

A Systematic Review of Adaptation of IR 4.0 during COVID-19 Pandemic among Global SMEs

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Abstract. The study examines the adaptation of IR 4.0 technologies by small and medium-sized enterprises (SMEs) in the post-pandemic business era. A PRISMA-based systematic review of selected papers was employed using four keyword strings to extract articles from SCOPUS, Web of Science (WoS), and Google Scholar. The key strings included “Adaptation of IR 4.0 during pandemic COVID-19 among SMEs”, “SMEs 4.0 and COVID-19”, “Industry 4.0, SMEs, COVID-19”, and “Industry 4.0 in SMEs”. A mix of qualitative, quantitative, and mixed-method studies and reviews was included in the final dataset of 30 papers. Only journal papers published in the English language between 2019 till 2022 were included, aligning with the post-pandemic context of the study. The review categorizes the risks SMEs faced during the pandemic, including operational disruptions, financial challenges, and cost-related issues. It identifies IR 4.0 technologies that foster SME digitization, such as big data analytics, cloud computing, system integration, and process flexibility. The findings indicate that the adoption of IR 4.0 technologies equips SMEs with the digital capabilities necessary for resilience in future crisis. The review indicated an increased need for technological innovations in SMEs facilitated by policy building to support the transition and ensure business survival, recovery, and revitalisation in the post-pandemic corporate world. The current study also provided detailed findings, implications, limitations, and future research directions.

Keywords: Industry 4.0, IR 4.0, SMEs, COVID-19, Systematic Review, PRISMA

1. Introduction

The third industrial revolution, Industry 3.0 facilitated organisations to adopt the conventional methodologies of automation. Meanwhile, organisations transformed from conventional automation to the adaptation of various technologies during the fourth revolution (IR 4.0 or Industry 4.0), which established smart strategies for manufacturing, digital integration in the value chain of the company, and vertical and horizontal integration from the free flow of information and communication throughout the various participants within the organisational supply chain (Jiang et al., 2022; Zakoldaev et al., 2020; Zakoldaev et al., 2019). Industry 4.0 can have many benefits for SMEs resulting from the comprehensive digitisation of the entire product lifecycle, enabling organizations to leverage data and enhance flexibility in various aspects such as production and services (Shafiq et al., 2016). The integration of IR 4.0 technologies can enhance products and service and improve flexibility along with empowering SMEs to enhance their competitive edge (Masood & Sonntag, 2020). Nevertheless, SMEs encountered numerous challenges in resources, finances, knowledge, and labour market risks to transition from the third industrial revolution to IR 4.0 (Dutta et al., 2021; Kumar & Ayedee, 2021; Song et al., 2022; Yang & Chuang, 2020). The COVID-19 pandemic also encouraged SMEs to adopt IR 4.0 strategies and technologies to ensure survival in the industry (Madhavan et al., 2022; Michna & Kruszewska, 2022; Turkyilmaz et al., 2021). Several past studies revealed a need for SMEs to become more dynamic and innovative to resolve crises arising from the pandemic (Dyduch et al., 2021; Klein & Todesco, 2021; Serumaga-Zake & van der Poll, 2021) and offered several recommendations for survival in the post-pandemic business (Giunipero et al., 2022; Mendy, 2022; Zutshi et al., 2021).

While previous research has investigated the incorporation of IR 4.0 technologies within SMEs (Lutfi et al., 2022), there has been an absence of a comprehensive review that consolidates the findings concerning how these technologies specifically contributed to the growth of SMEs during the COVID-19 pandemic. Additionally, while Park et al. (2022) synthesized existing literature in terms of adoption of IR 4.0 and the impact of COVID-19, the study was limited to architecture and smart cities. Similarly, in the context of COVID-19, other researchers have focused on the healthcare sector (Ahsan & Siddique, 2022; Rudrapati, 2022). Therefore, the present review intends to bridge these research gaps by methodically evaluating the existing literature related to the integration of IR 4.0 strategies by SMEs worldwide in the context of the COVID-19 pandemic. It is essential to take into consideration the pandemic as the outbreak created new opportunities for adopting IR 4.0 technologies to ensure business continuity and survival (Michna & Kruszewska, 2022; Pu et al., 2021). The pandemic also broadened the research context for the implementation of industrial revolution strategies in the SMEs (Anshari & Almunawar, 2021; Serumaga-Zake & van der Poll, 2021). The SMEs have increasingly adopted IR 4.0 strategies to ensure productivity, mitigate challenges regarding financial situations and business continuity, and overcome the disease spread (Anshari & Almunawar, 2021; Michna & Kruszewska, 2022; Piccarozzi et al., 2018).

In summary, most studies indicated the need to adapt and use IR 4.0 technologies to overcome issues concerning finance, business survival, communication with employees and customers, and resource optimisation. While few studies have examined how SMEs can use IR 4.0 technologies to build resilience, there is a need for a summative review to review the risks and benefits of IR 4.0 technologies for SMEs COVID-19 crisis mitigation and resilience building. Therefore, the current study proposed the following objectives:

RQ1: What are some of the risks and issues encountered by SMEs due to the pandemic?

RQ2: What IR 4.0 technologies are the most suitable for SMEs?

RQ3: How can IR 4.0 technologies assist SMEs in similar pandemic situations?

RQ4: Can IR 4.0 technological adaptations by SMEs become a means of increased resilience?

Previous studies have reviewed the literature regarding IR 4.0 application; however, there is a lack of focus of adoption of IR 4.0 technologies in the context of SMEs (Zabidin et al., 2020). Additionally, as the present study focuses on evaluating the implementation of IR 4.0 technologies in the post-pandemic period, it significantly adds to the existing literature. As a result, various stakeholders, including SMEs, technology developers and policymakers are provided with a comprehensive understanding to consider the elements that influence their adoption of IR 4.0 technologies.

The remainder of this study is structured as follows. The subsequent section is a detailed overview of the methodology and data collection. The third section presents the review results of 30 selected papers from 2019 to 2022. An overview of findings and discussions in similar studies is provided in Section 4, while the final section concludes the study with contributions, limitations, and future research directions.

2. Methodology

The current systematic literature review methodology has evolved in medicine and social science to produce quality literature reviews that can summarise literary findings in a specific domain and assist policymaking and future research (Mohamed Shaffril et al., 2021). The PRISMA methodology was utilised to conduct the systematic literature review in the present study (Page et al., 2021) between July 1st 2022 and September 20th 2022. The data collection and analysis involved several steps in generating a database of the reviewed papers and easily collecting the required information. The PRISMA chart in Figure 1 is an overview of the entire data collection process.

The third overall strategy was also described in detail. The research process began with identifying the most suitable databases, namely Scopus and WoS. Another search engine included in the data extraction process was Google Scholar. These databases were selected due to being mostly used in international management studies and are the most preferred online libraries among major universities (Martín-Martín et al., 2018; Page et al., 2021). The databases worked well to provide various publications for the current review. Google Scholar was the main search engine and the most common and easiest free academic research tools (Gusenbauer, 2019). The COVID-19 pandemic, which emerged in 2019, caused disruptions across industries and caused a significant shift in business environment. By focusing on papers published during and after the pandemic, the study aimed to capture the immediate and evolving responses of SMEs towards adapting to the new conditions. Additionally, the study targeted the years up to 2022 to capture the post-pandemic insights and ensure the inclusion of the most current and relevant research findings available at the time of the study. The study intended to provide the up-to-date and accurate understanding of how SMEs adapted to changing business landscape and implemented IR 4.0 technologies.

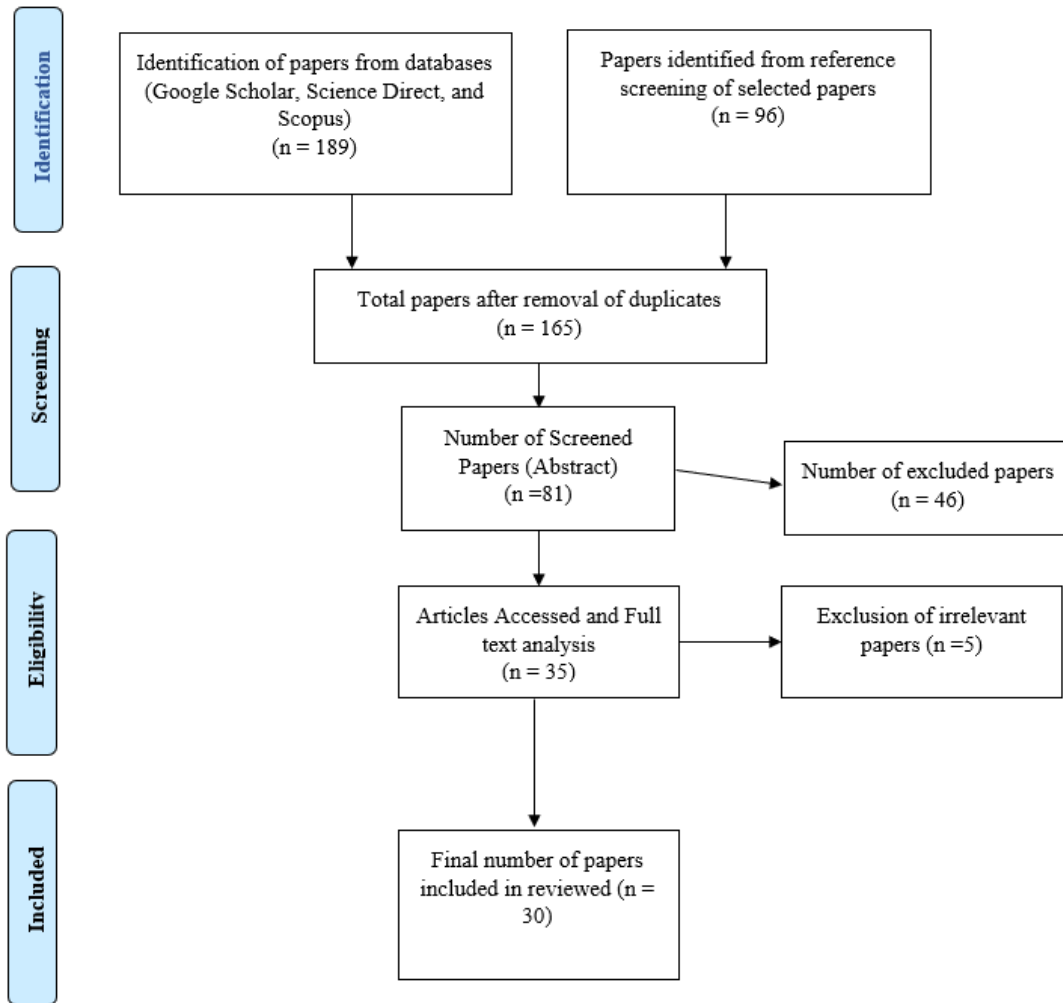


Fig.1: PRISMA Flowchart

Note: Author's Elaboration

To retrieve relevant articles, the researcher adopted keywords related to the objectives of the study. Keywords such as “Industry 4.0” or “Smart technologies” or “I4.0 technologies” were used coupled with the keywords for the contextual setting including “SMEs” or “small and medium enterprises” and “pandemic” or “Covid-19.” Using these keywords, four keyword-based strings were used on all the databases and search engines, namely “Adaptation of IR 4.0 during pandemic COVID-19 among SMEs”, “SMEs 4.0 and COVID-19”, “Industry 4.0, SMEs, COVID-19”, and “Industry 4.0 in SMEs”, which assisted in extracting numerous studies. The filters available in various databases and the search engine were further utilised to narrow the search at each filtration stage. Table 1 presents the results from the first search using the key string for each of the sources.

Table 1: Step One of Data Collection

	Scopus	WoS	Google Scholar	Total
Adaptation of IR 4.0 during the COVID-19 pandemic among SMEs	98	64	161	323
SMEs 4.0 and COVID-19	109	76	271	456
Industry 4.0, SMEs, COVID-19	81	89	175	345
Industry 4.0 in SMEs	213	121	233	567
				1691

Note: Author's Elaboration

The second phase involved filtering papers that exclude Industry 4.0 based on business, management, social science, and finance selections on Scopus and WoS. Moreover, the years and business and management filters were applied to Google Scholar, as depicted in Table 2.

Table 2: Step two of Data Collection

	Scopus	WoS	Google Scholar	Total
Adaptation of IR 4.0 during the COVID-19 pandemic among SMEs	98	64	161	73
SMEs 4.0 and COVID-19	109	76	271	109
Industry 4.0, SMEs, COVID-19	81	89	175	121
Industry 4.0 in SMEs	54	21	54	129
				432

Note: Author's Elaboration

Non-peer-reviewed articles published in international journals were also excluded. Moreover, non-English articles were removed. This step involved reading abstracts to ensure they followed the study requirements. Furthermore, any literature that is not considered scientific, such as chapters of books or conference papers, = was excluded. The resulting papers (also depicted in the PRISMA chart in Figure 1) are presented in Table 3.

Table 3: Step Three of Data Collection

	Scopus	WoS	Google Scholar	Total
Adaptation of IR 4.0 during the COVID-19 pandemic among SMEs	23	22	20	65
SMEs 4.0 and COVID-19	19	21	17	57
Industry 4.0, SMEs, COVID-19	36	32	19	87
Industry 4.0 in SMEs	12	51	13	76
				285

Note: Author's Elaboration

The 285 selected papers from various resources were considered fit for the research objectives as various filters were applied. At this stage, the researcher analysed the abstracts upon removing all the duplicates. A total of 35 papers were selected for full screening after abstract analysis and 30 of which were selected in the final data set. Furthermore, the quality of the articles was assessed based on the

processes adopted by prior researchers (Spanos & Angelis, 2016). The checklist criteria were also adapted from previous scholarly works (Sadoughi et al., 2020). The quality assessment criteria included the adequacy of the research objectives discussion, the clarity of the research problem and questions, the availability and thorough description of utilised data, the comprehensive explanation of the adopted methodology, and the comprehensive presentation of research results that effectively address the research questions.

Table 4: Final Steps of Data Collection

	Scopus	WoS	Google Scholar	Total	Removed
Duplicates	46	72	2	120	All
Abstract Overviewed	40	54	71	165	46
Full Paper Screening	11	14	10	35	5
Final Selection	12	11	7	30	None

Note: Author’s Elaboration

3. Results

The results were divided into five sections. In the first section, the fundamental characteristics of the reviewed papers were presented. The second section summarised the methodological overview of the selected papers. In the third section, the risk and issues encountered by SMEs during COVID-19 were reported. Meanwhile, the fourth section summarised the IR 4.0 strategies presented in the reviewed papers and the potential benefits of the COVID-19 pandemic. The final section presented how the IR 4.0 adaptations increased SMEs’ resilience based on the reviewed papers.

3.1. Characteristics of Papers

The first characteristic that was examined was the publishing years of the papers. Figure 2 indicates that the papers were published from 2019 to 2022. Systematic reviews normally report results based on research of over 10 years. Nonetheless, the search in the current study was limited to 2019 to 2022 as the objectives required analysing the post-pandemic impact and IR 4.0 strategies among SMEs. No papers were extracted from 2019, while 13 were extracted from 2020, 10 from 2021, and seven from 2022.

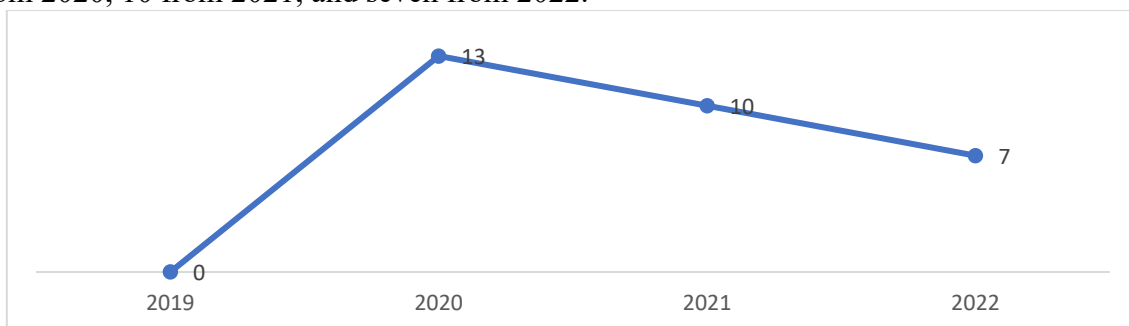


Fig.2: Distribution of Reviewed Papers Per Year

Note: Author’s Elaboration

Analysis of the journals included in the current review revealed many international journals. In contrast, only two journals had over one paper contributed to the final set of reviewed papers (see Table 5).

Table 5: Journal Distribution of Reviewed Papers

Journal Name	Number of Papers
Business Excellence and Management	1
Computers & Industrial Engineering	1
Computers in Industry	1
Environmental Hazards	1
Academy of Marketing Studies Journal	1
Geografia	1
Handbook of Research on Global Networking Post-COVID-19	1
Information Systems Frontiers	1
International Journal of Disaster Risk Reduction	1
International Journal of Innovation Studies	1
International Journal of Productivity and Performance Management	1
International Journal of Science, Technology & Management	1
<i>J. Xi'an Univ. Arch. Technol</i>	2
Journal of Business Research	1
Journal of Innovation and entrepreneurship	1
Journal of Intelligent Manufacturing	1
Journal of International Studies	1
Journal of Occupational and environmental medicine	1
Journal of Open Innovation: Technology, Market, and Complexity	1
Journal of Small Business & Entrepreneurship	1
Production Planning & Control	1
R&D Management	1
Research in Transportation Economics	1
SN Applied Sciences	1
<i>Sustainability</i>	3
The Indonesian Accounting Review	1
Total	30

Note: Self Elaboration

Table 6 summarises the number of authors per paper. The largest contribution was from two or three authors (30% each), followed by 20% of papers with four authors, 10% with five authors, 7% with one author, and only 3% with over five authors. This finding is expected considering that over five authors are more common in engineering research. Business research usually has two to five authors (Piccarozzi et al., 2018).

Table 6: Number of Authors per Paper

n of Authors	Number of Papers	Percentage
1	2	7%
2	9	30%
3	9	30%
4	6	20%
5	3	10%
5+	1	3%

Note: Author's Elaboration

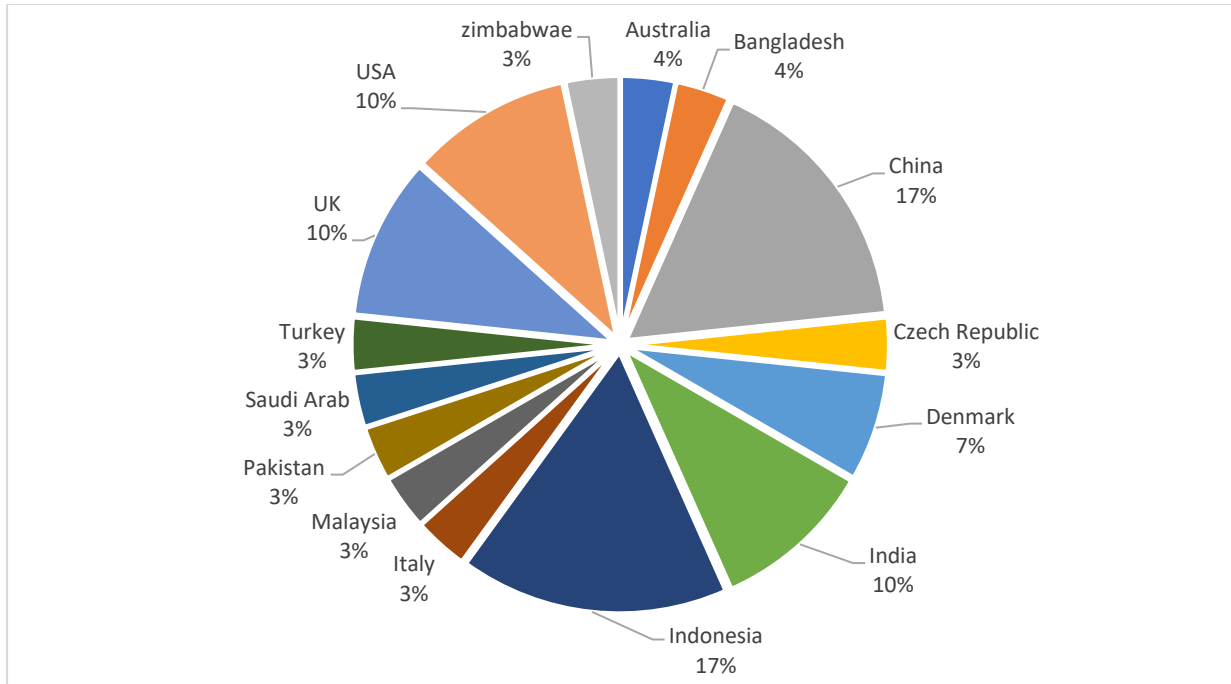


Fig.3: Country-Wise Distribution of Reviewed Papers
 Note: Author’s Elaboration

The analysis revealed that research contributions from different countries were included in the review. The most significant contribution was from China and Indonesia, with 17% of the research from each country. India, the USA, and the UK contributed 10% each. Denmark contributed 7% of the papers, and Bangladesh and Australia contributed 4% of the research papers. In comparison, the remaining countries that contributed 3% were Zimbabwe, Turkey, Saudi Arabia, Pakistan, Malaysia, Italy, and the Czech Republic.

3.2. Methodological Overview

The reviewed paper methodology analysis disclosed that 20 of the included papers were empirical, while the remaining ten were conceptual. Most empirical research was published in 2020, which has declined since then. Meanwhile, conceptual research experienced growth over the years.

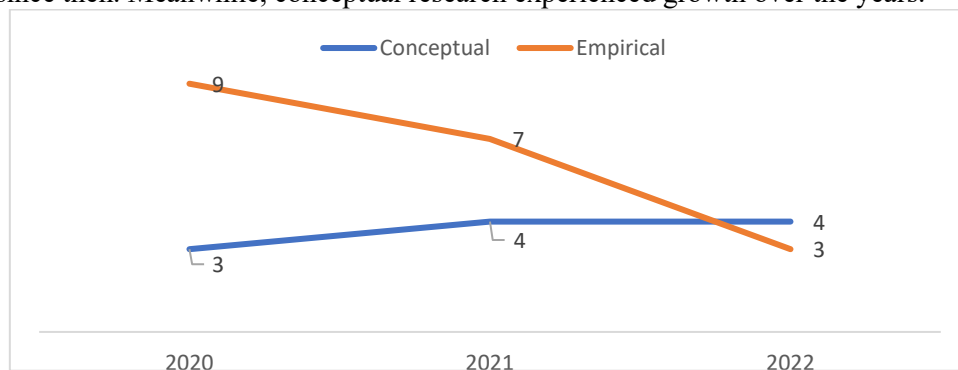


Fig.4: Type of paper per year
 Note: Author’s Elaboration

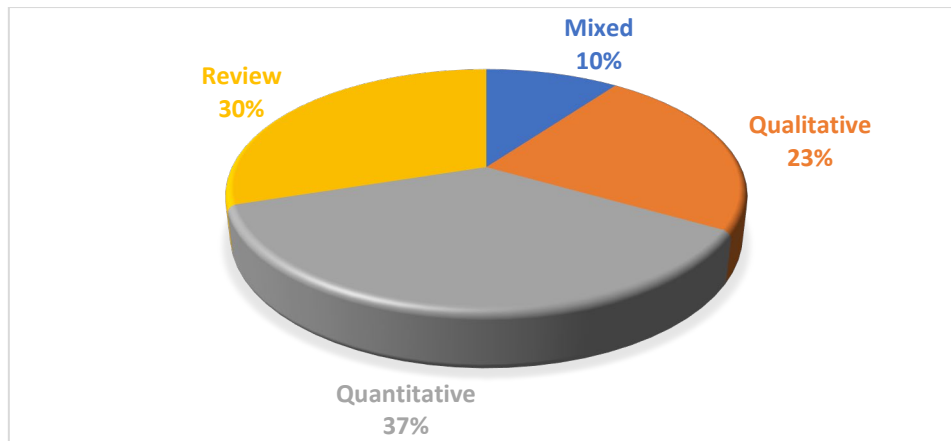


Fig.5: Methodological Type Distribution of Papers
 Note: Author's Elaboration

Figure 5 depicts the type of methodologies used in the papers. The majority of papers employed the quantitative method (37%). All papers were based on survey-based analysis, with data collected using questionnaires. In contrast, 30% of the included papers were review papers. One of these papers was a literature survey, while the remaining were systematic review papers.

Meanwhile, 23% of the reviewed papers were qualitative. Four of the seven qualitative papers were based on interviews, whereas the remaining three were case study-based analyses. A total of 10% of the papers were mixed method-based papers. One study was a mix of case study-based analysis and a semi-structured interview, the second was a field observation and literature analysis, and the last combined a questionnaire and an interview-based data collection.

3.3. Risks and Issues Encountered by SMEs Due to COVID-19

The sections below discuss and categorise the risk categories SMEs encounter due to the COVID-19 pandemic. Table 7 summarises the classification of the findings of the 15 reviewed papers. In terms of the patterns that emerged in risks and issues, 10 out of 15 papers covering risks were concerned with financial challenges while activity disruption due to COVID-19 was mentioned in six papers. The most strongly elaborated and discussed risk and issues were related to financial and cost-related challenges.

3.3.1 Financial and cost-related challenges for SMEs

Businesses across the global market encountered the financial impacts of the pandemic. Nevertheless, the financial burden severely affected SMEs due to the resource shortage to reduce or manage operating costs, namely mortgage payments, utilities, rents, and insurance policies (Giunipero et al., 2022; Zutshi et al., 2021). The issue during the early pandemic was whether the attorneys would survive due to the existential dispute of meeting financial needs and business restrictions. The SMEs encountered multiple challenges, such as lack of access to raw materials (Suryani et al., 2021), zero to low market demand (Cepel et al., 2020), and refusal of labour or workers to rejoin the workforce due to fear of infection (Lu et al., 2020; Zutshi et al., 2021), specifically among SMEs in China (Lu et al., 2020). Contingency plans that were well designed would enable SMEs to meet fixed and overhead costs and stay functional for three to six months, even without cash inflow or slower inflow (Adam & Alarifi, 2021; Omar et al., 2020).

The SMEs encountered severe liquidity crises due to the inability or delayed reimbursement of permanent operational costs (Lu et al., 2020). Furthermore, studies highlighted that the production of SME products was hindered and under pressure due to a lack of human resource availability, increased labour cost, and low employee turnover ratio (Lu et al., 2020; Omar et al., 2020; Zutshi et al., 2021). The SMEs that operated with self-employed entrepreneurs, which had no labour requirements, experienced easier survival and outlast the pandemic due to no challenges and additional costs associated with employee relief provision during the layoffs (Giunipero et al., 2022; Mendy, 2022;

Zutshi et al., 2021).

Nyanga and Zirima (2020) revealed severe financial concerns among SMEs in Zimbabwe due to the lockdown, which impacted the overall economic condition of SMEs and led to layoffs and work obstructions. Similarly, SMEs in Malaysia were most significantly impacted in the supply chain and financial department domains, thus requiring government support for their revival (Jc & Tc, 2020). As for the positive aspect of the SMEs' financial conditions, the economic losses experienced by these enterprises were more manageable and recoverable than larger organisations (Lu et al., 2020; Mendy, 2022; Suryani et al., 2021).

3.3.2 The COVID-19-Induced Activity Disruption among SMEs

The SMEs' activities and productions worldwide were severely interrupted due to the pandemic. Various studies emphasised that the supply chains, logistics, and procurement processes among SMEs were disrupted due to transportation obstruction during the pandemic, which increased the need for government and expert interventions to enhance resilience and perseverance in the SMEs (Hadi, 2020; Hadi & Supardi, 2020; Pu et al., 2021). Practical strategies for revitalising the Malaysian tourism industry were valuable for improving national SME outcomes (Hadi and Supardi (2020). Meanwhile, support from various partners, such as the government, agents, and communities for SMEs, can facilitate post-pandemic recovery. The use of protective measures, better business policy development, and advanced technologies allow SMEs to recover from the disruption caused by the pandemic (Hadi, 2020; Jc & Tc, 2020; Lu et al., 2021; Suryani et al., 2021).

3.3.3 The COVID-19 Induced Existential Challenges for SMEs

Lu et al. (2021) investigated 4,807 SMEs from the Chinese province of Sichuan. The pandemic drastically affected entrepreneurs' income capacity, resumption abilities, and confidence in SMEs, which created existential challenges for SMEs across various business sectors. Although these findings were specific, they are generalisable to other SMEs worldwide, which encountered similar economic and financial issues. As the pandemic brought universal impact on businesses' ability to generate revenue and conduct normal business operations, it resulted in a shared experience among SMEs globally. Nevertheless, some studies debated that the pandemic created opportunities for SMEs to enhance their service and product qualities by innovating their plans and establishing innovative strategies within their processing and manufacturing strategies (Yang & Chuang, 2020).

Table 7: Classification of Risks and Issues Reported by Reviewed Papers

Topic	Subtopic	Number of Papers	Percentage	References
Risks and Issues Encountered by SMEs	Financial and cost-related challenges	10 out of 15	66.7%	(Adam & Alarifi, 2021; Cepel et al., 2020; Giunipero et al., 2022; Jc & Tc, 2020; Lu et al., 2020; Mendy, 2022; Nyanga & Zirima, 2020; Omar et al., 2020; Suryani et al., 2021; Zutshi et al., 2021).
	The COVID-19 Induced Activity Disruption	6 out of 15	40%	(Hadi, 2020; Hadi & Supardi, 2020; Jc & Tc, 2020; Lu et al., 2021; Pu et al., 2021; Suryani et al., 2021)

The COVID-19 Induced Existential Challenges	2 out of 15	1.3%	(Lu et al., 2021; Yang & Chuang, 2020)
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Note: Author’s Elaboration

3.4. The IR 4.0 Strategies and Potential Benefits for Use by SMEs in COVID-19

Numerous strategies were offered to organisations in terms of IR 4.0. The evidence regarding the potential benefits was mentioned in a total of 17 articles, indicating that over half of the included articles considered the opportunities with the application of IR 4.0. These strategies involved increasing automation and digitisation of processes, which are the core requirement for business survival and continuity during the pandemic. One of the significant benefits enabled by IR 4.0 technology is the data-driven decision making enabled by the use of big data analytics whereas cloud computing enabled remote work and optimized services. This allowed prediction of disease spread as well. Operational continuity and remote monitoring can be facilitated by IoT. Additionally, it was noted that system integration improved communication, transparency, and informed decision-making, supporting virtual services. Process flexibility enhanced adaptation, while VR and AR boosted performance and safety. Additive Manufacturing quickly addressed crisis needs. Therefore, these strategies provided multiple benefits on the impact on SMEs and their performance during the pandemic, as discussed in detail in Table 8.

Table 8: Benefits of IR 4.0 Technologies for SMEs

Technologies offered by IR 4.0	Description	Benefits to SMEs in COVID-19	References
1 Big Data Analytics	Big data analytics allows companies to develop competencies, such as recognition of patterns or extracting information from the Internet of Things (IoT)-based equipment, increase the trackability and traceability of production processes to gain more control over manufacturing and delivery, optimisation of resource usage, and processing of large-scale data of customers to improve overall service provision. Moreover, big data analytics allows small and large companies to develop more sustainable practices within the organisation in the long term.	During the pandemic, organisations can benefit from the capabilities of big data by implementing these strategies to predict likability and chances of disease spread to develop more effective control strategies. Furthermore, SMEs can enjoy the power of real-time data as big data capabilities allow real-time tracking and prediction, thus allowing business personnel to make better decisions in the life cycle process. Furthermore, policy development is better informed by investment in such strategies.	(Chatterjee et al., 2022; Priyono et al., 2020; Song et al., 2022)
2 IoT	The IoT allows the collection of data from various devices linked to the Internet to improve performance, use of energy, and overall optimisation of cost and	The SMEs with employees working in proximity can use IoT-based strategies to monitor and police the employees regarding COVID-19-related	(Kumar & Ayedee, 2021; Samaranayake et al., 2022)

		<p>resource use. The IoT also allows the development of more flexible and reliable systems that ensure long-term sustainability at ethical considerations. Transitioning to automated systems that enable the collection of data from multiple sensors can also allow better monitoring of overall energy during product development, manufacturing, and distribution.</p>	<p>safety protocols. In addition to keeping social distancing, mask protocols, and other preventive measures under check, IoT strategies allow partial automation of SME manufacturing and distribution processes, thus improving business continuity in similar pandemic situations.</p>	
3	System Integration	<p>System integration denotes that all IT systems within an organisation are integrated and interconnected. This situation improves resource distribution and utilisation, allows for better human decision-making as it supports superlative human-computer interactions, and allows for a basis for automated decision-making in the overall system.</p>	<p>When the different departments of an SME are well connected in terms of communication with interconnected IT systems, artificial intelligence and data analytics can support in minimisation of disease spreading through prediction and monitoring capabilities. Furthermore, system integration also supports transparency, which improves communication between different human personnel and IT systems within the organisation. Moreover, the development of virtual services in the SME sector was helpful in response to the pandemic.</p>	<p>(Dutta et al., 2021; Messeni Petruzzelli et al., 2022; Priyono et al., 2020)</p>
4	Flexibility of Processes	<p>Process flexibility supported by IR 4.0 technologies ensures that SMEs' productivity is improved and the lead time is decreased as much as possible. Moreover, the energy consumption is reduced, and the overall resource utilisation is optimised.</p>	<p>Modern technologies, namely virtual reality systems, robotics, and other systems, enable more flexible manufacturing situations for SMEs, which will benefit SMEs in the future by supporting employability when in need.</p>	<p>(Priyono et al., 2020; Song et al., 2022)</p>
5	Virtual/Augmented reality	<p>The use of virtual and augmented reality-based practices in the industry allows for flexible, efficient, and more reliable performance of high-tech jobs, even when performed by average skilled workers, given that the highly integrated human-machine interaction provides</p>	<p>Technologies, such as virtual and augmented reality, have facilitated firms building online and virtual workspaces during the pandemic. Similarly, SMEs can enjoy these benefits in future pandemics by consolidating and bringing workers together in virtual spaces. Such strategies</p>	<p>(van Lopik et al., 2020; Yıldızbaşı & Ünlü, 2020; Yu & Schweisfurth, 2020)</p>

	stronger training and learning opportunities. Hence, such technologies increase comfort, ease of use, and performance gains.	ensure business continuity and the safety of people while reducing disease spread.	
6 Additive Manufacturing	The benefits of additive manufacturing strategies include reduced waste production, highly flexible and consistent geometrics of designs, cost-effective prototyping, easier and more flexible manufacturing of required spare parts, and increased throughput rate.	Additive manufacturing, known as 3D printing, was employed in critical and unprecedented situations during the pandemic. This process is an innovative IR 4.0 technology that has aided manufacturing of medical aids, ventilator parts, and masks during the pandemic. As for SMEs, this strategy supports the use of socio-Technical System theory during the pandemic to ensure the suitable use of such technologies for the betterment of the population.	(Chaudhuri et al., 2021)
7 Cloud Computing	Systems supported by cloud computing are flexible, reliable, and transparent, support improved data sharing, enhance supply chain communication, and increase the ability of monitoring and management. Furthermore, the system is supported by easy upgradeable technology with low running costs and energy requirements.	The pandemic shifted all kinds of services and business dealings online in response to the health crisis arising from the pandemic. Heavy amounts of data were being collected and managed by organisations during this time, which led to storage challenges. Cloud computing and storage services are a miraculous IR 4.0 strategy that allows companies to host data and services on clouds, which are memory components not physically owned by them. Cloud computing in SMEs is easier to use and cheaper than creating their data storage units. Therefore, cloud computing technology was helpful in the pandemic for small and large organisations based on analysing real-time data and optimising service provision.	(Akpan et al., 2022; Prihatiningtias & Wardhani, 2021)

Note: Author's Elaboration

IR 4.0 resulted in the development of numerous effective technologies during the pandemic. For instance, they allow more automated and effective disease screening and prevention to ensure business continuity. The challenges arising from the pandemic forced companies to adapt the technologies to

develop integrated solutions to overcome business challenges. Table 9 summarises the major technologies of IR 4.0 that were useful during the pandemic, including data-driven technological innovations, such as big data, cloud computing, and RV/AR strategies. In terms of frequency, 17 of the 30 articles included in the review covered the usefulness of IR 4.0 adaptation for SMEs during the pandemic. The most strongly mentioned IR 4.0 technologies in the articles were big data analytics and cloud computing.

Big data enables the detection of underlying trends to reveal useful information (Chatterjee et al., 2022; Priyono et al., 2020). Big data also improves trackability and gives management stronger control regarding resource optimisation (Song et al., 2022). The SMEs empowered by AI-driven strategies and cloud computing competencies also create better and more effective decision-making (Akpan et al., 2022; Prihatiningtias & Wardhani, 2021). Technologies involving system integration, IoT, and AR allow SMEs to upgrade system reliability and flexibility, which leads to supporting digital sourcing options and managing a smooth logistics process (Kumar & Ayedee, 2021; Omar et al., 2020; Priyono et al., 2020; Song et al., 2022). Increased communication across various components of the organisations and their supply chains was also assisted by flexibility and integration, thus optimising SMEs' performance outcomes.

3.5. Use of IR 4.0 Adaptations for SME Resilience during COVID-19

The reviewed literature revealed that the significance of SMEs in global economic development. Nonetheless, the pandemic damaged these businesses (Akpan et al., 2022; Cepel et al., 2020; Giunipero et al., 2022). Studies outlined recommendations on how SMEs can utilise IR 4.0 technologies to recover from the negative impacts of COVID-19. Although the beginning of 2020 revealed much confusion and fear of the disease, the past two years highlighted significant change, which implied acceptability and adaptability. This adaptability is only possible if the companies are open to technological creativity and innovative process modifications (Adam & Alarifi, 2021; Hadi, 2020; Hadi & Supardi, 2020; Stentoft et al., 2021).

The IR 4.0 and intelligent system development allow companies to employ smart strategies for integration that incorporate special interfaces, hardware, and software in organisational functionality to assist in the vertical or horizontal integration with the digital environment, (Hussain et al., 2021).

Horizontal integration allows technology integration to support effective data and information exchange between various SME components, such as machines, employees, customers, and various participants in the supply chain (Giunipero et al., 2022; Hadi & Supardi, 2020; Hussain et al., 2021). Vertical integration of technologies in an SME is a more remote and integrated use of numerous technologies, such as cloud computing and AR (Chaudhuri et al., 2021; Dutta et al., 2021; Hussain et al., 2021). Horizontal and vertical integration and adaptations of IR 4.0 technologies and strategies during the pandemic facilitated companies in making better decisions and improved technological adaptation by SMEs. They enabled communication and interaction between multiple participants to assist in business continuity.

Various capabilities were provided to SMEs by comprehending the technologies offered by IR 4.0, which increased SMEs' resilience based on the reviewed literature. First, these technologies allow SMEs to develop functional capabilities resulting from the information exchange between numerous components of the manufacturing systems, which leads to the development of smart systems (Yu & Schweisfurth, 2020; Zutshi et al., 2021). Second, a capability that enabled companies to survive during the pandemic is developing decentralised control. The various components of organisational manufacturing, procurement, and other processes are decentralised, often geographically apart, and do not require local individualised control and command. Nevertheless, the component can be controlled over the Internet through decentralised commands (Stentoft et al., 2021; van Lopik et al., 2020; Yıldızbaşı & Ünlü, 2020).

Data is also a critical capability-enhancing feature of IR 4.0 as the technologies generate increased

volumes of data that can assist in better predictability of functionality and productivity and manage informed decision-making (Kumar & Ayedee, 2021; Mendy, 2022; Song et al., 2022; Yang & Chuang, 2020). The flexibility and modularity of services and systems offered by the use of AR, IoT, and similar technologies increase the digitisation of the overall processes and functionality of SMEs, hence increasing resilience to similar future pandemic situations (Hadi, 2020; Hadi & Supardi, 2020; Jc & Tc, 2020).

Several studies reviewed the potential of IR 4.0 in resolving the issues encountered by SMEs during COVID-19. The aspects of how IR 4.0 is effective in increasing the resilience of SMEs against COVID-19 are listed as follows:

- Strategies involving big data analytics and cloud computing have been helpful in the survival of SMEs and larger organisations due to the predictability and reliability of results (Chatterjee et al., 2022; Priyono et al., 2020; Song et al., 2022).
- System integration helped increase SME adaptability and resilience in managing COVID-19-related challenges (Dutta et al., 2021; Messeni Petruzzelli et al., 2022; Priyono et al., 2020).
- Another technology that aided in managing COVID-19-related challenges is the IoT, which ensures maximisation of data production, data monitoring, automation of decision making, and other similar outcomes for SMEs to adapt to the required business environment changes and ensure business continuity (Kumar & Ayedee, 2021; Samaranayake et al., 2022)
- Manufacturing flexibility is also useful in enhancing production capacity by using flexible systems and additive manufacturing, which ensures the sustainability of manufacturing SMEs in the future (Chaudhuri et al., 2021; Priyono et al., 2020; Song et al., 2022).

Big data analytics can resolve the issues and challenges arising from COVID-19 in market penetration and access (Adam & Alarifi, 2021; Chatterjee et al., 2022; Chaudhuri et al., 2021). Moreover, AR technologies backed up by cloud computing can become a resource that overcomes the issues of labour shortages and provides the required medical support to SME employees (Adam & Alarifi, 2021; Dutta et al., 2021; Hadi & Supardi, 2020). The use of robotics, AR, and VR can also improve the effectiveness and efficiency of security and safety protocols that create a safer work environment for employees and increase consumer safety (van Lopik et al., 2020; Yıldızbaşı & Ünlü, 2020; Yu & Schweisfurth, 2020).

Hussain et al. (2021) emphasised that big data analytics, IoT, and cloud computing strategies can improve transitioning in cost-sharing opportunities in the industry, create labour-related incentives to increase attraction for the labour class and assist in recovering the overall logistics system. These strategies create opportunities for enhanced business openness that increase control and transparency in the supply chain, strengthen system configuration and integration, and create an environment of employee and consumer acceptance of IR 4.0 technologies (Messeni Petruzzelli et al., 2022; Pu et al., 2021; Song et al., 2022; Yu & Schweisfurth, 2020).

Table 9: Distribution of IR 4.0 Strategies Supporting SMEs during COVID-19

Strategy Supporting SMEs	Papers	%	References
Big Data Analytics	13 of 17	76.5%	(Akpan et al., 2022; Chatterjee et al., 2022; Dutta et al., 2021; Hussain et al., 2021; Kumar & Ayedee, 2021; Messeni Petruzzelli et al., 2022; Priyono et al., 2020; Pu et al., 2021; Samaranayake et al., 2022; Song et al., 2022; Stentoft et al., 2021; Yıldızbaşı & Ünlü, 2020; Yu & Schweisfurth, 2020)
IoT	10 of 17	58.8%	(Akpan et al., 2022; Dutta et al., 2021; Kumar & Ayedee, 2021; Messeni Petruzzelli et al.,

			2022; Priyono et al., 2020; Pu et al., 2021; Samaranayake et al., 2022; Stentoft et al., 2021; Yıldızbaşı & Ünlü, 2020; Yu & Schweisfurth, 2020)
System Integration	9 of 17	52.9%	(Akpan et al., 2022; Dutta et al., 2021; Kumar & Ayedee, 2021; Messeni Petruzzelli et al., 2022; Priyono et al., 2020; Samaranayake et al., 2022; Stentoft et al., 2021; Yıldızbaşı & Ünlü, 2020; Yu & Schweisfurth, 2020)
Flexibility of Processes	10 of 17	58.8%	(Akpan et al., 2022; Dutta et al., 2021; Kumar & Ayedee, 2021; Messeni Petruzzelli et al., 2022; Priyono et al., 2020; Samaranayake et al., 2022; Song et al., 2022; Stentoft et al., 2021; Yıldızbaşı & Ünlü, 2020; Yu & Schweisfurth, 2020)
Virtual/Augmented reality	3 of 17	17.6%	(van Lopik et al., 2020; Yıldızbaşı & Ünlü, 2020; Yu & Schweisfurth, 2020)
Additive Manufacturing	1 of 17	5.8%	(Chaudhuri et al., 2021)
Cloud Computing	12 of 17	70.5%	(Akpan et al., 2022; Dutta et al., 2021; Kumar & Ayedee, 2021; Messeni Petruzzelli et al., 2022; Prihatiningtias & Wardhani, 2021; Priyono et al., 2020; Pu et al., 2021; Samaranayake et al., 2022; Stentoft et al., 2021; Yang & Chuang, 2020; Yıldızbaşı & Ünlü, 2020; Yu & Schweisfurth, 2020)
Total	17 (out of 30)		

Note: Author's Elaboration

The results section elaborated on the findings of the articles which showed that most studies in the review were published in the year 2020 and adopted a quantitative methodology. A summary of the findings is presented in the table below.

Table 10 Summary of the key findings of the results.

Dimension	Key Findings	Papers
Risks and Challenges	Financial and Cost-related issues during lockdowns, low turnover, slow cash inflow	10
	Supply chain disruption caused by the pandemic	6
	Existing challenges; confidence, income capacity, reopening ability	2
Benefits	Traceability, service provision, data sharing,	17

	flexible and reliable systems, COVID-19 protocol monitoring, productivity enhancement, optimisation of resource utilisation, flexibility in processing and manufacturing,	
Most Prominent Technologies for Strategy	Big data analytics	13
	Cloud computing	12
Moderate Prominence for Strategy	IoT	10
	System Integration	9
	Flexibility	10
Emerging Technologies for Strategy	VR / AR	3
	Additive Manufacturing	1

4. Discussion

The business world underwent a dramatic change due to COVID-19. The start of the pandemic witnessed an absence of any medical consensus on the protocol of treatment, or any vaccine, which raised fear and misinformation. Nevertheless, over time, control measures such as lockdowns, confinement, and social distancing enabled disease control significantly. The reports in the review indicated that creating a new normal for business strategies and operations was essential for the continuity of SMEs in terms of conducting business. The SMEs were vulnerable and needed to recognise the opportunities and challenges to reinvent themselves and develop business strategies using the technological innovations of IR 4.0 to increase survival chances. These findings aligned with several reviewed papers (Giunipero et al., 2022; Hadi, 2020; Hadi & Supardi, 2020; Kumar & Ayedee, 2021; Mendy, 2022; Priyono et al., 2020; Zutshi et al., 2021) as well as other similar studies (Adam et al., 2021; Bellandi, 2020; Michna & Kruszewska, 2022; Mohammadian et al., 2020). The current business domain revealed a significant development of industrial practices that allow switching towards online business as the ways consumers behave during the lockdown and movement restrictions have changed (Fitriasari, 2020; Guo et al., 2020; Kala'lembang, 2021; Ssenyonga, 2021; Tong & Gong, 2020). In line with technological revolutions, the application of IR 4.0 involve threats, opportunities, and costs. Nonetheless, developed and emerging economies need to increase the use of IR 4.0 to ensure business revitalisation and recovery (Adam et al., 2021; Bellandi, 2020; Dyduch et al., 2021; Tong & Gong, 2020).

The pandemic provided SMEs with an opportunity to view the challenges of IR 4.0 from a new perspective and identify strategies that can be used to overcome the hindrances in the adaptation and adaptation of these technologies. A critical factor that needs to be considered is that these technologies are costly, which can be burdensome for SMEs. Nevertheless, the aftermath of the recent pandemic revealed that SMEs could not survive if they do not adopt technological innovations, as neglecting this aspect would obstruct business. The findings are elaborated on in terms of each research question in the subsequent sections.

RQ1: What are some of the risks and issues SMEs encounter due to the pandemic?

The classification of risks and issues encountered by SMEs during the COVID-19 pandemic include the disruption of activity and existential, financial, and cost-related challenges. Similar studies also reported comparable issues encountered by SMEs and larger organisations (Ali et al., 2021; Caballero-Morales, 2021; Grondys et al., 2021).

RQ2: What IR 4.0 technologies are the most suitable for SMEs?

The most commonly reported beneficial technologies of IR 4.0 that allow SMEs to digitise include big data-powered analytical abilities, cloud computing, system integration, and the flexibility of processes, which align with past research (Moeuf et al., 2018; Stentoft et al., 2019). These strategies were helpful in the pre-pandemic era in developing useful capabilities and capacities by SMEs. Moreover, technologies such as VR, AR, and Additive manufacturing have created a new meaning for SMEs in the post-pandemic era, enabling better monitoring of disease-related restrictions and digitising services and processes.

RQ3: How can IR 4.0 technologies assist SMEs in similar pandemic situations?

In future pandemic situations, SMEs will not encounter similar business continuity challenges as adopting IR 4.0 technologies would equip them with digital capabilities that were previously absent in the SME sector.

RQ4: Can IR 4.0 technological adaptations by SMEs become a means of increased resilience?

The findings indicated that SMEs are more resilient compared to the pre-pandemic era with digitisation and transitioning to cloud computing, big data, AR/VR technologies, and system flexibility and integration.

4.1. Theoretical Implications

The study's findings offer significant theoretical implications for adding valuable knowledge regarding IR 4.0 technology adoption and resilience within the SME context. The exploration of how SMEs responded to the COVID-19 pandemic through the lens of Industry 4.0 (IR 4.0) adaptation enhances the existing literature by highlighting how external shocks can stimulate SMEs to leverage on technological innovations as tools for recovery. This research contributes to the emerging research and debate surrounding the role of technology in enhancing business resilience, particularly in the face of unprecedented disruptions such as the pandemic. In addition, the study determined the importance of recognizing both the opportunities and challenges associated with IR 4.0 adoption for SMEs and highlighted how such technologies can redefine their strategies, capabilities, and digital competencies. This study extends the theoretical foundations of both SME management and technology adoption by providing a holistic understanding that acknowledges the multifaceted implications of technological adoption and integration for SMEs.

4.2. Practical Implications

The research findings provide critical implications for policymakers and SME managers. Policymakers can draw valuable insights from the study's exploration of the crucial role of IR 4.0 technologies in enhancing SME resilience. Hence, policies that are focused on providing incentives to SMEs in order to facilitate technology adoption and integrate can enhance their resilience and recovery from disruptions along with promoting long-term sustainability. Collaboration between policymakers and industry stakeholders can be beneficial in addressing the risks, such as financial and cost-related challenges, associated with the adoption of advanced technologies. SME managers can also gain from the findings of the study as it highlights the importance of integration technologies like big data analytics, additive manufacturing, cloud computing, and system integration as key enablers of resilience. Moreover, there is need for adaptive management where SMEs continually reassess their strategies in order to respond to changing circumstances. Managers can engage in capacity building, enhancing digital skills of workforce in order to foster a culture of technology adoption and innovation.

4.3. Limitations and Future Research Recommendations

The results presented in the study have to be interpreted within the context of several limitations. Regarding methodological limitations, the focus on English-language journal papers might have resulted in the exclusion relevant research from non-English sources. Future research can include a broader range of languages and sources to offer additional insights. Furthermore, recent developments beyond the study's time frame could not be included; therefore, future studies are required to capture ongoing advancements and adoption of IR 4.0 among global SMEs. The lack of specification regarding the geographical regions or specific sector could limit the generalizability of findings; hence, it is recommended that sector or region focused research can provide understanding on variations in adoption of IR 4.0 and its impact on SMEs. Similarly, future research could focus on a particular IR 4.0 technology in order to provide a detailed understanding of how a specific IR 4.0 technology impacts SMEs. Lastly, future research could examine other factors such as support mechanisms for adoption of IR 4.0 in SMEs to further build on the findings.

5. Conclusion

This systematic review highlighted that IR 4.0 strategies are helpful in the revitalisation, recovery, and resilient build-back of SMEs globally. The review included 30 papers, from quantitative surveys to semi-structured interviews, case studies, and systematic reviews. Summarily, SMEs are more digitised and resilient post-pandemic due to the increased adaptation of IR 4.0 technologies. The findings indicated that SMEs encountered various risks during the COVID-19 pandemic, including disruptions to business activities and existential, financial, and cost-related challenges. Furthermore, IR 4.0 offers various beneficial technologies that allow SMEs to digitise, including big data-powered analytical abilities, cloud computing, system integration, and the flexibility of processes, which align with past studies. The results also indicated that SMEs would be better equipped to overcome business continuity challenges in future pandemics by adopting IR 4.0 technologies. These technologies provide SMEs with previously absent digital capabilities, facilitating business continuity during challenging times. Additionally, transitioning to cloud computing, big data, and AR/VR technologies increase SME resistance compared to the pre-pandemic era. This outcome results from the increased flexibility and integration of these systems.

The present study contributes to business research and highlights the need for future research in SMEs' technological adaptation. The applicability of emerging technologies, such as additive manufacturing and AR technologies must be considered in SMEs. The review has added value to existing literature by showing how SMEs can respond to disruptive events through the implementation of technology for recovery and advancement. Policymakers are urged to create strategies that incentivize and facilitate SMEs' technology adoption in order to enhance their resilience and sustainability. The study provides guidance for SME managers for integrating IR 4.0 technologies into their operations which can enhance their capacity to adjust and recover from disruptions and foster a culture based on technological adoption. The study also highlighted several limitations, mainly no specification of any SME sector. Therefore, future research should focus on one or more SME sectors, such as manufacturing and service. Potential studies should also expand current literature with a specific survey on any IR 4.0 technology, namely big data, cloud computing, or AR/VR.

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