Kannan, S., & Gambetta, N. (2025). Technology-driven Sustainability in Small and Medium-sized Enterprises: A Systematic Literature Review. *Journal of Small Business Strategy*, *35*(1), 129–157. https://doi.org/10.53703/001c.126636

articles

Technology-driven Sustainability in Small and Medium-sized Enterprises: A Systematic Literature Review

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Keywords: SME, SDG, Sustainability, Technology, innovation, Systematic Literature

https://doi.org/10.53703/001c.126636

Journal of Small Business Strategy

Vol. 35, Issue 1, 2025

This systematic literature review explores how small and medium-sized enterprises (SMEs) leverage technology to integrate sustainability into their operations, thus contributing to the Sustainable Development Goals (SDGs). Through a comprehensive analysis of 208 articles from 147 journals, we identify eight key themes: external environment, organisational context, sustainability orientation, technology opportunities, innovation focus, knowledge management, assessment frameworks, and sustainability practices and outcomes. The study findings enable us to synthesise an integrated framework that illuminates the intersection of technology use and sustainability incorporation in SMEs. This review addresses critical literature gaps and provides a foundation for future research and practical applications in SME sustainability.

1. Introduction

The importance of small and medium enterprises (SMEs) in the global economy cannot be overstated. They represent approximately 90% of businesses and contribute up to 40% of national income in emerging economies and more than 50% of employment worldwide. SMEs play a pivotal role in driving economic growth and generating employment opportunities. They are important in enhancing societal well-being and fostering technological progress (Filho, 2015). However, SMEs face vulnerability regarding technological challenges, primarily due to their limited financial resources and expertise in effectively harnessing emerging technologies (Lopes, 2022). Financial technology (fintech), in particular, can play a significant role in the transition of SMEs towards more sustainable business models. The sustainability commitment of these companies influences their interest in investing in green technology, although economic and social value remains the primary motivation (Pizzi et al., 2021). While the commitment to sustainability influences their interest in investing in green technology, the primary drivers for these investments are often social and economic gains (Saunila et al., 2019).

Innovative technologies such as cloud computing provide SMEs with a means to maintain competitiveness against larger corporations by leveraging software and cutting-edge business systems to achieve economies of scale. Tech providers must know what SMEs need, while SMEs should keep updating themselves to achieve and maintain success (El-Haddadeh, 2020). However, adopting Industry 4.0 technologies for ethical and sustainable operations can be challenging, because of limited customer motivation, inadequate long-term planning, insufficient awareness of benefits, lack of management support and high initial costs. Challenges also extend to concerns about failure and demand uncertainty (R. Kumar et al., 2020).

In the pursuit of sustainable performance, SMEs prioritise technological and organisational factors over environmental considerations, which influence innovation, human resource management and green marketing. During the pandemic, adopting environmentally conscious procurement policies required SMEs to invest additional time and effort in sustainable development, to intensify research and development, and to embrace advanced technologies in production, services and marketing. Moreover, many SMEs demonstrated the potential to enhance their resilience by minimising hazardous waste and incorporating more eco-friendly materials (Alraja et al., 2022).

Given that micro, small and medium-sized enterprises significantly contribute to economies across both devel-

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oped and developing nations, further research is imperative to gain deeper insights into their sustainable development within the evolving globalised and digitalised landscape (Mukhoryanova et al., 2021).

We address this need by systematically reviewing the existing literature related to the use of technology by SMEs to incorporate sustainability into their business. On this basis, we synthesise trends and elaborate a theoretical framework for this important issue. In doing so, we contribute to the field of sustainability in SMEs, by providing a comprehensive up-to-date evaluation of the use of technology by SMEs to transform their business and make it more sustainable. This study enhances our understanding of the question, by analysing the latest academic papers, from a wide search of journals. By compiling and analysing a large body of literature in this field, we generate a comprehensive framework to provide a complete overview. Moreover, we examine several aspects in detail, including yearly journal trends, study distribution by region and journal, research methods, and prevalent themes. This investigation of how technology and innovation can improve the sustainability of small businesses could be of interest to managers, investors, regulators and academics, among others. Specifically, the study addresses the following research questions:

(i) What literature exists concerning the use of technology by SMEs to incorporate sustainability into their business?

(ii) What are the main issues addressed in the research on the use of technology by SMEs to incorporate sustainability into their business?

The rest of this paper is organised as follows: in Section 2, we explore the existing literature within the field to determine the research context. Section 3 then presents the study methods employed, after which we provide a comprehensive analysis of the literature considered. Potential directions for future research are discussed in Section 5, and finally the main conclusions drawn are summarised in Section 6.

2. Technology and SME sustainability

2.1. Use of different technologies by SMEs

According to a recent OECD survey, 70% of SMEs intensified their use of digital technologies following the outbreak of the COVID19 pandemic. Ameen et al. (2022) reported that in order to survive, SMEs in a wide range of industries incorporated innovative technologies such as mobile applications, AI, blockchain, and mixed and extended virtual reality. However, many need support to perform this transition, as they lack the skills, knowledge and capability to take advantage of the potential offered by these technologies (OECD, 2021). The OECD survey findings also reveal the existence of structural barriers to SMEs, such as inadequate business models and processes, insufficient investment or the absence of necessary collaterals to secure loans. In some cases, too, vital facilities such as a high-speed broadband service are not available.

Our literature review identified several innovative technologies that can contribute to the integration of sustainable practices and the development of a sustainable business model. One such is fintech, which can play an important role in the transition of SMEs towards a more sustainable business model and hence a better integration of circular economy practices (Pizzi et al., 2021). The sustainability commitment of these companies influences their interest in green technology, although the main motivation for investing in this field is usually to achieve added social and economic value (Saunila et al., 2019). Companies that address various goals and which are able to adapt to changing circumstances can make good use of applications and mobile devices as Industry 4.0. components. These are usually welcomed by the workforce, electricity costs are reduced, employee mobility is increased and company performance improved (Iakovets et al., 2022).

Innovative technologies such as cloud computing can enable SMEs to become more competitive against large companies, by achieving economies of scale via appropriate software and the latest business systems. To accomplish this, however, suppliers must understand the needs of SMEs, and these SMEs must continually update and adapt (El-Haddadeh, 2020).

Among other Industry 4.0 technologies that may be employed, Analytics and the Internet of Things (IoT) are considered the best for sustainable financing in the supply chain. Soni et al. (2022) recommend the use of a single technology because this requires less capital investment and is easier to implement. If technologies are to be combined, the use of big data with analytics is advised. However, the adoption of Industry 4.0 technologies for ethical and sustainable operations is subject to potential challenges, such as a lack of customer motivation, inadequate long-term planning, non-awareness of the contributions offered and the absence of management support, as well as high initial costs (R. Kumar et al., 2020).

2.2. Technology and its relationship with SME performance

The sustainable performance of SMEs is often spurred and improved by the adoption of information technologies such as big data, the IoT and smart factories. However, if business performance is to be positive and sustainable, the organisation's structure and processes must be supportive. Technological updating in SMEs is driven by social capital, links with multinationals and transnationals, innovation, exchange and networking, information technology, and the adoption of technology that improves productivity. For SMEs, innovation, especially the exploitation and exploration of technology, improves the chances of business survival and facilitates effective digital marketing. The integration of advanced marketing technologies and geographical expansion also influences perceptions of the importance of integrating the IoT into business operations. Technological and organisational factors are crucial inputs for innovation, human resource management and green marketing, and hence sustainable performance (Haseeb et al., 2019).

Technological updating in SMEs is associated with six driving forces: social capital, links with multinationals and

transnationals, innovation, exchange and networking, information technology and the adoption of technology that improves productivity. In addition, successful adaptation depends on three conditions: the availability of technologically trained labour; the timely identification of opportunities for new technologies; and support from the workforce and the prevailing political culture. Updating and innovation follow from the exploration and exploitation of technology (Prasanna et al., 2019).

A study of the Indian restaurant industry concluded that government initiatives and policies, public-private association and the encouragement of ICT service providers are the most influential causal factors for the application of information and communication technologies (ICT) for sustainable growth. It also showed that the adoption of ICT applications in public procurement and logistics can reduce the cost of transactions within the business organisation. Coordinated efforts and effective partnerships among development elements enable ICT applications and frameworks to reach more SMEs and thus improve operational efficiencies. Moreover, collaboration and strategic alliances within the supply chain can reinforce organisational capabilities (Singh et al., 2019).

Another relevant consideration is the interaction between companies' expansion into new locations and their adoption of advanced marketing technologies. The geographical expansion of the company can stimulate technological development. The size of the workforce also influences managers' perceptions of the importance of the IoT. Thus, Suciu et al. (2021) reported that SMEs with more than 50 employees consider the IoT an important element in developing an effective digital marketing strategy.

Technological and organisational factors are considered more significant than environmental factors, with respect to innovation, human resource management and green marketing, when SMEs seek sustainable performance. Thus, adopting procurement policies based on environmental criteria requires SMEs to invest time, effort and financial resources in sustainable development, R&D and the use of updated technology for production, service provision and marketing. The pandemic spurred many companies to make important structural changes, adapting and reorienting their activities towards digital technologies, in order to assure their continued survival and to overcome limited access to sources of finance, investment and innovation (Alraja et al., 2022; Del Baldo et al., 2022).

2.3. Sustainability and its relationship with SME performance

As the global focus on environmental and social issues intensifies, SMEs are increasingly recognising the need to integrate sustainable practices into their operations (Grimm, 2013; Shields & Shelleman, 2015). With the rapidly changing business landscape, sustainability has become a buzzword that cannot be ignored. Many SMEs are well aware that sustainable practices should be embraced, not only to benefit the environment, but also for their own long-term success. Kasiri et al. (2020) observed that more than two-thirds of SME owner/managers believed that sustainability engagement was worthwhile. However, SMEs, often considered the backbone of the economy, face unique challenges in relation to implementing sustainable initiatives. Limited resources, both financial and human, can make the adoption of eco-friendly practices seem daunting. On the other hand, research has shown that sustainability and profitability go hand in hand. By integrating sustainable practices into their operations, SMEs can not only reduce their environmental footprint but also enhance operational efficiency, improve brand reputation, attract socially conscious customers and gain a competitive advantage. But what exactly is the relationship between sustainability and SME performance? How does embracing sustainability positively influence the bottom line? To answer these questions, we must identify and assimilate previous research in this area, and highlight the issues remaining to be addressed. Through a comprehensive review of the relevant literature, this article examines the key drivers and benefits of sustainability for SMEs. It then explores how sustainable practices can help SMEs overcome challenges, such as resource constraints, and outlines practical strategies for integrating sustainability into their business models.

3. Methodology

3.1. Systematic literature review

In this systematic literature review (SLR), we explore the use of technology by SMEs to incorporate sustainability into their business practices, and consider the symbiotic relationship between sustainability, technology and SME performance. The SLR approach includes a comprehensive search strategy, data extraction, thematic coding, the synthesis of findings, quality assessment, and due consideration of possible limitations. In our SLR, the following procedure was applied. First, relevant academic databases were searched using keywords related to SMEs, technology, sustainability and the SDGs. Figure 1 shows the 17 UN Sustainable Development Goals. In total, 208 articles were identified and analysed. The articles were published across 147 journals, with *Sustainability* and *Journal of Cleaner Production* individually publishing most articles. The number of articles published annually increased from 2019, reflecting growing interest in the intersection of technology, SMEs and sustainability. The SLR performed is transparent, replicable and scientific, as indicated by Tranfield, Denyer & Smart (2003). Compared to traditional narrative reviews, SLR confers the following benefits: a) it has less potential for bias and yields a detailed outcome characterised by greater accuracy and thoroughness (Khatib et al., 2021; Leonidou et al., 2020), b) it provides a literature map of a specific research domain and facilitates data synthesis (Kauppi et al., 2018); c) it adheres to a well-defined protocol outlining the actions and steps to be taken, thus ensuring transparency and reproducibility (S. Kumar et al., 2022; Palmaccio et al., 2021).

In conducting this SLR, we followed the SPAR-4-SLR protocol guidelines indicated by Paul et al. (2021), in a two-phase structured approach: first, relevant documents were identified, read and comprehended; then, a bibliomet-

Figure 1. Sustainable Development Goals (Source: United Nations)

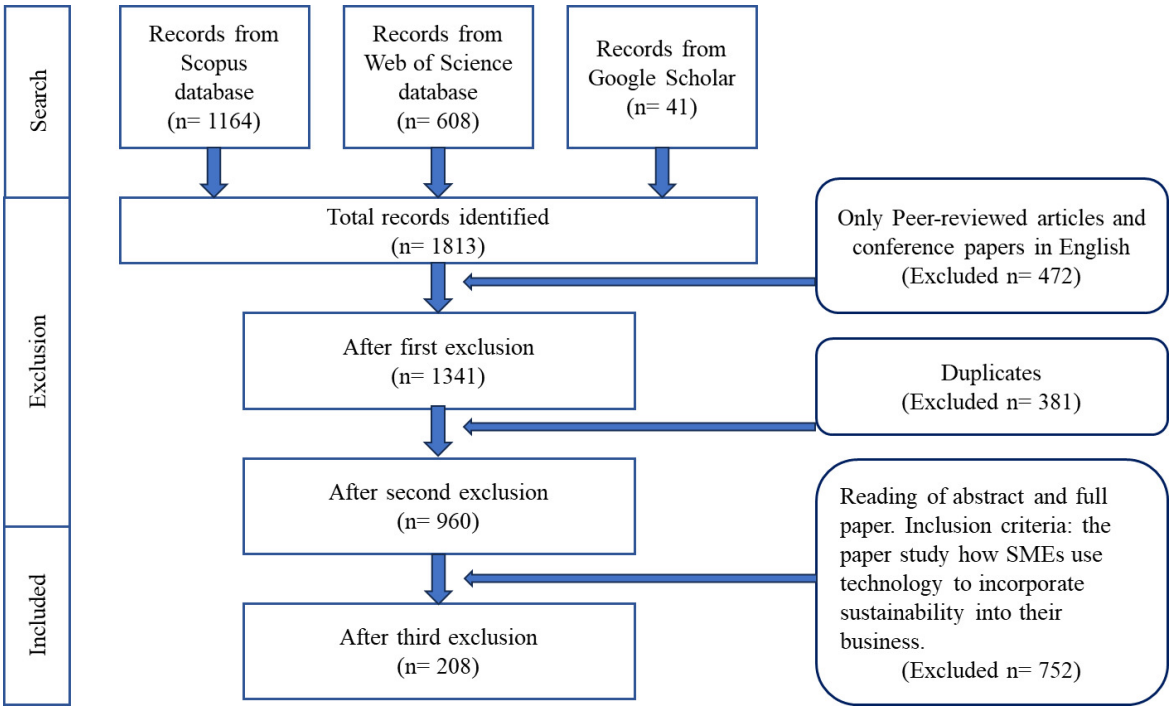

Figure 2. Research methodology applied

ric analysis was made of these articles. In greater detail, the SLR process consists of four key stages: (1) retrieving articles from databases, in accordance with the search strategy adopted; (2) identifying the specific articles to be analysed; (3) performing the analysis and synthesis; and (4) creating a useful theoretical framework. Figure 2 illustrates the data collection and analysis process, for each of these levels.

3.2. Search strategy

Three academic databases – Web of Science, Scopus and Google Scholar – were searched, using keywords and search terms with the Boolean operators (AND, OR). To make the search comprehensive, three groups of keywords and search terms were used and one keyword was required from each group, as follows:

- Group 1 (SMEs): "Small and medium sized enterprises" OR "SME" OR "Small businesses"
- Group 2 (Technology): "Technology" OR "Digitalization" OR "Digital transformation" OR "Automation" OR "ICT" OR "Industry 4.0"
- Group 3 (Sustainability): "Sustainability" OR "Sustainable" (to capture innovation, business model, value chain, development goals) OR "SDG"

3.3. Inclusion and exclusion criteria

The inclusion criteria for selecting relevant literature were that the articles should be peer reviewed or conference papers, published within the last 30 years (1993-2023). Non-English language publications and studies not directly related to the search criteria were excluded.

3.4. Data extraction

In this context, data extraction involves systematically collecting relevant information from the selected studies, including details such as the journal name, the title, author(s) and year of publication of the article, the research methodology used, the country in which the study was conducted, the key findings obtained, and the theoretical framework used.

3.5. Analysis and synthesis

The data compiled were then coded according to the themes and sub-themes identified, categorising the information into meaningful units to identify patterns, trends and relationships related to SMEs' use of technology for sustainability. Synthesis of the coded data provides a comprehensive overview of the literature on the research question considered. In this synthesis, we summarise the key findings, identifying commonalities and differences across studies, and create a framework to understand the use of technology by SMEs to achieve sustainable development.

4. Results

In this section, we present the findings obtained from the 208 articles considered for analysis (see Table 1 of the Appendix).

4.1. Statistical results

4.1.1. Relevant terms

The Word Cloud method synthesises big data via simple pattern recognition. Our graphic representation clearly shows that across a wide range of journals and articles, certain fundamental terms arise repeatedly. Figure 3 illustrates the Word Cloud obtained from the abstracts considered, highlighting the most prevalent terms employed. The size of the words in the image is determined solely by their frequency of occurrence in the selected articles. As can be seen, the key terms of our study, namely "sustainability", "sustainable", "technology" and "SMEs," are located at the centre of the figure. Among the articles considered,

Figure 3. Word Cloud

the term "sustainability" emerges 81 times, followed by "sustainable," (63 times) and "SME" (61 times). The terms "innovation" and "technology" are encountered 56 and 54 times, respectively. Thus, all of these terms are prominent among the articles examined (see Table 1 of the Appendix).

4.1.2. Publication year

Figure 4 represents the number of studies identified, by year of publication, that address the use of technology by SMEs to incorporate sustainability concerns into their business operations. Chronologically, the article by Owen and Darkwa (2000) was the first to meet the search criteria (see Annex 1). During the period 2001-2006 no articles meeting the search criteria were published, while during the period 2007-2018, 2-7 valid articles appeared each year. From 2019, the number of publications addressing this topic increased significantly. Thus, from 2019 to 2021 between 21 and 29 articles on this subject were published each year, and a peak of 57 publications was recorded for 2022. In the first seven months of 2023, another 37 articles appeared, which confirmed the rising trend observed.

In September 2015, 196 countries agreed to establish the 17 Sustainable Development Goals (SDGs) and the 169 targets of the 2030 Agenda for Sustainable Development, seeking to create an effective framework to eradicate poverty, reduce inequalities and to fight against climate change. All signatories acknowledged that these initiatives should be coupled with strategies to fuel economic growth, address social needs (such as education, health and employment opportunities) and protect the environment. These SDGs address a wide range of complex interrelated challenges, and cannot be attained without the joint effort and collaboration of governments, organisations, the public and private sectors, the community and academia. With respect to the focus of our study, the international commitment to the 2030 Agenda was a major factor underlying the rising numbers of research papers appearing since 2015.

In 2020, the outbreak of the COVID-19 pandemic provoked an extraordinary crisis in the world of business, and SMEs were among the most severely affected, due to the resource constraints to which they were subjected. Studies have identified numerous strategies adopted by SMEs to withstand the impact of the pandemic, one such being the heightened use of technology and innovation. This factor,

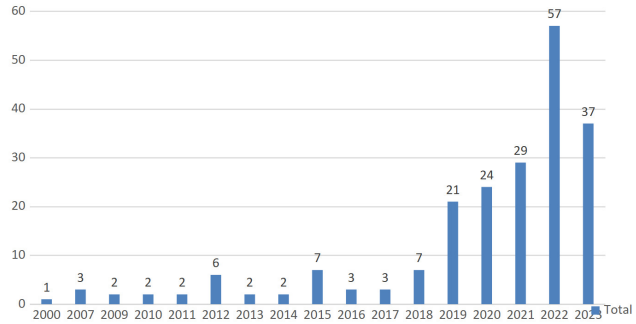

Figure 4. Publication year

too, is of importance in explaining the uptick in publications on this topic from 2020.

4.1.3. Journal analysis

The 208 papers that met the search criteria were distributed across 147 journals. Of these, 135 published only one article. The two leading journals, by numbers of articles published, were *Sustainability*, with 31 articles, and *Journal of Cleaner Production,* which published 14. Each of the 208 articles contained an average of 14 citations. However, the following ten articles each were referenced by 70 or more studies (ranging from 70 to 298): Khan et al. (2021); Khanzode et al. (2021); Centobelli et al. (2020); Chege and Wang (2020); Isensee et al. (2020); Kumar et al. (2020); Singh et al. (2019); Pacheco et al. (2018); Aboelmaged (2018); and Moore and Manring (2009). Of the ten articles most commonly cited, five were published in *Journal of Cleaner Production*, making this journal the most impactful in the research field considered.

4.1.4. Regional analysis

Of the 208 papers included in our analysis, 166 (80%) addressed the use of technology by SMEs in one or more countries to incorporate sustainability into their business. Of these, 19 analysed multi-country data and 147 focused on single markets. Only 23 countries attracted more than one study. India (22 studies), Malaysia (15), Indonesia (12) and Pakistan (9) were the leading countries in this respect, accounting for 58 publications in total. Twenty articles presented multi-country empirical investigations. Figure 5 shows the distribution by continent of the articles, revealing that 42% of the studies provide evidence from Asia and 24% from Europe. The 42 articles (20%) that do not mention a specific region are mainly literature reviews.

4.1.5. Methodologies

Figure 6 illustrates the varied methodologies used in the investigations considered in our analysis. Among the 208 papers, 74 (35%) adopted a quantitative approach, often using partial least square regression models. Around 21% were literature reviews, discussed the development of a theoretical framework, or formulated a conceptual model concerning the topic of interest. A further 10% were case

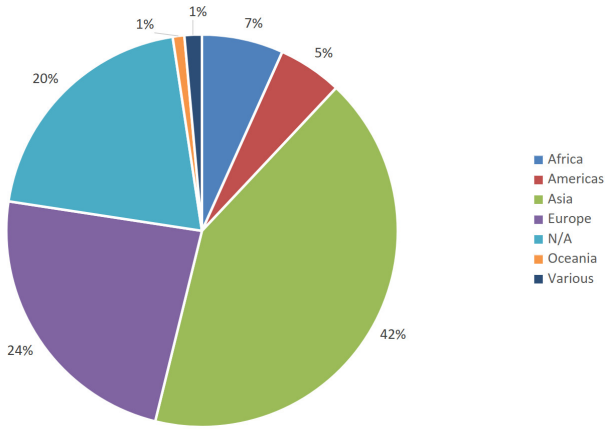

Figure 5. Regional analysis

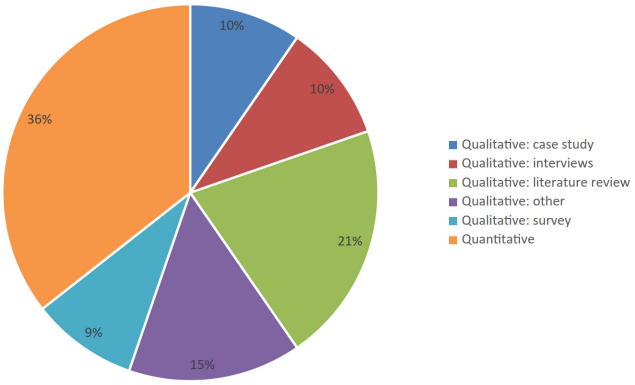

Figure 6. Methodology analysis

studies, another 10% obtained study data via interviews, and 9% employed surveys for this purpose. The remaining 15% were qualitative studies that also incorporated some quantitative analysis (Qualitative: other).

5. Theoretical framework based on the content of selected articles

Using our thematic analysis of this literature review, a theoretical framework was developed to provide a comprehensive understanding of how SMEs make use of technology to make their business more sustainable. The framework consists of several interrelated elements, including the external environment, organisational context, sustainability orientation, technology opportunities, innovation focus, knowledge management, assessment frameworks, sustainability practices, sustainability outcomes, and overall sustainability of the business. These elements highlight the key factors that influence SMEs' adoption of technology for sustainable development and provide a guide for future research in this field. Figure 7 illustrates the theoretical framework developed.

5.1. External environment

Government regulations increasingly require environmental and social accountability from firms of all sizes

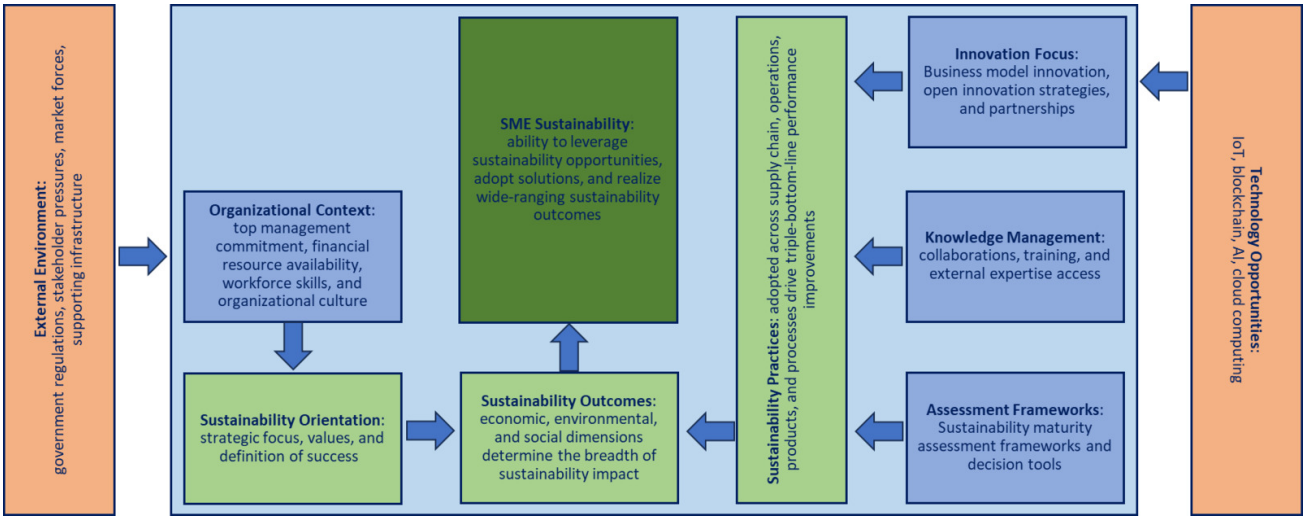

Figure 7. Theoretical framework (developed by the present authors)

(Asim et al., 2019; Hariastuti et al., 2022). Regulations such as carbon emission limits, energy efficiency standards, waste disposal rules and recycling mandates force SMEs to address sustainability issues. Failure to comply can result in fines, lawsuits and even losing the licence to operate. Customers, local communities, NGOs and other stakeholders may also pressure SMEs to address sustainability, through tactics such as purchasing criteria, protests and social media campaigns (Amoah et al., 2023; Baggia et al., 2019; Hossain et al., 2022; Nair et al., 2019) demanding sustainable business practices and transparency. Indeed, sustainability is becoming an expectation in many markets, and consumers and business customers increasingly factor sustainability into their eco-conscious purchase decisions. However, many SME owner-managers continue to be primarily motivated by economic performance rather than external stakeholder pressures (Mokonyama et al., 2022), making decisions aimed at maximising profitability and ensuring revenue growth and business viability. Nevertheless, the external cultural context often shapes how SMEs approach sustainability, as evidenced by the significant national and regional differences that have been identified (Sinyuk et al., 2021). Developed versus emerging economies, collectivist versus individualistic cultures, and other macro factors can all produce variations in how SMEs address sustainability issues (Diana et al., 2017).

5.2. Organisational context

Among the factors driving sustainability in SMEs, the leadership role played by entrepreneurial owner-managers is of critical importance (Khizar & Iban, 2022). Owners' personal values, beliefs, knowledge and priorities determine the priority given to sustainability versus competing demands. Lack of leadership support is a major barrier. In addition, developing partnerships and networks helps SMEs gain the capabilities needed for the effective implementation of sustainability-oriented policies (Kwak et al., 2023; Obayelu, 2018; Ramasamy & Sampath, 2023). Partners such as trade associations, universities, NGOs and corporations can provide training, technology access, peer learning opportunities and other resources to build sustainability capacity. Furthermore, the existence of an organisational culture supporting sustainability values will significantly boost the adoption of such practices (Isensee et al., 2020). Finally, when the national culture is characterised by a focus on ethics, eco-consciousness, transparency and stakeholder impact, sustainability is further supported. Nevertheless, sustaining culture change initiatives often presents a major challenge.

5.3. Sustainability orientation

A proactive strategic stance facilitates the integration of environmental and social issues into business strategy and operations. Achieving this requires owner/managers of SMEs to assign accountability, set goals, allocate resources and develop appropriate systems. However, some SMEs persist in a reactive orientation, focused solely on legal compliance. Hence, they only adopt new sustainability measures when forced to by new regulations, rather than acting proactively. A strong sustainability vision would provide purpose and motivation in this respect (Hariastuti et al., 2022; Mondal et al., 2023; Pacheco et al., 2018). An inspiring vision meaningfully connects sustainability to the company's core values and identity, and consistent communication is of crucial importance.

5.4. Technological opportunities

Investing in cleaner, more eco-efficient technologies enables SMEs to reduce the environmental impacts of their operations (Centobelli et al., 2020; Khan et al., 2023; Saunila et al., 2019). In this respect, relevant technologies include pollution control equipment, efficient production machinery, cogeneration systems, smart building controls and fleet telematics. Digital platforms such as sensors, the IoT and big data analytics facilitate the tracking, analysis and transparency of sustainability metrics (Penza, 2014; Ronaghi & Mosakhani, 2022), which in turn support perfor-

mance management. However, cost concerns, a perceived lack of expertise and limited access to financing often limit SMEs' adoption of sustainability technologies (Budinis et al., 2020; Sabandar, 2019). In consequence, many SMEs struggle to accurately assess their options and to secure funding for major capital investments (Prasad et al., 2022).

5.5. Innovation focus

SMEs can generate sustainability via innovative products, processes, business models and organisational forms (Jayashree et al., 2021; Khan et al., 2022). Other areas of interest for sustainability include the use of organic materials, resource-sharing platforms, and participation in social enterprises with a sustainability mission. However, for these innovations to flourish there must be appropriate capabilities and culture within the firm (Mondal et al., 2023), and hence leadership support for new ideas, effective collaboration, an openness to learning, and tolerance of risk and potential failure. Unfortunately, the innovation practices of SMEs often focus primarily on economic performance, with sustainability benefits viewed as being of secondary importance (Saudi et al., 2019). This dichotomy is reflected in ongoing debates and tensions between proponents of rapid business growth – despite the resulting pressure on the environment and resources – and those of sustainability.

5.6. Knowledge management

Effective knowledge management by SMEs is essential to successful sustainability initiatives (Khurana et al., 2019). Knowledge exchange with external partners provides sustainability insights (Kwak et al., 2023), while internal knowledge sharing enables and enhances implementation. SMEs often lack formal knowledge management systems, and so creative approaches are required, with the owner-manager acting as a sustainability knowledge hub (Nair et al., 2019; Yacob et al., 2019). In addition, appropriate training develops employee capabilities for sustainability practices (Sharma et al., 2023).

5.7. Assessment frameworks

Assessment frameworks, standards, guidelines and reporting mechanisms provide structures for SMEs to achieve sustainability (Kassem & Trenz, 2020; Pusnik et al., 2014; Quernheim et al., 2023; Zahoor et al., 2019). In the same context, assurance and integrated accounting practices are increasingly employed (Kassem & Trenz, 2020). In addition, sustainability rankings and awards provide them with performance benchmarks. However, the use of formal measurement tools still varies widely among SMEs (Islam et al., 2022; Rahman et al., 2017; Zhao et al., 2022), and complexity, cost and limited human resources persist as barriers to their adoption.

5.8. Sustainability practices

A wide range of practices related to operations, inputs, processes and outputs can support sustainability performance in SMEs, focusing on areas such as energy, water, materials, waste, procurement, logistics, product design, employee engagement and community initiatives (Gazi et al., 2012; Karaeva et al., 2023; Mandić et al., 2019; Qureshi et al., 2023; Tseng et al., 2023; Willenbacher et al., 2021; Yacob et al., 2019). The benefits of successful application include cost savings, risk reduction, and enhanced competitiveness, legitimacy and stakeholder relationships. Possible challenges, on the other hand, include costs, disruption and lack of expertise.

5.9. Sustainability outcomes

Actions to reinforce SME sustainability can generate positive results in economic, environmental and social dimensions. Documented sustainability benefits for SMEs include cost savings (Alena & Libor, 2012), reduced waste (Willenbacher et al., 2021), increased energy and water efficiency (Yacob et al., 2019), improved reputation (Rozak et al., 2021), increased sales and market access (Basri & Siam, 2019; Tsvetanova et al., 2022), and product and service innovation (Kwak et al., 2023; Popović-Pantić et al., 2020). However, outcomes are not uniformly positive across SMEs, because of variations in practices and contexts, and questions remain about potential tensions between sustainability and economic performance objectives. Accordingly, further research is needed on the results of sustainability-focused actions, on the trade-offs made and on measuring the performance achieved.

5.10. SME sustainability

In summary, various factors related to the external environment, organisational characteristics, orientation, technology, innovation, knowledge, assessment tools, and industry practices must be considered if SMEs are to improve their sustainability profile and outcomes. Significant barriers persist, and progress varies greatly among different companies. More research is needed on how SMEs can effectively balance business growth, profitability and sustainability.

6. Discussion

This systematic literature review provides valuable insights into the use of technology by SMEs to achieve sustainable development goals. The findings emphasise the importance of external pressures, leadership commitment and organisational culture in driving SMEs' adoption of these goals. The use of technologies such as cloud computing, fintech and Industry 4.0 enables SMEs to improve their competitiveness and environmental performance. However, challenges such as limited financial resources, lack of expertise and high costs can hinder technology uptake. Moreover, innovation and knowledge management often play a crucial role in driving sustainability initiatives. Assessment frameworks and sustainability practices can be employed to support the implementation and measurement of sustainability efforts. The positive outcomes of sustainability initiatives for SMEs include cost savings, efficiency gains,

waste reduction, improved reputation and increased market access. However, tensions between sustainability and economic goals persist in this sector. Therefore, future research should focus on balancing business growth, profitability and sustainability in SMEs. The following conclusions can be drawn from our synthesis of the literature in this field:

- External pressure from stakeholders is a factor driving the adoption of sustainability, but economic considerations remain the primary motivation for SMEs. Leadership commitment and organisational culture facilitate the integration of sustainability within the organisation.
- Technologies such as cleaner production, digital platforms, IoT sensors, automation and cloud computing provide opportunities to monitor, analyse and reduce environmental impacts. However, costs, expertise barriers and perceived risks constrain adoption.
- SME innovation plays a crucial role, and product, process, business model and marketing innovations all contribute to the firm's ability to meet its sustainability objectives. Success is also facilitated by effective knowledge management, in both internal and external networks.
- Assessment tools such as standards, metrics and timely accurate reporting enable sustainability measurement and transparency. However, their complexity limits widespread adoption by SMEs.
- Sustainability-related practices, in areas such as energy consumption, materials, logistics, procurement, waste management and community engagement can produce tangible sustainability benefits, but also involve trade-offs.
- The potential benefits from effective policies in this area include cost savings, efficiency gains, waste reduction, reputation enhancement, new revenues and improved stakeholder relationships. Nevertheless, tensions between sustainability and economic goals persist for many SMEs.

Overall, while progress is evident, SMEs still face significant challenges in fully transitioning their business models, cultures and systems to embed sustainability. Research gaps remain regarding how to effectively balance business growth with environmental and social sustainability.

The integrated theoretical framework developed from our thematic analysis provides a foundation for future research. Quantitative hypothesis testing focused on specific relationships in the framework would yield further insights. Comparative case studies exploring the sustainability journeys of SMEs in different sectors and countries could reveal best practices. Action research partnerships with SMEs to implement and evaluate technology-enabled sustainability initiatives would produce practical recommendations.

This systematic literature review contributes a comprehensive, reliable overview of current knowledge on the intersection of technology adoption and sustainability for SMEs. The findings and proposed framework offer a valuable resource for further study in areas such as information systems, sustainability, innovation and entrepreneurship. For practitioners, the review reveals insights that SMEs can apply to leverage technologies enabling them to enhance business resilience, competitiveness and eco-consciousness. Sustainability is an imperative for all businesses; understanding how SMEs can effectively harness emerging technologies to drive sustainability is and will continue to be an important avenue for researchers and practitioners. For policymakers, the review showcases opportunities to support SMEs in this respect, through incentives, infrastructure development, training programmes and public-private partnerships focused on sustainability technologies and innovation. Such measures are urgently required as many SMEs lack awareness, expertise and resources to effectively capitalise on digital solutions. Targeted initiatives that lower barriers and demonstrate sustainability benefits would greatly accelerate the adoption of these measures. In view of the economic importance of SMEs, investments to enhance their environmental and social performance would generate significant public value.

This review is subject to certain limitations, but these also highlight useful areas for future research. First, the search was restricted to English-language publications, excluding potentially valuable literature in other languages. Second, most of the SMEs in our sample operate in the manufacturing sector, with less representation of service industries. There are significant differences between these areas, and so further research focusing more on the services context would be a valuable complement to the present study. Third, our review does not consider literature on SME sustainability issues unrelated to technology use, although other fields of research could provide useful information for comparison. Finally, the qualitative synthesis approach, while rigorous, relies on interpretation in identifying themes. This inevitable subjectivity means that other scholars might code the data differently.

This review represents an invaluable knowledge base for stakeholders in diverse fields, including academia, industry, government and civil society, thereby contributing to advancing sustainable development. The insights gained provide a multifaceted understanding of the obstacles involved, of enablers and of the potential to leverage technologies, from production automation to cloud platforms, as catalysts for SMEs to transform themselves into socially and environmentally conscious enterprises. Operationalising sustainability remains a complex challenge that requires persistent research, thoughtful practice and cross-sector collaboration. The aim of this review is to impel progress towards greater sustainability by offering a comprehensive reference map of existing knowledge and uncharted frontiers.

7. Practical implications

The study findings have significant implications for practitioners, policymakers and educators involved in promoting sustainability and technology adoption among SMEs. For practitioners, our research underscores the critical role of technology integration in enhancing sustainability efforts. SME leaders should prioritise the adoption of

key technologies such as cloud computing, the Internet of Things and data analytics to improve operational efficiency and environmental performance. Developing a clear sustainability vision aligned with business goals, and integrating it into all aspects of operations is of crucial importance. Collaboration and networking with other businesses and institutions can help SMEs overcome resource constraints and access essential knowledge and capabilities. Investing in training programmes to enhance employee capabilities in sustainability practices and digital technologies is a vital measure to address the skills gap identified in our study.

Policymakers should develop targeted support programmes for SMEs seeking to adopt sustainable technologies. These could include financial incentives such as grants, tax breaks or low-interest loans to help SMEs overcome financial barriers. It is also necessary to invest in digital infrastructure and to create a balanced regulatory environment that encourages sustainable practices without overburdening SMEs. Facilitating knowledge-sharing platforms can enable the exchange of best practices between SMEs, larger corporations and research institutions.

Educators play a key role in preparing future SME leaders. Integrating the consideration of sustainability and digital technology into business and entrepreneurship curricula is essential. Measures such as developing hands-on training programmes, using real-world case studies and collaborating with industry can provide students with practical skills in sustainable business practices and technology management. Moreover, executive education programmes for current SME owner-managers would help address the ongoing need for knowledge updates in this rapidly evolving field.

By addressing these implications, stakeholders can contribute to creating an ecosystem that supports SMEs in their journey towards sustainable and technologically advanced operations. This, in turn, can contribute to achieving broader sustainability goals and economic development, as highlighted in our findings on the potential impact of SMEs on achieving the Sustainable Development Goals.

8. Conclusion

In conclusion, the use of technology by SMEs to achieve sustainable development is a critical area of research and practice. The systematic literature review we describe provides a comprehensive overview of the current knowledge on this topic. Its findings highlight the key elements and relationships that influence SMEs' adoption of technology for sustainable development. The theoretical framework developed on the basis of the review offers a guide for future research and practice. Despite challenges and tensions, SMEs can make use of technological solutions to drive sustainable development. Policymakers, practitioners and researchers should collaborate to support SMEs in leveraging technology for sustainable business practices and thus contribute to achieving the SDGs.

Funding

This work was supported by the AUDA Foundation [Project AUDA-2023].

Submitted: June 21, 2024 CST, Accepted: September 26, 2024 CST

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Appendix

Table 1.

Year	Authors	Article Title	Source Title
2000	Owen Jr. W.; Darkwa O.	Role of multipurpose community telecentres in accelerating national development in Ghana	First Monday
2007	Thomas A.J.	Creating sustainable small to medium enterprises through technological innovation	Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture
2007	Woy U.; Qing W.	Developing sustainable new product development procedures in SMEs utilising available technologies	International Journal of Agile Manufacturing
2007	Woy U.; Wang Q.	New product development: Implementing procedures for sustainable product development in SMEs utilising available technologies	IET Conference Publications
2009	Moore S.B.; Manring S.L.	Strategy development in small and medium sized enterprises for sustainability and increased value creation	Journal of Cleaner Production
2009	Rosa M.D.	Technological innovation and valorisation of traditional food: A sustainable combination?; [Valorizzazione e innovazione tecnologica nei prodotti della tradizione: Un binomio sostenibile?]	Italian Journal of Agronomy
2010	Anbumozhi V.; Gunjima T.; Prem Ananth A.; Visvanathan C.	An assessment of inter-firm networks in a wood biomass industrial cluster: Lessons for integrated policymaking	Clean Technologies and Environmental Policy
2010	Singh A.; Narain R.; Yadav R.C.	An exploratory study of the SCM practices and IT usage: An emerging market context	International Journal of Information Technology and Management
2011	Sceulovs, D; Gaile-Sarkane, E; Kaze, V	E-ENVIRONMENT BENEFITS FOR LATVIAN SUSTAINABLE BUSINESS DEVELOPMENT	MANAGEMENT THEORY AND STUDIES FOR RURAL BUSINESS AND INFRASTRUCTURE DEVELOPMENT
2011	Temri L.	Innovations technologiques environnementales dans les petites entreprises: Proposition d'un modèle d'analyse	Innovations
2012	Lelah, A; Mathieux, F; Brissaud, D; Vincent, L	Collaborative network with SMEs providing a backbone for urban PSS: a model and initial sustainability analysis	PRODUCTION PLANNING & CONTROL
2012	Dasanayaka S.W.S.B.	Critical success factors affecting the development of clusters for small and medium scale information technology firms in Sri Lanka	International Journal of Entrepreneurship and Small Business
2012	Gazi, A; Skevis, G; Founti, MA	Energy efficiency and environmental assessment of a typical marble quarry and processing plant	JOURNAL OF CLEANER PRODUCTION
2012	Alena, B; Libor, G	Green ICT Adoption Survey Focused on ICT Life-cycle from the Consumer's Perspective (SMEs)	JOURNAL OF COMPETITIVENESS
2012	Pardo, RJH; Bhamra, T; Bhamra, R	Sustainable Product Service Systems in Small and Medium Enterprises (SMEs): Opportunities in the Leather Manufacturing Industry	SUSTAINABILITY
2012	Sowe S.K.; McNaughton M.	Using multiple case studies to analyse open source software business sustainability in sub-Saharan Africa	IFIP Advances in Information and Communication Technology
2013	Parker, CM; Zutshi, A; Fraunholz, B; Crofts,	A Method for Examining SME Descriptions of Environmental Sustainability Online	GREEN TECHNOLOGIES AND BUSINESS

Year	Authors	Article Title	Source Title
	MR		PRACTICES: AN IT APPROACH
2013	Joseph N.P.S.; Mahmood A.K.; Choo P.Y.; Wong S.W.; Phan K.Y.; Lim E.H.	Battles in volatile information and communication technology landscape: The Malaysia small and medium enterprise case	International Journal of Business Information Systems
2014	Penza M.	COST action TD1105 on new sensing technologies for air-pollution control and environmental sustainability: Overview in Europe and New Trends	Lecture Notes in Electrical Engineering
2014	Pusnik M.; Sucic B.; Al-Mansour F.; Crema L.; Cozzini M.; Mahbub S.; Holzner C.; Kohlmaier J.	Framework for sustainability assessment of small and medium-sized enterprises	Chemical Engineering Transactions
2015	Filho E.R.	Brazilian design for sustainability: In search of a local approach	Journal of Cleaner Production
2015	Mauricio-Moreno H.; Miranda J.; Chavarria D.; Ramirez-Cadena M.; Molina A.	Design S3-RF (Sustainable x Smart x Sensing - Reference Framework) for the future manufacturing enterprise	IFAC-PapersOnLine
2015	Dawal, S; Tahriri, F; Jen, Y; Case, K; Tho, N; Zuhdi, A; Mousavi, M; Amindoust, A; Sakundarini, N	Empirical evidence of AMT practices and sustainable environmental initiatives in malaysian automotive SMEs	INTERNATIONAL JOURNAL OF PRECISION ENGINEERING AND MANUFACTURING
2015	Ahmad, N; Mehmood, R	Enterprise systems: are we ready for future sustainable cities	SUPPLY CHAIN MANAGEMENT-AN INTERNATIONAL JOURNAL
2015	Cândido A.P.; Vianna C.T.; Gauthier F.O.; Aradas A.R.-P.; Koslovsky M.A.N.	Proposed model for evaluation and supervision of management of technological innovation in small and medium organizations; [Proposta de modelo para avaliação e supervisão de gestão da inovação tecnológica em pequenas e médias organizações]	Espacios
2015	Bi, ZM; Liu, YF; Baumgartner, B; Culver, E; Sorokin, JN; Peters, A; Cox, B; Hunnicutt, J; Yurek, J; O'Shaughnessey, S	Reusing industrial robots to achieve sustainability in small and medium-sized enterprises (SMEs)	INDUSTRIAL ROBOT-THE INTERNATIONAL JOURNAL OF ROBOTICS RESEARCH AND APPLICATION
2015	Ness B.; Åkerman A.	Sustainable diffusion of sustainable technologies? An entrepreneur-led initiative to promote improved cookstoves in rural western Kenya	Sustainability: Science, Practice, and Policy
2016	Jagoda K.; Lin X.; Calvert V.; Tao S.	Accountability of venture support agencies: Do they really help?	Entrepreneurship Research Journal
2016	Fernando Y.; Shaharudin M.S.; Wahid N.A.	Eco-innovation practices: A case study of green furniture manufacturers in Indonesia	International Journal of Services and Operations Management
2016	Dušková M.	Key enabling technologies in relation to sustainable development	Proceedings of the 27th International Business Information Management Association Conference
2017	Rahman, NHA; Ghani, EK; Hamzah, N; Aziz, KA	AN EMPIRICAL ANALYSIS OF CONTROL ACTIVITIES IN MANAGING RISK FOR SUSTAINAbLE MALAYSIAN MANUFACTURING SMES	ASIA-PACIFIC MANAGEMENT ACCOUNTING JOURNAL
2017	Shin, DI	An exploratory study of innovation strategies of the internet of things SMEs in South Korea	ASIA PACIFIC JOURNAL OF INNOVATION AND ENTREPRENEURSHIP
2017	Diana, GC; Jabbour, CJC; Jabbour, ABLD; Kannan, D	Putting environmental technologies into the mainstream: Adoption of environmental technologies by medium-sized manufacturing firms in Brazil	JOURNAL OF CLEANER PRODUCTION
2018	Epping, K; Zhang, H	A Sustainable Decision-Making Framework for Transitioning to Robotic Welding for	SUSTAINABILITY

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		Small and Medium Manufacturers	
2018	Yazdi, PG; Azizi, A; Hashemipour, M	An Empirical Investigation of the Relationship between Overall Equipment Efficiency (OEE) and Manufacturing Sustainability in Industry 4.0 with Time Study Approach	SUSTAINABILITY
2018	Pacheco D.A.D.J.; Caten C.S.T.; Jung C.F.; Navas H.V.G.; Cruz-Machado V.A.	Eco-innovation determinants in manufacturing SMEs from emerging markets: Systematic literature review and challenges	Journal of Engineering and Technology Management - JET-M
2018	Jin Y.; Ji S.	Mapping hotspots and emerging trends of business model innovation under networking in Internet of Things	Eurasip Journal on Wireless Communications and Networking
2018	Pigosso D.C.A.; Schmiegelow A.; Andersen M.M.	Measuring the readiness of SMEs for eco-innovation and industrial symbiosis: Development of a screening tool	SUSTAINABILITY
2018	Obayelu A.E.	Public-private partnerships for inclusive agribusiness sustainability in Africa	Agriculturae Conspectus Scientificus
2018	Aboelmaged, M	The drivers of sustainable manufacturing practices in Egyptian SMEs and their impact on competitive capabilities: A PLS-SEM model	JOURNAL OF CLEANER PRODUCTION
2019	Nayak, G; Dhaigude, AS	A conceptual model of sustainable supply chain management in small and medium enterprises using blockchain technology	COGENT ECONOMICS & FINANCE
2019	Yacob, P; Wong, LS; Khor, SC	An empirical investigation of green initiatives and environmental sustainability for manufacturing SMEs	JOURNAL OF MANUFACTURING TECHNOLOGY MANAGEMENT
2019	Makiwa P.; Steyn R.	An investigation of the government-related factors that inhibit small to medium enterprises' adoption and effective use of information and communication technology in developing countries: The Case of Zimbabwe	Communications in Computer and Information Science
2019	Singh, RK; Luthra, S; Mangla, SK; Uniyal, S	Applications of information and communication technology for sustainable growth of SMEs in India food industry	RESOURCES CONSERVATION AND RECYCLING
2019	Avram, A; Benvenuto, M; Avram, CD; Gravili, G	Assuring SME's Sustainable Competitiveness in the Digital Era: A Labor Policy between Guaranteed Minimum Wage and ICT Skill Mismatch	SUSTAINABILITY
2019	Khurana, S; Haleem, A; Mannan, B	Determinants for integration of sustainability with innovation for Indian manufacturing enterprises: Empirical evidence in MSMEs	JOURNAL OF CLEANER PRODUCTION
2019	Baggia, A; Maletic, M; Znidarsic, A; Brezavscek, A	Drivers and Outcomes of Green IS Adoption in Small and Medium-Sized Enterprises	SUSTAINABILITY
2019	Asim, S; Li, C; Makhdoom, HUR; Zafar, Z	Entrepreneurial Technology Opportunism and Its Impact on Business Sustainability with the Moderation of Government Regulations	ENTREPRENEURIAL BUSINESS AND ECONOMICS REVIEW
2019	Saudi M.H.M.; Sinaga O.; Roespinoedji D.; Razimi M.S.A.	Environmental sustainability in the fourth industrial revolution: The nexus between green product and green process innovation	International Journal of Energy Economics and Policy
2019	Sabandar S.Y.	Financial technology: Smes answer the opportunities and challenges of industrial revolution 4.0	Journal of Advanced Research in Dynamical and Control Systems
2019	Hampton S.; Blundel R.; Fawcett T.; Shaw C.	Growing greener: Creating a New Values-based Environmental Engagement Toolkit for SME Intermediaries	IOP Conference Series: Earth and Environmental Science
2019	Saengchai, S; Mitprasat, M;	How the adoption of sustainable technology affects the organizational performance	JOURNAL OF HUMAN SPORT AND EXERCISE

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	Jermsittiparsert, K	of SMEs in Thai Sports industry	
2019	Pozo H.; Akabane G.K.; Tachizava T.	Innovation and technology processes in micro and small business	Cogent Business and Management
2019	Singh, H; Abu Mansor, N; Krubally, M; Balder, N; Ullah, H	Investigating the impact of dynamic and relational learning capabilities on green innovation performance of SMEs	INTERNATIONAL JOURNAL OF ADVANCED AND APPLIED SCIENCES
2019	Mandić M.; Đokić J.; Gajić N.; Uljarević J.; Kamberović Ž.	Production of technology metals from waste electronics	Journal of Applied Engineering Science
2019	Nair, J; Chellasamy, A; Singh, BNB	Readiness factors for information technology adoption in SMEs: testing an exploratory model in an Indian context	JOURNAL OF ASIA BUSINESS STUDIES
2019	Asim S.; Li C.; ur Rehman Makhdoom H.	ROLE OF TOP MANAGEMENT ADVOCACY IN SME'S BUSINESS SUSTAINABILITY: A MEDIATION THROUGH TECHNOLOGY OPPORTUNISM	International Journal of Management and Sustainability
2019	Basri, WSM; Siam, MRA	Social media and corporate communication antecedents of SME sustainability performance A conceptual framework for SMEs of Arab world	JOURNAL OF ECONOMIC AND ADMINISTRATIVE SCIENCES
2019	Zahoor S.; Abdul-Kader W.; Zain M.	The prospect of smart-remanufacturing in automotive SMEs: A case study	Proceedings of the International Conference on Industrial Engineering and Operations Management
2019	Persada S.F.; Baihaqi I.	Towards the industry 4.0 business model for small medium enterprises (SMES) business incubation: Pollution reduction perspectives	Pollution Research
2019	Saunila, M; Rantala, T; Ukko, J; Havukainen, J	Why invest in green technologies? Sustainability engagement among small businesses	TECHNOLOGY ANALYSIS & STRATEGIC MANAGEMENT
2020	Bakar, MFA; Talukder, M; Quazi, A; Khan, I	Adoption of Sustainable Technology in the Malaysian SMEs Sector: Does the Role of Government Matter?	INFORMATION
2020	Budinis, S; Sachs, J; Giarola, S; Hawkes, A	An agent -based modelling approach to simulate the investment decision of industrial enterprises	JOURNAL OF CLEANER PRODUCTION
2020	Luis Alberto B.G.; Claudio R.E.; Marcelo R.T.; Alexis M.P.; Martín I.A.; Paola J.M.	Analysis of competitiveness factors for the sustainable productivity of SMEs in Trujillo (Peru); [Análisis de los factores de competitividad para la productividad sostenible de las PYMES en Trujillo (Perú)]	Revista de Metodos Cuantitativos para la Economia y la Empresa
2020	Kumar, R; Singh, RK; Dwivedi, YK	Application of industry 4.0 technologies in SMEs for ethical and sustainable operations: Analysis of challenges	JOURNAL OF CLEANER PRODUCTION
2020	Menon S.; Shah S.	Are SMEs Ready for Industry 4.0 Technologies: An Exploratory Study of i 4.0 Technological Impacts	Proceedings of International Conference on Computation, Automation and Knowledge Management, ICCAKM 2020
2020	Kassem E.; Trenz O.	Automated sustainability assessment system for small and medium enterprises reporting	SUSTAINABILITY
2020	Bisht H.S.; Singh D.	Challenges faced by micro, small and medium enterprises: A systematic review	World Review of Science, Technology and Sustainable Development
2020	Happonen A.; Santti U.; Auvinen H.;	Digital age business model innovation for sustainability in University Industry	E3S Web of Conferences

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	Räsänen T.; Eskelinen T.	Collaboration Model	
2020	Popović-Pantić S.; Semenčenko D.; Vasilić N.	Digital technologies and the financial performance of female smes in Serbia: The mediating role of innovation	Economic Annals
2020	Paliwal V.; Chandra S.; Sharma S.	Indian MSME's Sustainable Adoption of Blockchain Technology for Supply Chain Management: A Socio-Technical Perspective	IFIP Advances in Information and Communication Technology
2020	Nwaiwu F.; Duduci M.; Chromjakova F.; Otekhile C.-A.F.	Industry 4.0 concepts within the czech sme manufacturing sector: An empirical assessment of critical success factors	Business: Theory and Practice
2020	Safar, L; Sopko, J; Dancakova, D; Woschank, M	Industry 4.0-Awareness in South India	SUSTAINABILITY
2020	Lutfi A.	Investigating the moderating role of environmental uncertainty between institutional pressures and ERP adoption in Jordanian SMEs	Journal of Open Innovation: Technology, Market, and Complexity
2020	Mangla S.K.; Raut R.; Narwane V.S.; Zhang Z.; priyadarshinee P.	Mediating effect of big data analytics on project performance of small and medium enterprises	Journal of Enterprise Information Management
2020	Jayawardhana, K	OPEN INNOVATION ORIENTATION AND SUSTAINABILITY OF SMEs: DO ENTREPRENEURIAL ORIENTATION AND RESOURCE BRICOLAGE MATTER?	RISUS-JOURNAL ON INNOVATION AND SUSTAINABILITY
2020	Olmos R.M.J.; Cifuentes A.S.	Potential of Improvement of energy efficiency in Mexican's small and medium-sized manufacturing companies, a case study	ECOS 2020 - Proceedings of the 33rd International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems
2020	Ingaldi, M; Ulewicz, R	Problems with the Implementation of Industry 4.0 in Enterprises from the SME Sector	SUSTAINABILITY
2020	Centobelli P.; Cerchione R.; Esposito E.	Pursuing supply chain sustainable development goals through the adoption of green practices and enabling technologies: A cross-country analysis of LSPs	Technological Forecasting and Social Change
2020	Andriani D.P.; Nur Aini A.P.; Anwar A.A.; Adnandy R.	Risks analysis on digital platforms adoption to elevate SME businesses in developing country	Journal of Physics: Conference Series
2020	Lenart G.; Marolt M.; Vidmar D.; Borštnar M.K.; Pucihar A.	SMEs business model innovation: Does enterprise size matter?	32nd Bled eConference Humanizing Technology for a Sustainable Society, BLED 2019 - Conference Proceedings
2020	Das, S; Kundu, A; Bhattacharya, A	Technology Adaptation and Survival of SMEs: A Longitudinal Study of Developing Countries	TECHNOLOGY INNOVATION MANAGEMENT REVIEW
2020	Brozzi, R; Forti, D; Rauch, E; Matt, DT	The Advantages of Industry 4.0 Applications for Sustainability: Results from a Sample of Manufacturing Companies	SUSTAINABILITY
2020	Chege, SM; Wang, DP	The influence of technology innovation on SME performance through environmental sustainability practices in Kenya	TECHNOLOGY IN SOCIETY
2020	Isensee, C; Teuteberg, F; Griese, KM; Topi, C	The relationship between organizational culture, sustainability, and digitalization in SMEs: A systematic review	JOURNAL OF CLEANER PRODUCTION
2021	Ali, MH; Chung, LN; Kumar, A; Zailani, S;	A sustainable Blockchain framework for the halal food supply chain: Lessons from	TECHNOLOGICAL FORECASTING AND SOCIAL

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	Tan, KH	Malaysia	CHANGE
2021	Serumaga-Zake J.M.; van der Poll J.A.	Addressing the impact of fourth industrial revolution on south african manufacturing small and medium enterprises (SMEs)	SUSTAINABILITY
2021	Chatterjee, S; Chaudhuri, R; Sakka, G; Grandhi, B; Galati, A; Siachou, E; Vrontis, D	Adoption of Social Media Marketing for Sustainable Business Growth of SMEs in Emerging Economies: The Moderating Role of Leadership Support	SUSTAINABILITY
2021	Jayashree S.; Hassan Reza M.N.; Malarvizhi C.A.N.; Maheswari H.; Hosseini Z.; Kasim A.	Article the impact of technological innovation on industry 4.0 implementation and sustainability: An empirical study on malaysian small and medium sized enterprises	SUSTAINABILITY
2021	Sinyuk T.; Panfilova E.; Pogosyan R.	Digital transformation of SME business models as a factor of sustainable socio-economic development	E3S Web of Conferences
2021	Kulej-Dudek, E	Ecolabnet service packages as a response to the needs of manufacturing enterprises in the SME sector of the Baltic Sea Region	PRODUCTION ENGINEERING ARCHIVES
2021	Asoba S.N.; Mcunukelwa R.M.; Mefi N.	ELEMENTS FOR A COMPETITIVE BUSINESS ENVIRONMENT IN THE CONTEXT OF THE FOURTH INDUSTRIAL REVOLUTION: AN OVERVIEW OF THE SOUTH AFRICAN ENVIRONMENT	Academy of Entrepreneurship Journal
2021	Raj, GNLP; Kirubakaran, V	Energy Efficiency Enhancement and Climate Change Mitigations of SMEs through Grid-Interactive Solar Photovoltaic System	INTERNATIONAL JOURNAL OF PHOTOENERGY
2021	Khan, SAR; Godil, DI; Jabbour, CJC; Shujaat, S; Razzaq, A; Yu, Z	Green data analytics, blockchain technology for sustainable development, and sustainable supply chain practices: evidence from small and medium enterprises	ANNALS OF OPERATIONS RESEARCH
2021	Mubarak, MF; Tiwari, S; Petraite, M; Mubarik, M; Rasi, RZRM	How Industry 4.0 technologies and open innovation can improve green innovation performance?	MANAGEMENT OF ENVIRONMENTAL QUALITY
2021	Mladineo M.; Ćubić M.; Gjeldum N.; Crnjac Žižić M.	Human-centric approach of the Lean management as an enabler of Industry 5.0 in SMEs	Mechanical Technology and Structural Materials
2021	Shi R.; Kumar V.; Ekren B.	Impact of New Technology on Sustainability of Supply Chains: Empirical Evidence from Manufacturing SMEs in China	Lecture Notes in Information Systems and Organisation
2021	Onu P.; Mbohwa C.	Industry 4.0 opportunities in manufacturing SMEs: Sustainability outlook	Materials Today: Proceedings
2021	Pu, GL; Qamruzzaman, M; Mehta, AM; Naqvi, FN; Karim, S	Innovative Finance, Technological Adaptation and SMEs Sustainability: The Mediating Role of Government Support during COVID-19 Pandemic	SUSTAINABILITY
2021	Willenbacher, M; Scholten, J; Wohlgemuth, V	Machine Learning for Optimization of Energy and Plastic Consumption in the Production of Thermoplastic Parts in SME	SUSTAINABILITY
2021	Wisniewska-Salek, A	MANAGING A SUSTAINABLE SUPPLY CHAIN - STATISTICAL ANALYSIS OF NATURAL RESOURCES IN THE FURNITURE INDUSTRY	MANAGEMENT SYSTEMS IN PRODUCTION ENGINEERING
2021	Khanzode A.G.; Sarma P.R.S.; Mangla S.K.; Yuan H.	Modeling the Industry 4.0 adoption for sustainable production in Micro, Small & Medium Enterprises	Journal of Cleaner Production
2021	Zamorano, J; Alfaro, M; de Oliveira, VM; Fuertes, G; Duran, C; Ternero, R; Sabattin, J; Vargas, M	New manufacturing challenges facing sustainability	MANUFACTURING LETTERS

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2021	Gao, HY	RESEARCH ON ENTERPRISE FINANCIAL MANAGEMENT INNOVATION UNDER THE BACKGROUND OF BIG DATA PLATFORM-BASED ON THE PERSPECTIVE OF ECOLOGY	FRESENIUS ENVIRONMENTAL BULLETIN
2021	Ogrean, C; Herciu, M	ROMANIA'S SMES ON THE WAY TO EU'S TWIN TRANSITION TO DIGITALIZATION AND SUSTAINABILITY	STUDIES IN BUSINESS AND ECONOMICS
2021	Mora, H; Morales-Morales, MR; Pujol-Lopez, FA; Molla-Sirvent, R	Social cryptocurrencies as model for enhancing sustainable development	KYBERNETES
2021	Rozak, H; Adhiatma, A; Fachrunnisa, O; Rahayu, T	Social Media Engagement, Organizational Agility and Digitalization Strategic Plan to Improve SMEs' Performance	IEEE TRANSACTIONS ON ENGINEERING MANAGEMENT
2021	Mukhoryanova O.; Kuleshova L.; Rusakova N.; Mirgorodskaya O.	Sustainability of micro-enterprises in the digital economy	E3S Web of Conferences
2021	Dotelli G.; Negretti T.A.; Santori S.; Bonanomi L.; Mauri G.	SUSTAINABLE LEATHER FOR SUSTAINABLE FASHION	Procedia Environmental Science, Engineering and Management
2021	Meng, L; Qamruzzaman, M; Adow, AHE	Technological Adaption and Open Innovation in SMEs: An Strategic Assessment for Women-Owned SMEs Sustainability in Bangladesh	SUSTAINABILITY
2021	Soondka A.Q.; Smuts H.	The Impact of Industry 4.0 on the Business Models of Small and Medium Enterprises: A Systematic Literature Review	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)
2021	Jayashree, S; Reza, MNH; Malarvizhi, CAN; Maheswari, H; Hosseini, Z; Kasim, A	The Impact of Technological Innovation on Industry 4.0 Implementation and Sustainability: An Empirical Study on Malaysian Small and Medium Sized Enterprises	SUSTAINABILITY
2021	Yousaf, Z; Radulescu, M; Sinisi, CI; Serbanescu, L; Paunescu, LM	Towards Sustainable Digital Innovation of SMEs from the Developing Countries in the Context of the Digital Economy and Frugal Environment	SUSTAINABILITY
2021	Cosentino, A; Paoloni, P; Iannone, B; Temperini, V	Tradition, innovation and relationships: Emergent profiles from agro-food Italian industry	BRITISH FOOD JOURNAL
2022	Soni, G; Kumar, S; Mahto, RV; Mangla, SK; Mittal, ML; Lim, WM	A decision-making framework for Industry 4.0 technology implementation: The case of FinTech and sustainable supply chain finance for SMEs	TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE
2022	Sanchez, NH; Oskam, J	A new tourism cycle on the Canary Islands: scenarios for digital transformation and resilience of small and medium tourism enterprises	JOURNAL OF TOURISM FUTURES
2022	Tsvetanova L.; Carraresi L.; Wustmans M.; Bröring S.	Actors' strategic goals in emerging technological innovation systems: evidence from the biorefinery sector in Germany	Technology Analysis and Strategic Management
2022	Mokonyama M.; Malatji M.; Mlitwa N.	Addressing operational challenges of small and medium enterprises of the logistics industry-Potential for autonomous vehicles	8th International Conference on Engineering and Emerging Technologies, ICEET 2022
2022	Vrontis, D; Chaudhuri, R; Chatterjee, S	Adoption of Digital Technologies by SMEs for Sustainability and Value Creation: Moderating Role of Entrepreneurial Orientation	SUSTAINABILITY
2022	Hanaysha J.R.; Al-Shaikh M.E.; Kumar P.	An Examination of Customer Relationship Management and Business Sustainability in Small and Medium Enterprises	International Journal of Customer Relationship Marketing and Management
2022	Mijan R.; Noor S.M.; Mustapha M.J.;	An Inside-Out Model of Brand Orientation for SME Branding	Jurnal Komunikasi: Malaysian Journal of

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	Briandana R.		Communication
2022	Prasad, S; Rao, AN; Lanka, K	Analysing the Barriers for Implementation of Lean-led Sustainable Manufacturing and Potential of Blockchain Technology to Overcome these Barriers: A Conceptual Framework	INTERNATIONAL JOURNAL OF MATHEMATICAL ENGINEERING AND MANAGEMENT SCIENCES
2022	Islam A.; Wahab S.A.; Latiff A.S.A.	Annexing a Smart Sustainable Business Growth Model for Small and Medium Enterprises (SMEs)	World Journal of Entrepreneurship, Management and Sustainable Development
2022	Chatterjee, S; Chaudhuri, R; Shah, M; Maheshwari, P	Big data driven innovation for sustaining SME supply chain operation in post COVID-19 scenario: Moderating role of SME technology leadership	COMPUTERS & INDUSTRIAL ENGINEERING
2022	Singh, M; Singh, K; Sethi, AS	Contribution of green manufacturing for realizing business performance in Indian small and medium scale organizations (SME's)	JOURNAL OF SCIENCE AND TECHNOLOGY POLICY MANAGEMENT
2022	Maqsood, S; Zhou, Y; Lin, XT; Huang, S; Jamil, I; Shahzad, K	Critical success factors for adopting green supply chain management and clean innovation technology in the small and medium-sized enterprises: A structural equation modeling approach	FRONTIERS IN PSYCHOLOGY
2022	Gupta, S; Prathipati, B; Dangayach, GS; Rao, PN; Jagtap, S	Development of a Structural Model for the Adoption of Industry 4.0 Enabled Sustainable Operations for Operational Excellence	SUSTAINABILITY
2022	Dossou, PE; Laouenan, G; Didier, JY	Development of a Sustainable Industry 4.0 Approach for Increasing the Performance of SMEs	PROCESSES
2022	Khan, SAR; Piprani, AZ; Yu, Z	Digital technology and circular economy practices: future of supply chains	OPERATIONS MANAGEMENT RESEARCH
2022	Budiarto D.S.; Prabowo M.A.; Uyob S.; Diansari R.E.	Diversification Strategy and its Impact on Sustainability: Research on Indonesian SMEs	International Journal of Applied Economics, Finance and Accounting
2022	Zhao, W; Luo, ZS; Liu, QL	Does supply chain matter for environmental firm performance: mediating role of financial development in China	ECONOMIC CHANGE AND RESTRUCTURING
2022	Huynh, PH	Enabling circular business models in the fashion industry: the role of digital innovation	INTERNATIONAL JOURNAL OF PRODUCTIVITY AND PERFORMANCE MANAGEMENT
2022	Khizar, HMU; Iqbal, J	Entrepreneurial responsible orientation in small and medium businesses: the case of Pakistan	KYBERNETES
2022	Voza, D; Szewieczek, A; Grabara, D	ENVIRONMENTAL SUSTAINABILITY IN DIGITALIZED SMEs: COMPARATIVE STUDY FROM POLAND AND SERBIA	SERBIAN JOURNAL OF MANAGEMENT
2022	Britzelmaier B.; Rommel P.; Schlosser J.M.; Weidler C.	Green controlling in medium-sized companies in Baden-Württemberg: an insight view	Global Business and Economics Review
2022	Yadav, V; Gahlot, P	Green Lean Six Sigma sustainability-oriented framework for small and medium enterprises	INTERNATIONAL JOURNAL OF QUALITY & RELIABILITY MANAGEMENT
2022	Nie, LB; Gong, H; Lai, XP	Green research intensity and diversified performance: the moderating role of environmental regulation	EUROPEAN JOURNAL OF INNOVATION MANAGEMENT
2022	Hariastuti, NLP; Pratikto; Santoso, PB; Tama, IP	Identifying Driving Factors of Technological Innovation to Create Sustainable Value in Metal Manufacturing SMEs	INDUSTRIAL ENGINEERING AND MANAGEMENT SYSTEMS

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2022	Raut S.; von Gersdorff G.; Schemminger J.; Adolphs J.; Sturm B.	Improving food processing through integration of artificial intelligence in the drying process: a perspective	Lecture Notes in Informatics (LNI), Proceedings - Series of the Gesellschaft fur Informatik (GI)
2022	Aamer, AM; Al-Awlaqi, MA	Individual entrepreneurial factors affecting adoption of circular business models: An empirical study on small businesses in a highly resource-constrained economy	JOURNAL OF CLEANER PRODUCTION
2022	Lopes J.D.	INDUSTRY 4.0 AND THE SMALL BUSINESS SOMETHING BEHIND THE TECHNOLOGY - A LITERATURE REVIEW	Serbian Journal of Management
2022	Cerveny, L; Sloup, R; Cervena, T; Riedl, M; Palatova, P	Industry 4.0 as an Opportunity and Challenge for the Furniture Industry-A Case Study	SUSTAINABILITY
2022	Chaudhuri, R; Chatterjee, S; Vrontis, D; Chaudhuri, S	Innovation in SMEs, AI Dynamism, and Sustainability: The Current Situation and Way Forward	SUSTAINABILITY
2022	Aminullah, E; Fizzanty, T; Nawawi, N; Suryanto, J; Pranata, N; Maulana, I; Ariyani, L; Wicaksono, A; Suardi, I; Azis, NLL; Budiatri, AP	Interactive Components of Digital MSMEs Ecosystem for Inclusive Digital Economy in Indonesia	JOURNAL OF THE KNOWLEDGE ECONOMY
2022	Teoh M.F.; Ahmad N.H.; Abdul-Halim H.; Ramayah T.	Is Digital Business Model Innovation the Silver Bullet for SMEs Competitiveness in Digital Era? Evidence from a Developing Nation	Vision
2022	Ibidunni, AS; Ufua, DE; Opute, AP	Linking disruptive innovation to sustainable entrepreneurship within the context of small and medium firms: A focus on Nigeria	AFRICAN JOURNAL OF SCIENCE TECHNOLOGY INNOVATION & DEVELOPMENT
2022	Vlad, F; Severin, I	MANAGEMENT THROUGH PROCESSES IN SMES USING QUALITY 4.0.	ACTA TECHNICA NAPOCENSIS SERIES-APPLIED MATHEMATICS MECHANICS AND ENGINEERING
2022	Korne T.; Köhler C.; Ewald P.; Freyler D.	Maturity Models for Environmental Sustainability – Assessment of Applicability to Manufacturing SMEs; [Reifegradmodelle der ökologischen Nachhaltigkeit: Beurteilung der Eignung für fertigende KMU]	Zeitschrift Kunststofftechnik/Journal of Plastics Technology
2022	Hossain, MI; Ong, TS; Teh, BH; Said, RM; Siow, ML	Nexus of Stakeholder Integration, Green Investment, Green Technology Adoption and Environmental Sustainability Practices: Evidence from Bangladesh Textile SMEs	PERTANIKA JOURNAL OF SOCIAL SCIENCE AND HUMANITIES
2022	Viale L.; Vacher S.; Frelet I.	Open innovation as a practice to enhance sustainable supply chain management in SMEs	Supply Chain Forum
2022	Strakova, J; Talir, M; Vachal, J	OPPORTUNITIES AND THREATS OF DIGITAL TRANSFORMATION OF BUSINESS MODELS IN SMES	ECONOMICS & SOCIOLOGY
2022	Saary, R; Karpati-Daroczi, J; Tick, A	PROFIT OR LESS WASTE? DIGITAINABILITY IN SMEs - A COMPARISON OF HUNGARIAN AND SLOVAKIAN SMEs	SERBIAN JOURNAL OF MANAGEMENT
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	J; Cambal, J; Skrabulakova, EF	of the Enterprise	
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2023	Uddin A.; Cetindamar D.; Hawryszkiewycz I.; Sohaib O.	The Role of Dynamic Cloud Capability in Improving SME's Strategic Agility and Resource Flexibility: An Empirical Study	SUSTAINABILITY

Supplementary Materials

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