

DIGITAL TECHNOLOGIES IN THE CONTEXT OF SMALL AND MEDIUM-SIZED ENTERPRISES OF THE MANUFACTURING INDUSTRY

Christian TOROS*

Faculty of Business, Management and Economics, University of Latvia, Raiņa bulvāris 19, Rīga, LV-1586, Latvia

Received 29 February 2024; accepted 15 April 2024

Abstract. In the literature, digitalization is often designated as a so-called megatrend. One of the key characteristics of megatrends is that they are characterized by their ability to influence the environment in a variety of areas. In the case of digital change, this process is powered by digital technologies. Scientific publications from the recent past were examined as part of a literature review with the aim to identify and assess digital technologies and their areas of application in the context of small and medium-sized enterprises (SMEs) from the manufacturing industry. The study highlights that a significant proportion of scientific research in this area focuses on “Industry 4.0” and the associated digital technologies. However, it also became clear that there are different classifications of digital technologies in literature. It has also been shown that there is a wide variety of technologies and devices that are considered as digital technologies in the respective literature sources. Without appropriate sub-categorization, this variety could make it difficult to compare digital technologies in cross-literature studies. Furthermore, the study revealed indications that the interplay of digital technologies appears to be an underrepresented topic in the studies examined. For this reason, this study encourages a more holistic view of the digital technologies used by manufacturing SMEs.

Keywords: digitalization, digital technologies, classification, SMEs, manufacturing industry.

JEL Classification: M10, O33.

1. Introduction

Nowadays, it seems almost normal to refer to digitalization as a megatrend, analogous to various publications (Höse et al., 2023; Hüther, 2020; Winkler et al., 2023).

However, this raises the question of what actually characterizes a megatrend? One of the fundamental characteristics of megatrends is that they have the ability to significantly influence the environment in various areas (Freundl, 2023).

In the opinion of Streibich (2015), digitalization is already taking on forms that could go beyond a megatrend. Furthermore, digitalization is described as a transformative force that is able to raise essential aspects of our reality to a higher level and, for example, promote the generation of innovations.

The key drivers of this digital development include digital technologies (Arranz et al., 2023; Mihiu et al., 2023).

A special feature of digital technologies is their adaptability, which is based, among other things, on their

enormous flexibility. Due to their wide range of applications, their benefits are not limited to specific sectors or industries. In addition, they can be used in almost all areas of a company. For example, they can play a supporting role in the creation of new products, services, processes and business models as part of the innovation process (Ciarli et al., 2021).

Furthermore, the use of digital technologies in companies can help to improve performance (Chaudhuri et al., 2022; Elia et al., 2021), break new entrepreneurial ground (Costa et al., 2023; Soluk et al., 2021) and under certain circumstances also improve the ability to act in order to respond better to unexpected events (Troise et al., 2022).

The use of digital technologies is therefore a necessary prerequisite for most companies to maintain their competitiveness in an increasingly digitalized environment (Ciarli et al., 2021).

According to the understanding of Añón Higón and Bonvin (2024), it should also be made clear that the

* Corresponding author. E-mail: c.toros@t-online.de

benefits of using digital technologies are not tied to a specific company size and can therefore also play an important function for small and medium-sized enterprises (SMEs).

The integration and use of digital technologies has recently become an important task, especially in the manufacturing industry (Yang et al., 2021).

For this reason, the present study has set itself the task of examining the scientific research of recent years in the field of companies from the manufacturing industry with a focus on digital technologies within the framework of a systematic literature review. The terms digital technologies and digital tools are used interchangeably in this paper. However, the term digital technologies will be used exclusively in the further course of this study.

The aim of this study is to consolidate the digital technologies and their application areas in the context of SMEs that have been examined in the literature in the recent past, which are explicitly listed or examined in the respective literature sources of the systematic literature review under the generic term digital technologies, and to carry out an assessment in this regard.

The research method used in this study is a systematic literature review. In addition, SMEs in the manufacturing industry are the research object of this study.

This study has specifically concentrated only on companies that belong to the group of SMEs. With regard to the differentiation of SMEs from, for example, large companies, this study has not made its own distinction with regard to SMEs. Instead, this study is based on the respective underlying understanding of SMEs from the various literature sources that were included in the study as part of the systematic literature review.

There were several reasons for the decision to focus on SMEs from the manufacturing industry.

On the one hand, SMEs have to overcome various challenges on their path to digitalization. In this context, it is particularly important to point out that the financial possibilities of SMEs are often limited. This circumstance represents a fundamental challenge with regard to the digital transformation of SMEs. For this reason, SMEs need to examine very carefully which digital technologies will actually help them move forward (Le-Dain et al., 2023).

On the other hand, another aspect should also be mentioned in this light. This concerns the scientific research that has been carried out to date in connection with digitalization. Scientific research has mostly focused on large companies in its studies, which has led to studies on SMEs being comparatively underrepresented (Ardito et al., 2021).

This point is of particular importance because scientific studies have already indicated that the process of incorporating digital technologies in SMEs can differ from that in large companies (Soluk & Kammerlander, 2021).

In this context, Estensoro et al. (2022) refer to scientific studies that assume that it could be much more difficult for SMEs to actually take advantage of the

opportunities offered by “Industry 4.0” compared to large companies.

Furthermore, the importance of SMEs for the global economy is another reason why this study places SMEs at the center of interest. According to the World Bank, around nine out of ten companies globally belong to the group of SMEs. In addition, on average at least every second employee in the world is employed by an SME (The World Bank, 2019).

The structure of this study is briefly explained below.

Section one deals with “Industry 4.0” and the associated digital technologies. Furthermore, the role of SMEs in connection with “Industry 4.0” is also highlighted in this respect.

Section two first presents the research questions that are to be investigated in this study as part of a literature analysis. In addition, the procedure for the selection of literature sources is explained within the framework of the chosen research methodology on which this study is based.

Section three summarizes the results of the literature analysis and subdivides them according to the respective research questions.

The following section concludes with a summary of the results of the study and the derivation of implications.

This study is completed with a final section in which the limitations of the investigations carried out are shown. Furthermore, a brief outlook shows how this study can contribute to future research topics respectively research works.

2. “Industry 4.0”

In the context of companies in the manufacturing industry, various names are used for the digital change (Schönfuß et al., 2021).

In European usage, however, the term “Industry 4.0” has predominantly become established (Masood & Sonntag, 2020).

The term “Industry 4.0” celebrated its communicative premiere over 20 years ago, when it was made accessible to the general public at the Hannover Messe in 2011 (Becker et al., 2020; Steinhoff, 2016).

Massive technological changes have already led to upheavals in the past and ultimately also triggered technological progress. In particular, these are mainly due to advances in the fields of mechanics, electrics and information technology. The current developments that come to bear in “Industry 4.0” are primarily focused on the ability to connectivity, which should bring about communication within the manufacturing environment and result in self-organizing and self-directing production processes (Appelfeller & Feldmann, 2018, p. 112).

This digital development process, which is taking place in the manufacturing industry, is primarily based on the integration of digital technologies. The beneficial effects of “Industry 4.0” and the associated digital

technologies have been recognized by SMEs, which are striving either to generate efficiency advantages in their production through self-initiated activities respectively to ensure the preservation of transport routes for goods through external initiatives, for example (Arroyabe et al., 2024).

Further advantages of digital technologies can lie in increased adaptation to changes, in the enhancement of certain features and in cost savings (Ranka & Vasudevan, 2022).

However, there are also controversial views regarding the benefits of digital technologies. At the very least, they assume that the exclusive inclusion of digital technologies does not automatically have a positive effect on companies. There are also studies that show that a large proportion of efforts to integrate digital technologies are not crowned with success (Rajala & Hautala-Kankaanpää, 2023).

In the understanding of Arroyabe et al. (2024), the interplay of digital technologies and processes for managing production is conducive to the success of companies in the manufacturing industry and is therefore also an important element on the path to digital change.

The research work by Islam et al. (2023) recognizes various positive influencing factors in a holistic digitalization process, especially for SMEs. This could open up new ways for SMEs to create innovations and the opportunity to tap into new digital sales channels. These options offer SMEs the prospect of sustainably improving their competitive position on the market.

However, even in the case of “Industry 4.0”, the literature has so far mainly focused on the investigation of large companies (Arroyabe et al., 2024).

This situation currently seems to be changing, as scientific research interest in SMEs in the field of digitalization has increased in the recent past (Rajala & Hautala-Kankaanpää, 2023).

This change is considered necessary in several respects. This is partly due to the enormous importance that SMEs have for the manufacturing industry and partly because SMEs sometimes have to deal with much greater resistance to the requirements of “Industry 4.0” than their larger competitors in the manufacturing industry, for example (Mittal et al., 2018).

In their study, Arroyabe et al. (2024), for example, list a lack of information and the leadership of companies as possible causes that could hinder the transition of SMEs to “Industry 4.0”.

One other relevant aspect that could pose a difficult task for efforts in the digitalization process involves the security measures that are intended to protect the company from potential virtual threats (Horváth & Szabó, 2019).

In addition, employees in SMEs also have less free capacity to deal with the further development of digitalization in the company. Furthermore, decisions concerning the further development of SMEs often depend on the managing director, who in many cases is also the proprietor of the organization. This means that important

changes in the context of digitalization can depend on the competencies and knowledge of the decision-maker. Finally, another challenge for SMEs is that they often have restricted financial capacities and therefore have to plan investments and the resulting revenues very well. However, decisions in this area are not exactly easy, as they can sometimes involve very high risks (Bernaert et al., 2014).

This is partly due to the fact that it is very difficult to calculate the profitability of digital technologies in advance of investment decisions (Le-Dain et al., 2023).

Nevertheless, the changing environment requires SMEs to adapt to these new circumstances. These changes are expressed, for example, by an ever-shorter period of marketability of products, diverging market requirements or a change in customer behavior. In order to meet these requirements and to avoid jeopardizing their own future viability, companies need to get to grips with digital technologies (Horváth & Szabó, 2019).

The digital technologies frequently associated with “Industry 4.0” are among others “[...] big data, cloud computing, artificial intelligence, and machine learning (AI/ML), robotics, data analytics and blockchain in an interconnected industrial environment through the Internet of Things (IoT) [...]” (Arroyabe et al., 2024).

Furthermore, in addition to the digital technologies mentioned above, Bressanelli et al. (2018) list “3D printing” and “virtual and augmented reality” in connection with those digital technologies that they consider to be among the main pillars of “Industry 4.0”.

Due to the fact that digital technologies offer this potential for all companies, they differ from conventional technologies. Conventional technologies can be characterized above all by their high degree of individualization. However, in the case of digital technologies, the right choice of digital technologies could play a much more important role. Therefore, the knowledge about the most commonly used digital technologies and their areas of application within their own industry sector could play a key role for companies (Hassan et al., 2023).

In a nutshell, it can be said that the inclusion and application of digital technologies are an important basic prerequisite for the realization of “Industry 4.0” in companies (Tamvada et al., 2022).

In addition, the use of digital technologies in companies can open up a wide range of design options that can be used to perceive and implement new business activities (Nambisan et al., 2019).

3. Research methodology

The research methodology used in this research work is based on a systematic literature review.

This literature analysis exclusively used the Scopus literature database in the course of the literature search.

The choice of Scopus is based on the fact that Scopus is one of the leading literature databases in the various research disciplines (Ferreira et al., 2023).

In addition, the Scopus literature database is also one of the most comprehensive collections of high-quality scientific literature (Yang & Sulaiman, 2023).

The research questions of this study are first explained below. The keywords and search strategy used to find the literature and the selection process for including the literature are then described in more detail.

3.1. Research questions

This study concentrates on digital technologies in SMEs from the manufacturing industry. Digital technologies play an important role in the digitalization of companies and are one of the factors driving this development process forward (Mihu et al., 2023; Zahoor et al., 2023).

In order to shed more light on this prominent position of digital technologies, the following research questions are to be answered in the course of this study as part of a systematic literature review:

- **Research question 1a:**
Which digital technologies are explicitly mentioned and/or cited in the literature under the generic term of digital technologies?
- **Research question 1b:**
Which digital technologies used under the generic term of digital technologies were explicitly considered in the investigations of the respective research papers?
- **Research question 2:**
In which areas of application should the digital technologies used under the generic term of digital technologies and explicitly examined in the respective research papers be applied?

3.2. Search strategy and selection parameters

The most important keywords in this search are digital technologies, SMEs and the manufacturing industry. To increase the number of hits, different variants of the three main terms mentioned are used within the search text.

The literature search was carried out using the following search query in the Scopus literature database:

(TITLE-ABS-KEY (“small and medium size enterprise*” OR “small and medium-size enterprise*” OR “small and medium-sized enterprise*” OR sme* OR “small and medium size compan*” OR “small and medium-size compan*” OR “small and medium-sized compan*” OR “small and medium size firm*” OR “small and medium-size firm*” OR “small and medium-sized firm*”) AND (TITLE-ABS-KEY (“manufacturing industr*” OR “production industr*” OR “fabrication industr*” OR “industrial manufacturing” OR “manufacturing sector*” OR “production sector*” OR “fabrication sector*” OR manuf*)) AND (TITLE-ABS-KEY (“digital technolog*” OR “digital tool*”)).

This query resulted in a total of 189 hits in the database. Subsequently, the search strategy was further refined by using various filter functions.

- According to the view of Sauer and Seuring (2023), a minimum period of five years is recommended

for a literature review. For this reason, the results in the next step were limited to the years 2019 to 2024. This is to ensure that the literature examined is as up-to-date as possible and that the overall depth of the literature analysis is sufficient. This reduced the total number of results by 21 hits, leaving a total of 168 hits.

- In order to transfer the literature hits into an economic frame of reference, the knowledge area of the literature search was restricted to the field of business studies. This led to a further reduction of 95 hits to 73 literature sources.
- This was followed by the next restriction, which focused on the kind of research work. The results were filtered according to articles and conference papers. The total number of hits was therefore reduced by a further ten sources, bringing the total number of hits down to 63.
- The search results were then selected according to their current status with regard to their publication process. At this point, only publications that had already completed this process were considered, reducing the number of results by eleven hits and leaving 52 publications after this filter stage.
- In the second last filter step to narrow down the results, the remaining literature studies were limited to English and German for reasons of manageability. This step meant that a further literature source was excluded from the following investigations. After this, 51 sources were still available.
- The final filtering process reduced the total number of literature sources by selecting only those sources that could be reviewed without restrictions. This circumstance caused that a further 30 studies were not considered for continuation of the study. On completion of the filtering process, 21 research works remained in the search.

Once the results had been narrowed down using the filters, the next step was to examine the remaining 21 articles on the basis of their titles, keywords and abstracts in order to check the relevance of the literature with regard to the research project.

In a final step, those articles that were still considered after this preliminary examination were subjected to an intensive examination with regard to their content and their significance for answering research questions.

The insights gained from the investigation led to a further 16 articles being removed from the search results list, so that ultimately five literature sources were included in the final literature analysis.

4. Outcomes of the analysis

The results of this investigation are examined and assessed in more detail in the following three sections in accordance with the respective research questions.

4.1. Named and/or cited digital technologies

The following section is intended to answer research question 1a.

The development of digital technologies continues to advance (Ciarli et al., 2021).

In addition, a large number of digital technologies have already been developed in recent years, which could already be available for use by companies in principle (Nambisan et al., 2019).

The following Table 1 provides an overview of which digital technologies were explicitly named and/or cited as such in the literature sources of the literature analysis.

Table 1. Summary of digital technologies explicitly named and/or cited in the research works selected within the literature review (source: the table has been created by author based on (Arroyabe et al., 2024; Ballerini et al., 2023; Bettiol et al., 2023; Chavez et al., 2020; Ranka & Vasudevan, 2022))

Sources:	Digital technologies:
(Arroyabe et al., 2024)	“big data”; “cloud computing”; “artificial intelligence and machine learning (AI/ML)”; “smart devices”; “robotics”; “data analytics”; “blockchain”; “High-speed infrastructure”; “email”; “website”
(Ballerini et al., 2023)	“Digital platforms”
(Bettiol et al., 2023)	“Computer numerical controlled (CNC) automatic machines”; “Enterprise Resource Planning (ERP)”; “Customer Relationship Management (CRM)”; “E-commerce”; “autonomous robots and value chain integration systems”; “SCM”; “cloud system”; “cyber-security”; “3D printing and rendering”; “new (automatic) production machine”; “artificial intelligence and Internet of Things (IoT)”
(Chavez et al., 2020)	“ERP systems”; “manufacturing execution systems, MES” and “disturbance data handling system”
(Ranka & Vasudevan, 2022)	“Internet of Things”; “Big Data”; “Cloud Computing”; “Additive Manufacturing”; “Tracking Tracing Technologies”; “Cyber-Physical Production Systems”; “smart phones”; “watches”; “tablets”

What is striking when looking at Table 1 is the wide variety and broad spectrum of technologies and end devices that are subsumed under the umbrella term of digital technologies in the literature. In this context, it would be advantageous for comprehensibility and comparability for both science and practice if uniform sub-segments could be defined within the digital technologies in order to be able to classify and group the digital technologies accordingly.

4.2. Digital technologies included in the investigations

In order to answer research question 1b, the literature sources included in the literature analysis are examined to determine which digital technologies were explicitly included in the investigation of the respective research work.

Table 2 below provides an overview of the results regarding research question 1b.

Table 2. Summary of the specific digital technologies from Table 1 that were considered in the investigations of the respective research papers selected as part of the literature review (source: the table has been created by author based on (Arroyabe et al., 2024; Ballerini et al., 2023; Chavez et al., 2020))

Sources:	Digital technologies included in the investigations:
(Arroyabe et al., 2024)	“AI”; “cloud computing”; “robotics”; “smart devices”; “big data analytics”; “high-speed infrastructure”; “blockchain”
(Ballerini et al., 2023)	“Digital platforms”
(Chavez et al., 2020)	“ERP systems”; “manufacturing execution systems, MES” and “disturbance data handling system”

Despite the relatively small amount of literature included in this literature review, Table 2 nevertheless shows that very few specific digital technologies seem to be in the focus of the respective research activities.

4.3. Application areas of the digital technologies included in the investigations

In the context of answering research question 2, the literature sources included in the literature review are examined to determine in which fields of application the digital technologies are to be used.

This question is limited exclusively to those digital technologies that were explicitly included in the investigation part of the respective research work.

Table 3 below summarizes the findings on research question 2.

Table 3. Summary of applications areas of specific digital technologies included in the investigations in the research works selected within the literature review (source: the table has been created by author based on (Arroyabe et al., 2024; Ballerini et al., 2023; Chavez et al., 2020))

Sources:	Application areas of digital technologies:
(Arroyabe et al., 2024)	The digital technologies used in the study are not assigned to any specific application within this research work. Instead, they should be used to determine the level of development of digitalization in companies.
(Ballerini et al., 2023)	“e-commerce”
(Chavez et al., 2020)	“deviation management”

Similar tendencies as in Table 2 can also be seen in Table 3. The application areas of digital technologies and end devices explicitly mentioned under the generic term of digital technologies are hardly addressed in the studies examined.

5. Conclusions and implications

The results of this study are intended to provide an overview of the digital technologies summarized under the term digital technologies and their areas of application, which play an essential role in the literature of SMEs in the manufacturing sector.

In particular, these overviews are intended to support the responsible persons and especially the decision-makers in SMEs in the manufacturing industry in gaining an overview of the various digital technologies in their sector.

In addition, this work aims to encourage the aforementioned groups of people from SMEs to engage more intensively with this topic area and the diverse manifestations of digital technologies within their industry sector due to the importance of digital technologies described above.

Furthermore, the findings from the literature analysis have led to the following conclusions.

The studies have shown that although a significant proportion of research studies in the field of SMEs in the manufacturing industry deal with “Industry 4.0” and the associated digital technologies (Arroyabe et al., 2024; Ranka & Vasudevan, 2022), these studies often do not consider the digital technologies in the respective studies individually, but only as a group. Only a few of the research papers differentiate between the various digital technologies and address their specific features in terms of their functions or the various applications for which they are best suited.

For example, only one of the research papers examined in the literature review focused on research into a single digital technology.

The study also revealed that there is hardly any uniform classification of digital technologies. This can lead to the same technologies or end devices being referred to or categorized differently in various studies. However, these different classifications are not exactly conducive to scientific research.

In addition, the results from research question 1a showed that there is a very large number of different technologies and end devices that are summarized under the collective term of digital technologies. In this context, the definition of sub-segments, for example, could contribute to a better understanding and comparison of digital technologies, from which both science and companies could benefit.

The indications from research questions 1b and 2 also show that the literature only seems to focus on a few specific digital technologies and their areas of application in its studies.

Furthermore, the literature sources place little emphasis on the importance of the interconnections and mutual effects of digital technologies. This view is in line with the research work of Blichfeldt and Faillant (2021), who argue that digital technologies can interact with each other.

However, further research in this regard could be very beneficial, especially for SMEs.

It is precisely this knowledge of possible connections, modes of action and mutual interrelationships among digital technologies (Blichfeldt & Faillant, 2021) that could be of great benefit, especially for SMEs, as they generally only have restricted opportunities (Arranz et al., 2023).

For example, due to their rather modest financial background and their mostly lack of expertise (Arranz et al., 2023; Masood & Sonntag, 2020), SMEs could benefit in several ways from progress in this area of research with regard to the uptake and introduction of digital technologies.

This knowledge would not only help them to possibly implement the more suitable digital technologies in the company, but would also help them to introduce several digital technologies, for example, to select the most efficient combination of digital technologies.

This would in turn support SMEs in generating the greatest possible benefit from the interplay of different digital technologies.

These efficiency gains could ultimately help SMEs to remain competitive in the future.

6. Limitations and future outlook

For the sake of completeness, it should of course be mentioned that the results of this study are subject to various limitations.

The most important limitation results from the chosen research methodology, which consists of the method of a systematic literature review.

In this context, it should also be noted that the investigations carried out in this work are also limited because the literature search carried out is based on a single database only.

Moreover, it should be noted that, as a consequence, only very few research studies could be included in the literature analysis.

One of the main aims of this research work is to create a basis for future research work and to support further research in the field of digital technologies.

In this regard, an explicit call is made for further research respectively for more research works to be carried out in the following areas.

It would be fundamentally helpful for further research into digital technologies if the subject area of classifying and delimiting digital technologies were to make further progress.

There is otherwise a risk that the area of digital technologies could very soon become non-transparent and confusing if the evolution of digital technologies continues at this fast rate (Kolagar et al., 2022).

This could also have a negative impact on scientific research, for example, if it made it considerably more difficult to compare research works in connection with digital technologies.

In addition, future research should focus more on the investigation of individual digital technologies as well as the combined application and mutual influence of digital technologies.

For this reason, analogous to Blichfeldt and Faullant (2021), this research paper advocates a more holistic investigation of digital technologies in future research studies.

References

- Añón Higón, D., & Bonvin, D. (2024). Digitalization and trade participation of SMEs. *Small Business Economics*, 62(3), 857–877. <https://doi.org/10.1007/s11187-023-00799-7>
- Appelfeller, W., & Feldmann, C. (2018). *Die Digitale Transformation des Unternehmens. Systematischer Leitfaden mit Zehn Elementen zur Strukturierung und Reifegradmessung* [The digital transformation of the company. Systematic guide with ten elements for structuring and measuring maturity]. Springer. <https://doi.org/10.1007/978-3-662-54061-9>
- Ardito, L., Raby, S., Albino, V., & Bertoldi, B. (2021). The duality of digital and environmental orientations in the context of SMEs: Implications for innovation performance. *Journal of Business Research*, 123, 44–56. <https://doi.org/10.1016/j.jbusres.2020.09.022>
- Arranz, C. F. A., Arroyabe, M. F., Arranz, N., & de Arroyabe, J. C. F. (2023). Digitalisation dynamics in SMEs: An approach from systems dynamics and artificial intelligence. *Technological Forecasting and Social Change*, 196, Article 122880. <https://doi.org/10.1016/j.techfore.2023.122880>
- Arroyabe, M. F., Arranz, C. F. A., de Arroyabe, I. F., & de Arroyabe, J. C. F. (2024). The effect of IT security issues on the implementation of industry 4.0 in SMEs: Barriers and challenges. *Technological Forecasting and Social Change*, 199, Article 123051. <https://doi.org/10.1016/j.techfore.2023.123051>
- Ballerini, J., Herhausen, D., & Ferraris, A. (2023). How commitment and platform adoption drive the e-commerce performance of SMEs: A mixed-method inquiry into e-commerce affordances. *International Journal of Information Management*, 72, Article 102649. <https://doi.org/10.1016/j.ijinfomgt.2023.102649>
- Becker, W., Ulrich, P., Schmid, O., & Feichtinger, C. (2020). Grundlagen [Basics]. In W. Becker, P. Ulrich, O. Schmid, & C. Feichtinger (Eds.), *Industrielle Digitalisierung. Management und Controlling im Mittelstand* [Industrial digitalization. Management and controlling in medium-sized companies] (pp. 7–36). Springer. https://doi.org/10.1007/978-3-658-28815-0_3
- Bernaert, M., Poels, G., Snoeck, M., & de Backer, M. (2014). Enterprise architecture for small and medium-sized enterprises: A starting point for bringing EA to SMEs, based on adoption models. In J. Devos, H. van Landeghem, & D. Deschoolmeester (Eds.), *Information systems for small and medium-sized enterprises. Progress in IS*. (pp. 67–96). Springer. https://doi.org/10.1007/978-3-642-38244-4_4
- Bettiol, M., Capestro, M., Di Maria, E., & Micelli, S. (2023). Ambidextrous strategies in turbulent times: The experience of manufacturing SMEs during the COVID-19 pandemic. *International Journal of Physical Distribution & Logistics Management*, 53(2), 248–272. <https://doi.org/10.1108/IJPDLM-10-2021-0422>
- Blichfeldt, H., & Faullant, R. (2021). Performance effects of digital technology adoption and product & service innovation – A process-industry perspective. *Technovation*, 105, Article 102275. <https://doi.org/10.1016/j.technovation.2021.102275>
- Bressanelli, G., Adrodegari, F., Perona, M., & Sacconi, N. (2018). Exploring how usage-focused business models enable circular economy through digital technologies. *Sustainability*, 10(3), Article 639. <https://doi.org/10.3390/su10030639>
- Chaudhuri, A., Subramanian, N., & Dora, M. (2022). Circular economy and digital capabilities of SMEs for providing value to customers: Combined resource-based view and ambidexterity perspective. *Journal of Business Research*, 142, 32–44. <https://doi.org/10.1016/j.jbusres.2021.12.039>
- Chavez, Z., Baalsrud Hauge, J., Bellgran, M., Gullander, P., Johansson, M., Medbo, L., Medbo, P., & Ström, M. (2020). Digital tools and information needs assessment for efficient deviation handling in SMEs. In K. Säfsen & F. Elgh (Eds.), *Proceedings of the Swedish production symposium (SPS2020)* (pp. 24–35). IOS Press. <https://doi.org/10.3233/ATDE200140>
- Ciarli, T., Kenney, M., Massini, S., & Piscitello, L. (2021). Digital technologies, innovation, and skills: Emerging trajectories and challenges. *Research Policy*, 50(7), Article 104289. <https://doi.org/10.1016/j.respol.2021.104289>
- Costa, A., Presenza, A., & Abbate, T. (2023). Digital transformation in family-owned winery SMEs: An exploratory analysis in the South-Italian context. *European Journal of Innovation Management*, 26(7), 527–551. <https://doi.org/10.1108/EJIM-02-2023-0108>
- Elia, S., Giuffrida, M., Mariani, M. M., & Bresciani, S. (2021). Resources and digital export: An RBV perspective on the role of digital technologies and capabilities in cross-border e-commerce. *Journal of Business Research*, 132, 158–169. <https://doi.org/10.1016/j.jbusres.2021.04.010>
- Estensoro, M., Larrea, M., Müller, J. M., & Sisti, E. (2022). A resource-based view on SMEs regarding the transition to more sophisticated stages of industry 4.0. *European Management Journal*, 40(5), 778–792. <https://doi.org/10.1016/j.emj.2021.10.001>
- Ferreira, V. G., Rosa, J., Almeida, N. M., Pereira, J. S., Sabater, L. M., Vendramin, D., Zhu, H., Martens, K., & Higuti, J. (2023). A comparison of three main scientific literature databases using a search in aquatic ecology. *Hydrobiologia*, 850(6), 1477–1486. <https://doi.org/10.1007/s10750-022-05067-5>
- Freundl, M. (2023). *Methoden zur Strategischen Vorausschau: Megatrends* [Methods for strategic foresight: Megatrends]. <https://www.baks.bund.de/de/aktuelles/methoden-zur-strategischen-vorausschau-megatrends>
- Hassan, S. S., Meisner, K., Krause, K., Bzhalava, L., & Moog, P. (2023). Is digitalization a source of innovation? Exploring the role of digital diffusion in SME innovation performance. *Small Business Economics*, 62, 1469–1491. <https://doi.org/10.1007/s11187-023-00826-7>
- Horváth, D., & Szabó, R. Z. (2019). Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities? *Technological Forecasting and Social Change*, 146, 119–132. <https://doi.org/10.1016/j.techfore.2019.05.021>
- Höse, K., Amaral, A., Götze, U., & Peças, P. (2023). Manufacturing flexibility through industry 4.0 technological concepts—Impact and assessment. *Global Journal of Flexible*

- Systems Management*, 24(2), 271–289.
<https://doi.org/10.1007/s40171-023-00339-y>
- Hüther, M. (2020). Potenziale und Umsetzung der Digitalisierung auf Unternehmensebene [Potential and implementation of digitalization at company level]. *Wirtschaftsdienst*, 100(S1), 12–19. <https://doi.org/10.1007/s10273-020-2610-x>
- Islam, A. A. A., Trinugroho, I., & Suryanto (2023). SMEs' flight to digital and green economy: Evidence from Indonesia. *International Journal of Business and Society*, 24(1), 362–379. <https://doi.org/10.33736/ijbs.5622.2023>
- Kolagar, M., Parida, V., & Sjödin, D. (2022). Ecosystem transformation for digital servitization: A systematic review, integrative framework, and future research agenda. *Journal of Business Research*, 146, 176–200. <https://doi.org/10.1016/j.jbusres.2022.03.067>
- Le-Dain, M.-A., Benhayoun, L., Matthews, J., & Liard, M. (2023). Barriers and opportunities of digital servitization for SMEs: The effect of smart product-service system business models. *Service Business*, 17(1), 359–393. <https://doi.org/10.1007/s11628-023-00520-4>
- Masood, T., & Sonntag, P. (2020). Industry 4.0: Adoption challenges and benefits for SMEs. *Computers in Industry*, 121, Article 103261. <https://doi.org/10.1016/j.compind.2020.103261>
- Mihu, C., Pitic, A. G., & Bayraktar, D. (2023). Drivers of digital transformation and their impact on organizational management. *Studies in Business and Economics*, 18(1), 149–170. <https://doi.org/10.2478/sbe-2023-0009>
- Mittal, S., Khan, M. A., Romero, D., & Wuest, T. (2018). A critical review of smart manufacturing & industry 4.0 maturity models: Implications for small and medium-sized enterprises (SMEs). *Journal of Manufacturing Systems*, 49, 194–214. <https://doi.org/10.1016/j.jmsy.2018.10.005>
- Nambisan, S., Wright, M., & Feldman, M. (2019). The digital transformation of innovation and entrepreneurship: Progress, challenges and key themes. *Research Policy*, 48(8), Article 103773. <https://doi.org/10.1016/j.respol.2019.03.018>
- Rajala, A., & Hautala-Kankaanpää, T. (2023). Exploring the effects of SMEs' platform-based digital connectivity on firm performance – the moderating role of environmental turbulence. *Journal of Business & Industrial Marketing*, 38(13), 15–30. <https://doi.org/10.1108/JBIM-01-2022-0024>
- Ranka, D., & Vasudevan, H. (2022). A model for challenges and opportunities in the implementation of digitized transforming enablers in manufacturing industries. In R. M. Singari & P. K. Kankar (Eds.), *Advances in transdisciplinary engineering: Vol. 27. Advanced production and industrial engineering* (pp. 514–519). IOS Press. <https://doi.org/10.3233/ATDE220788>
- Sauer, P. C., & Seuring, S. (2023). How to conduct systematic literature reviews in management research: A guide in 6 steps and 14 decisions. *Review of Managerial Science*, 17(5), 1899–1933. <https://doi.org/10.1007/s11846-023-00668-3>
- Schönfuß, B., McFarlane, D., Hawkrigde, G., Salter, L., Athanassopoulou, N., & de Silva, L. (2021). A catalogue of digital solution areas for prioritising the needs of manufacturing SMEs. *Computers in Industry*, 133, Article 103532. <https://doi.org/10.1016/j.compind.2021.103532>
- Soluk, J., & Kammerlander, N. (2021). Digital transformation in family-owned Mittelstand firms: A dynamic capabilities perspective. *European Journal of Information Systems*, 30(6), 676–711. <https://doi.org/10.1080/0960085X.2020.1857666>
- Soluk, J., Kammerlander, N., & Darwin, S. (2021). Digital entrepreneurship in developing countries: The role of institutional voids. *Technological Forecasting and Social Change*, 170, Article 120876. <https://doi.org/10.1016/j.techfore.2021.120876>
- Steinhoff, C. (2016). *Aktueller Begriff: Industrie 4.0* [Current term: Industry 4.0]. Deutscher Bundestag, Wissenschaftliche Dienste. <https://www.bundestag.de/resource/blob/474528/cae2bfac57f1bf797c8a6e13394b5e70/Industrie-4-0.pdf>
- Streibich, K.-H. (2015). Softwareindustrie im Umbruch: Das Digitale Unternehmen der Zukunft [Software industry in transition: The digital company of the future]. In C. Linnhoff-Popien, M. Zaddach, & A. Grahl (Eds.), *Marktplätze im Umbruch* [Marketplaces in upheaval] (pp. 15–18). Springer. https://doi.org/10.1007/978-3-662-43782-7_4
- Tamvada, J. P., Narula, S., Audretsch, D., Puppala, H., & Kumar, A. (2022). Adopting new technology is a distant dream? The risks of implementing Industry 4.0 in emerging economy SMEs. *Technological Forecasting and Social Change*, 185, Article 122088. <https://doi.org/10.1016/j.techfore.2022.122088>
- The World Bank. (2019). *Small and medium enterprises (SMEs) finance: Improving SMEs' access to finance and finding innovative solutions to unlock sources of capital*. <https://www.worldbank.org/en/topic/smefinance>
- Troise, C., Corvello, V., Ghobadian, A., & O'Regan, N. (2022). How can SMEs successfully navigate VUCA environment: The role of agility in the digital transformation era. *Technological Forecasting and Social Change*, 174, Article 121227. <https://doi.org/10.1016/j.techfore.2021.121227>
- Winkler, S., Günther, J., & Pfennig, R. (2023). Nachhaltige Digitalisierung oder Nachhaltigkeit durch Digitalisierung? [Sustainable digitalization or sustainability through digitalization?] *HMD Praxis der Wirtschaftsinformatik*, 60(4), 815–836. <https://doi.org/10.1365/s40702-023-00987-9>
- Yang, L., & Sulaiman, Z. (2022). Bibliometrics analysis of social media and entrepreneurship research using Scopus database. *International Journal of Electronic Commerce Studies*, 13(4), 97–134. <https://doi.org/10.7903/ijecs.2119>
- Yang, M., Fu, M., & Zhang, Z. (2021). The adoption of digital technologies in supply chains: Drivers, process and impact. *Technological Forecasting and Social Change*, 169, Article 120795. <https://doi.org/10.1016/j.techfore.2021.120795>
- Zahoor, N., Zopiatis, A., Adomako, S., & Lamprinakos, G. (2023). The micro-foundations of digitally transforming SMEs: How digital literacy and technology interact with managerial attributes. *Journal of Business Research*, 159, Article 113755. <https://doi.org/10.1016/j.jbusres.2023.113755>