultimately, this alignment enhances task performance and cultivates an enduring culture of continuous learning essential for long-term enterprise resilience.

B. Limitation and Recommendations

Several methodological limitations constrain the findings of this study. First, the modest sample size and single-sector focus on food manufacturing limit generalisability across broader SME sectors. Second, the restricted geographical scope may not fully reflect regional variations in infrastructure, workforce readiness, and technological adoption. Third, reliance on self-reported data introduces potential subjective bias, as participant perceptions may not fully reflect operational realities. Finally, the cross-sectional design captures only a temporal snapshot, missing the ongoing evolution of Industry 4.0 technologies and long-term workforce adaptation.

To address these constraints, future research should incorporate larger, more heterogeneous samples across diverse industrial sectors and geographic regions to facilitate

robust comparative analysis. Employing longitudinal research designs would offer valuable insights into how skills disruption and workforce readiness evolve over time. Furthermore, integrating objective metrics such as institutional training records and firm performance indicators, alongside self-reported data would significantly enhance empirical validity

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VIII. REFERENCES

- Anuar, AR 2016, 'Addressing skills gap in small-sized enterprises: Malaysian case study', *The European Proceedings of Social & Behavioural Sciences*, pp. 717–722, doi:10.15405/epsbs.2016.08.101.
- Clark, VLP & Creswell, JW 2011, *Designing and conducting mixed methods research*, 2nd edn, SAGE Publications, Thousand Oaks.
- Creswell, JW 2008, *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*, 3rd edn, Pearson Education, Upper Saddle River.
- Creswell, JW 2012, *Educational research: Planning, conducting and evaluating quantitative and qualitative research*, 4th edn, Pearson, Boston.
- Horváth, D & Szabó, RZ 2019, 'Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities?', *Technological Forecasting and Social Change*, vol. 146, pp. 119–132, doi:10.1016/j.techfore.2019.05.021.
- Isa, M, Setyawan, A, Syamsudin, Nugroho, P & Wajdi, F 2015, 'An assessment of SME competitiveness in Indonesia', *Journal of Competitiveness*, vol. 7, no. 2, pp. 60–74.
- Jovanovski, B, Seykova, D, Boshnyaku, A & Fischer, C 2019, 'The impact of Industry 4.0 on the competitiveness of SMEs', *International Scientific Journal "Industry 4.0"*, vol. 4, no. 5, pp. 250–255.
- Lacey, A & Luff, D 2009, *Qualitative data analysis*, National Institute for Health Research (NIHR) Research Design Service for Yorkshire & the Humber, viewed 17 September 2026, <https://www.rds-yh.nihr.ac.uk>.
- Lee, D & Lee, S 2022, 'A study of the competitiveness and development strategy of Korean venture companies in the Fourth Industrial Revolution using SWOT/AHP', *Sustainability*, vol. 14, no. 9, art. no. 5459.
- Ling, YM, Abdul Hamid, NA & Lee, TC 2020, 'Is Malaysia ready for Industry 4.0? Issues and challenges in manufacturing industry', *International Journal of Integrated Engineering*, vol. 12, no. 7, pp. 134–150, doi:10.30880/ijie.2020.12.07.016.
- Mohamad, N & Zarir Yusoff, M 2023, 'Faktor-faktor yang mempengaruhi tahap penerimaan teknologi dalam kalangan pengusaha kecil dan sederhana industri kerepek di Parit Raja' [Factors influencing the technology acceptance stage among small and medium entrepreneurs in the chip industry in Parit Raja], *Research in Management of Technology and Business*, vol. 4, no. 1, pp. 107–121, doi:10.30880/rmtb.2023.04.01.008.
- Mohd Makhbul, Z, Nazmy Abd Latif, M & Mohamad Hasun, F 2018, 'Kedwicekatan organisasi: Kompetensi penting

- mendepani Industri 4.0' [Organizational readiness: Key competencies for facing Industry 4.0], *Proceedings of the 5th International Conference on Management and Muamalah 2018 (ICoMM 2018)*, Bangi, Malaysia.
- Muhamad, MQB, Syed Mohamad, SJAN & Mat Nor, N 2020, 'Prefiguring issues of SMEs readiness in Malaysia as the future of Industry 4.0 unfolds', *International Journal of Academic Research in Business and Social Sciences*, vol. 10, no. 12, pp. 268–279, doi:10.6007/ijarbss/v10-i12/8159.
- Patton, MQ 1990, *Qualitative evaluation and research methods*, 2nd edn, Sage Publications, Newbury Park.
- Strauss, A & Corbin, J 2008, *Basics of qualitative research: Techniques and procedures for developing grounded theory*, 3rd edn, Sage Publications, Thousand Oaks.
- World Economic Forum 2018, *The future of jobs report*, Centre for the New Economy and Society, World Economic Forum, Geneva.
- Zhai, T, Deborah, G, Yik, C, Vaisnavi, K, Rao, M & Lima-De-Oliveira, R 2022, *Industry 4.0 technology adoption in Malaysian manufacturing: Strategies for enhancing competitiveness*, working paper, Asia School of Business, viewed 17 September 2026, <https://asb.edu.my/faculty-research/working-papers-database>.