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Investigation of artificial intelligence in SMEs: a systematic review of the state of the art and the main implementation challenges

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Abstract
While the topic of artificial intelligence (AI) in multinational enterprises has been receiving attention for some time, small and medium enterprises (SMEs) have recently begun to recognize the potential of this new technology. However, the focus of previous research and AI applications has therefore mostly been on large enterprises. This poses a particular issue, as the vastly different starting conditions of various company sizes, such as data availability, play a central role in the context of AI. For this reason, our systematic literature review, based on the PRISMA protocol, consolidates the state of the art of AI with an explicit focus on SMEs and highlights the perceived challenges regarding implementation in this company size. This allowed us to identify various business activities that have been scarcely considered. Simultaneously, it led to the discovery of a total of 27 different challenges perceived by SMEs in the adoption of AI. This enables SMEs to apply the identified challenges to their own AI projects in advance, preventing the oversight of any potential obstacles or risks. The lack of knowledge, costs, and inadequate infrastructure are perceived as the most common barriers to implementation, addressing social, economic, and technological aspects in particular. This illustrates the need for a wide range of support for SMEs regarding an AI introduction, which covers various subject areas, like funding and advice, and differentiates between company sizes.

Keywords Artificial intelligence · SMEs · Manufacturing · Barriers · PESTEL

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1 Introduction

In recent years, the integration of AI into the industry has gained increasing significance (Zhang et al. 2022). The advantages of AI solutions, such as improved production control and optimization, better prediction of machinery failures, and enhanced quality assurance, have driven companies to incorporate AI into their operational processes. Therefore, according to several researchers, AI is considered to be one of the most important elements of Industry 4.0 (Barton et al. 2022; Bencsik 2020). They argue that AI is the only way to make efficient use of the large volumes of newly acquired data (Szedlak et al. 2020). This is especially true in manufacturing (Bettoni et al. 2021).

However, the new potential of AI is mainly realized by multinational enterprises (MNEs) (Mittal et al. 2018; Teerasoponpong and Sopadang 2021). This is also reflected in a study by Szedlak et al. (2020) according to which around 90% of SMEs did not have any applications of AI. But in the past few years, an increasing number of SMEs are recognizing the potential of AI solutions. In survey of 2021, 77% of respondents said that they see great possibilities for using AI in SMEs as well. The same study showed that this potential is not limited to individual business activities but can be applied to almost all areas (Ulrich and Frank 2021).

With the increasing recognition and pursuit of AI implementation by SMEs, the issue associated with the impact of varying company sizes becomes more apparent. The existing insights and experiences predominantly focus on large enterprises (Welte et al. 2020). However, their applicability to SMEs is largely limited. The varying starting conditions of the different company sizes have a particularly substantial impact, especially when it comes to the implementation of AI. These differences include, for example, the financial capabilities of a company, the availability of data, or the desired complexity of an AI application (Agerri et al. 2014; Jain et al. 2021). Hence considering AI publications based on enterprise size provides a distinct advantage and therefore it is crucial to illustrate AI as closely aligned with a company's specific circumstances (Bauer et al. 2020; Hansen and Bøgh 2021). Besides the importance of the distinction according to enterprise size has already been highlighted in reviews on other new technologies (Cotrino et al. 2020; Mittal et al. 2018).

Nevertheless, there is a lack of research that explicitly addresses the specific characteristics and needs of SMEs when it comes to implementing AI applications (Bhuvaneshwari Alias Sunita Kulkarni and Mishrikoti 2019). This is also underlined by two identified open research gaps from previous publications: (i) "This study recommends more systematic reviews […] across business functions that could benefit more from the AI techniques such as accounting, quality management and human resources management " (Cubric 2020, p. 11) and (ii) "literature research shows that no relevant studies exist that systematically address the issues and requirements of SME in the application of ML technologies " (Bauer et al. 2020, p. 8).

Therefore, our goal is to use a systematic literature review (SLR) to analyze the current state of research on AI with an explicit focus on SMEs and to identify the perceived barriers of SMEs to AI implementation. We refer to AI holistically, without

restricting our focus to specific AI methods. The overview of the state of the art aims to highlight the current deficit in this research domain. Simultaneously, it concretizes certain areas, for example regarding to business activities, that have been overlooked so far. Identifying the challenges faced by SMEs in AI implementation enables exact and targeted support from both academics and government in the future. This, in turn, facilitates a faster and more widespread adoption of this technology in smaller enterprises. At the same time, this raises awareness of the disparity in perceived obstacles among different company sizes. In our SLR, we focus on manufacturing companies in the industry. This focus is important due to the distinctiveness from other economic sectors such as consulting or services. These companies have entirely different starting conditions, for instance, in terms of data capture and potentials regarding AI.

From this, our two subsequent research questions arise:

RQ1. What is the current state of the art of research on AI in the industrial sector regarding SMEs?
RQ2. What are the challenges for SMEs in the implementation of AI in the industrial sector?

The remainder of this article is structured as follows: The next section deals with the theoretical background of the terms AI and SME. Afterwards, we describe the used methodology in detail before we present our findings to the research questions. Next, we discuss our outcomes including an interpretation and critical reflection. In the end, we summarize the results in a conclusion and highlight the limitations.

2 Background to the study

For a uniform and deeper understanding of our study, definitions and their historical development over the time are shown initially for the most important terms. This is, on the one hand, the concept of AI and, on the other hand, the categorization of company sizes. In the latter case, the focus is on the group of SMEs.

In 1956 the term "artificial intelligence" was proposed for the first time by McCarthy at the Dartmouth Conference (McCarthy et al. 2006), which today is often regarded as the birth of AI (Copeland 1993). However, it was not until the 1970s that the development and research of AI solutions began on a meaningful level (Marr 1977; Waterman and Newell 1971). But even then, the possibilities were limited due to the available data and the low level of technical development at that time.

But it is only with industry 4.0 that AI has gained momentum, as it led to a massive increase of technical devices generating, collecting, and making data available. This was the basis for complex and extensive AI applications. In addition, networking has made it possible to exchange large amounts of data with each other, and technical progress has enabled computers to use these large volumes of data effectively (Sousa et al. 2019). Since that time, more precisely from around 2010 onwards, the publications on AI have increased considerably. This applies to many different AI methods such as machine learning (ML), natural language processing (NLP) or computer version (Abioye et al. 2021). Nevertheless,

in our study we focus on AI as a whole and refrain from emphasizing a selected AI method.

Nowadays, the utilization of AI has become widespread, whether it is interacting with a chatbot, doing a web search or using a voice assistant such as Alexa (Brill et al. 2019). AI can be found in almost all areas of life, although the development of AI is still at the beginning (Nikitas et al. 2020). However, the scope of applications is not only expanding in everyday life, but also in industry, in the field of education, in medicine and many more. This is due, among other aspects, to the wide multiplicity of research fields around AI. It is remarkable that almost 60% of the publications are assigned to the sector education and only about 5% focus on companies (Zhang et al. 2022).

Despite the intensive research in the field of AI, there is still no consistent definition. Rather, it is a collective term for applications that can solve tasks which previously required human intervention (Zhang and Lu 2021). A common definition by Hashimoto et al. (2018) states: "Artificial intelligence (AI) can be loosely defined as the study of algorithms that give machines the ability to reason and perform cognitive functions such as problem solving, object and word recognition, and decision-making."

For a clear understanding of our study, it is crucial to recognize not only the term AI, but also the theoretical background of SMEs. As with AI, there is no standard definition for the grouping of company sizes. This led to more than 200 meanings for SMEs being already found in 1981 by Nieschlag (1981). These could be standardized in the following years, at least to a certain extent. For example, the European commission agreed on a common definition in 1996 (European Commission 1996). After its revision in 2005, all companies with fewer than 250 employees and either less than 50 million in annual revenue or an annual balance sheet total of less than 43 million are covered by the term SME (European Commission 2003). In this context, the European Union (EU) categorizes the term SME as follows: (i) micro enterprises (< 10 employees, < 2 million turnover), (ii) small enterprises (< 50 employees, < 10 million turnover), (iii) medium-sized enterprises (< 250 employees, < 50 million turnover). Although the definition distinguishes between micro, small and medium enterprises, in practice and in research the combined term SME is used almost exclusively (Gibson and van der Vaart 2008). However, many countries and organizations outside the EU define this term very differently. Berisha and Shiroka-Pula (2005) showed an overview to illustrate the difference in the definitions of SMEs based on the maximum number of employees. But a more detailed classification of large companies is requested also quite often. The European Commission (2022), for example, proposed a further category, the so-called middle-sized enterprises (or mid-caps), for companies with between 250 and 1.499 employees. In comparison to alternative definitions, the EU classification has become more established in the respective countries, leading to its utilization in diverse contexts such as the definition of limits for funding as well (European Commission et al. 2022). For this reason, coupled with the high prevalence of SMEs that possess the potential for AI applications in European (Riillo and Jakobs 2022), the definition provided by the EU serves as the foundation for the conducted SLR.

The importance of SMEs for a national economy cannot be underestimated. Although individual companies do not have a major impact, the large number of enterprises that fall into this group means that they are often referred to as the backbone of the economy (Kaymakci et al. 2022). The World Bank assumes that, depending on the definition of SME, at least 40% of national income (GPD) is generated by SMEs in emerging countries (World Bank 2015). At the same time, 50–60% of the world's population work for SMEs (Ben Abdelaziz et al. 2020).

In relation to AI, the progress of development is not only important for large enterprises anymore, but also for SMEs. A substantial contribution to this has been made by the substantial reduction in the costs of developing or introducing an AI solution. For example, according to Zhang et al. (2022) the costs of an image classification system fell by almost 64% from 2018 to 2022. As a result, the applications are also becoming increasingly interesting for companies with lower financial resources. Furthermore, Barton et al. (2022) presented that, in addition to big data, AI is also a key attribute for SMEs in the context of Industry 4.0. The potential is not limited to individual areas. Instead, AI can support applications in almost every department. Nevertheless, various studies concluded that AI is being used so far in less than 10% of SMEs (Bauer et al. 2020; Iftikhar and Nordbjerg 2022; Szedlak et al. 2021).

This background is the starting point of our SLR, which shows that both AI and SMEs have an important role to play in successful economic development. The following selection describes in detail the used research method, the process, and the scope of the study.

3 Research methodology

To answer the research questions, we conducted a systematic literature review based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol (Moher et al. 2009). A systematic review highlights the current state of the start of a specific field, shows agreements and disagreements of different studies, and identifies research gaps (Kitchenham 2004). Based on its transparency and replicability, the systematic approach was selected (Leidner and Kayworth 2006), which enables to verify the results in an easy way and reduce the risk of selection bias (Knobloch et al. 2011).

The PRISMA protocol divides the process in four steps: (i) identification, (ii) screening, (iii) eligibility, and (iv) inclusion (Moher et al. 2009). The identification phase is needed to define the scope of the research. To get an overall overview, it is necessary to include all appropriate studies that can help to answer the research questions (Keele 2007).

For this reason, in a first step we analyzed the used search strings of 77 systematic reviews about AI (a lineup with the reviews can be accessed at: http://bit.ly/41ac4lX) and the most frequent terms of the Artificial Intelligence Index Report 2022 of Zhang et al. (2022). We adopted all keywords that we found in at least five percent of the reviews (see Table 1) and the two most common terms of the index report in our own search strategy. Based on our research questions,

Table 1 Search strings AI

Search string	Frequency (%)	Search string	Frequency (%)
Artificial intelligence	100	Chatbot	6
Machine learning	74	Machine intelligence	5
Deep learning	44	Reinforcement learning	5
Neural network	43	Deep mining	5
AI	30	Data science	5
Natural language processing	14	Support vector machine	5
Data mining	9	Algorithm	5
Big data	9	Machine version	5
Robot	6		

we defined two further keywords groups, one by enterprise size and one by sector. Due to the already shown limited prevalence of AI publications concerning SMEs and the resulting lack of research (Žigiene et al. 2019), we intentionally adopted a broad approach in selecting keywords. Furthermore, in our search, we intentionally refrained from adding a further category of search strings related to challenges. This decision was made to include case studies as well that may not explicitly address challenges in their title or abstract but nonetheless highlight barriers during the description of their case study. Therefore the search was conducted with following terms: ("Artificial intelligence" OR "machine learning" OR "deep learning" OR "neural network" OR "AI" OR "natural language processing" OR "data mining" OR "big data" OR "robot" OR "chatbot" OR "machine intelligence" OR "reinforcement learning" OR "deep mining" OR "data science" OR "support vector machine" OR "algorithm" OR "machine version" OR "training data" OR "dataset") AND ("SME*" OR "small and medium enterpris*" OR "small and medium-sized enterprises " OR "small and medium businesses " OR "small and medium-sized businesses " OR "small and medium companies " OR "small and medium sized companies " OR "micro small and medium enterprises " OR "micro small and medium sized enterprises " OR "MSME " OR "micro enterpris* " OR "micro-sized enterpris* " OR "micro compan* " OR "micro-sized compan* " OR "micro business* " OR "micro sized business* " OR "micro firm* " OR "micro-sized firm* " OR "small enterpris* " OR "small-sized enterpris* " OR "small compan* " OR "small-sized compan* " OR "small business* " OR "small sized business* " OR "small firm* " OR "small-sized firm* " OR "medium enterpris* " OR "medium-sized enterpris* " OR "medium compan* " OR "medium-sized compan* " OR "medium business* " OR "medium-sized business* " OR "medium firm* " OR "medium-sized firm* ") AND ("industrial" or "manufacturing" or "secondary sector").

The databases Scopus, Web of Science, EBSCO, and ProQuest were used. All of them comply to the quality requirements for a suitable academic search system of Gusenbauer and Haddaway (2020). To eliminate duplicates, the software Mendeley Reference Management was utilized after downloading the publication title, author, and abstract from the databases.

In line with PRISMA, the following inclusion criteria were applied: (i) focus on AI in industrial sector by small and medium companies, (ii) publications as of 2010, as suggested by Hansen and Bøgh (2021), and (iii) written in English. On the other hand, the exclusion criteria were also considered, which are the following: (i) papers not specifically related to AI but to technology in general, (ii) "false positive" papers, for example papers that use the acronym SME for smart manufacturing environments (Yan et al. 2017) and (iii) full article not available. For a sufficient quality of the included articles, the following conditions were taken into account: (i) only journal articles or conference papers and (ii) only peer-reviewed publications.

These criteria were used on the title and abstract in the screening phase and on the full text in the eligibility phase. In total, 71 papers met the criteria and were therefore included in the systematic literature review. As shown in Fig. 1, initially the result of the keywords search was overall 1395 records. After removing 335 duplications, 1060 titles and abstracts were read. 911 of them did not comply with the required criteria, so that a full text evaluation took place for 149 papers. There 78 research works were excluded which finally results in 71 selected papers. The predominant reason (947 articles) for excluding the publications was the lack of focus on AI. The high number can

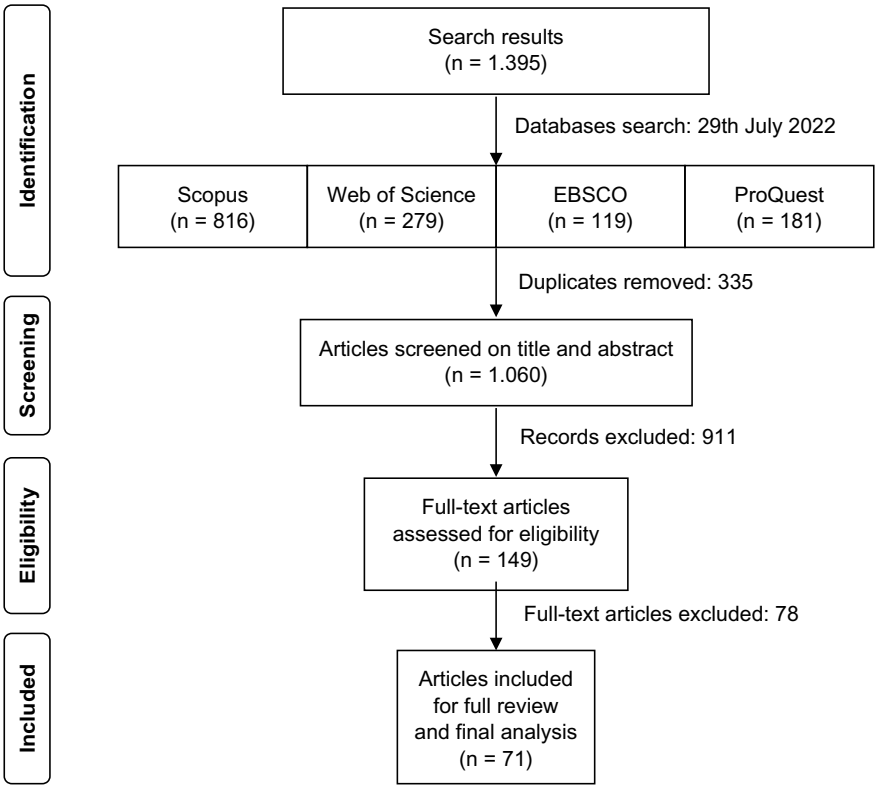

Fig. 1 PRISMA flow chart

be attributed to the broad search strings related to AI, as some terms only have an indirect connection to the AI theme. To gain a comprehensive overview of AI publications in SMEs, these publications were initially selected during the search but were excluded during the screening or eligibility phase if no connection to AI was identified, or if AI only served as an example. An additional 23 publications were eliminated due to 'false positive' abbreviations that had no relevance to AI or SMEs. The reason for the exclusion of the remaining 19 articles from our SLR was the unavailability of the full article.

In consideration of the research questions, the data extraction was carried out to highlight the key findings of the separate articles, as recommended by Kitchenham (2004). For this reason, for each paper the following characteristics were recorded into Excel: (i) title, (ii) topic, (iii) source of publishing, (iv) year, (v) study design, (vi) method of AI, (vii) function based on Porter's value chains (Porter 1985), (viii) definition of SME, and (ix) challenges for AI adoption regarding to SMEs. With the help of charts and spreadsheets commonalities and contrasts, research gaps and new ways of looking were elaborated (Torraco 2005). Wohlin et al. (2000) emphasized the risk of biases of (i) construct validity, (ii) external validity, (iii) internal validity, and (iv) conclusion validity in a SLR. To reduce these as far as possible, a particular attention was paid to the biases in the whole processing phase. Furthermore, the structure was chosen very precisely, for example the choice of databases according to Gusenbauer and Haddaway (2020). Nevertheless, a complete avoidance of the biases is not possible. For example, the focus of most publications is on case studies and on enterprises that already dealt with AI. Only few articles included data of businesses and people without any points of contacts to AI. Moreover, the evaluations of the results and patterns of the conducted studies are often a limitation. Due to the RQ2, special attention was paid to the challenges. Therefore, we counted in how many and in which publications the barriers are mentioned. The classification of the obstacles was orientated on the PESTEL model, which divides the categories into (i) political, (ii) economic, (iii) social, (iv) technological, (v) environment, and (vi) legal (Yüksel 2012). The PESTEL model furnishes a comprehensive and systematically organized overview of the challenges identified by companies. This categorization has demonstrated its efficacy on multiple occasions, even when applied to the internal barriers of an enterprise, as evidenced in different publications addressing other new technologies (Alaloul et al. 2020; Oestereich and Teuteberg 2016).

4 Results

This section presents the main findings, which can be divided into two groups: (i) characteristics of the studies, and (ii) challenges of SMEs in the implementation of AI.

4.1 Characteristics of the selected studies

First, the most important characteristics of the selected publications were analyzed to present the current state of the art of research on AI in the industrial sector

regarding SMEs and to answer RQ1. The assignment of the papers to the distinctive features for each category can be accessed at: http://bit.ly/41ac4lX.

4.1.1 Chronology of the research

Initially, the selected studies were examined according to the year of publication. Thereby three phases can be recognized. In the initial phase spanning from 2010 to 2017, just one article per year was published about AI and SMEs in the industrial sector, indicating that this topic was confined to a niche domain during this period. A reason is the customary initial examination of emerging technologies in a broad, general context. Only over time, a more nuanced evaluation will develop, with a focus on specific attributes such as company size (Welte et al. 2020). With the increase in publications on AI in manufacturing companies in the following years (Rathore et al. 2021), publications on AI in SMEs also increased in the second phase (2018–2020). Smaller companies are now also beginning to address this topic more in individual cases (Kim et al. 2019b). However, initial experience has shown the need for a separate research focus on the differences between enterprise sizes due to distinctive initial situations (Barton et al. 2022; Mittal et al. 2018), which is reflected in the increase in corresponding publications in the second phase. In the third phase of 2021, there has been a sharp increase, almost tripling compared to the previous year. This surge is attributable to the expanding media prominence of AI and the advancement of AI applications, progressively tailored to the requirements and starting conditions of smaller enterprises (Teerasoponpong and Sopadang 2021). Consequently, these companies are increasingly recognizing and using the potential of AI (Zhang et al. 2022). This has led to a substantial rise, notably observed in the heightened number of published case studies. Ongoing technological advancements coupled with the expanding visibility of AI in the public imply the likelihood of a sustained increase in this trend in the forthcoming years (Fig. 2).

4.1.2 Categorization according to study design

When considering the methodological design, first a distinction is made between qualitative, quantitative, and mixed methods. Thereby, the strong dominance of qualitative studies is remarkable. Over three-quarters (55) of the articles used this

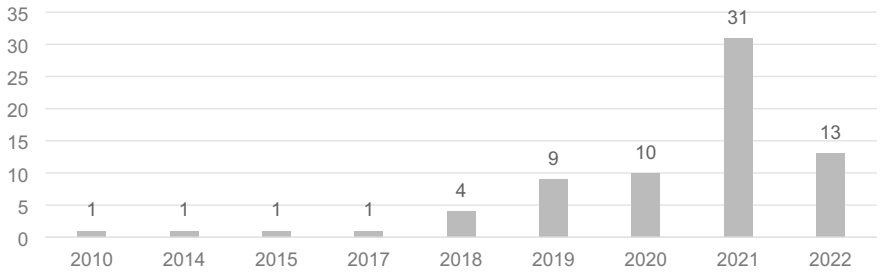

Fig. 2 Number of publications over the years

approach. One reason for the overweight of the qualitative studies is the heaping use of case studies. 33 of the selected articles have chosen this approach among others. This can be ascribed, in part, to the limited prevalence of AI adoption within SMEs (Willenbacher et al. 2021). While case studies can be conducted and analyzed in technologically pioneering companies, the implementation of quantitative methods, such as surveys, is more difficult to implement due to the high demand for participating SMEs. This arises from the observation that numerous potential companies have not yet sufficiently engaged with the AI domain, making it difficult for them to participate in surveys (Seseni and Mbohwa 2018). This underscores as well why many of the case studies described the AI solution from a view of information technology (IT), for example, to explain the algorithm in detail. In the nascent stages of novel technology, the engagement primarily emanates from IT-proficient enterprises and researchers, directing their attention toward the technical factors (Putnik et al. 2021; Singh and Desai 2022). At a later juncture, broader perspectives as business aspects, subsequently are added.

4.1.3 Classification of the publications regarding to business activities

The thematic classification of the papers into business activities was undertaken according to Porter's value chain. It divides a company into primary activities, which includes (i) inbound logistic, (ii) operations, (iii) outbound logistics, (iv) marketing and sales, and (v) service as well as secondary activities with (vi) procurement, (vii) human resource management, (viii) technological development and (ix) infrastructure (Porter 1985). This facilitates an analysis across the entire process chain of a company, incorporating all crucial activities (Stabell and Fjeldstad 1998). As a result, activities that have been overlooked or underrepresented so far, become conspicuously visible.

Several of the selected papers could not be assigned specifically to one of the activities, because these addressed the topic of AI for the entire enterprise. The pronounced emphasis observed in the remaining articles (44) on operational aspects is noteworthy, with other activities, aside from technological development (7), either mentioned only occasionally or not mentioned at all. This shows that, to date, only a fraction of the diverse activities within a business concerning AI in SMEs have been scrutinized through publications, revealing substantial research gaps. For the predominant focus on operations, various reasons are given. On the one hand, this domain in manufacturing enterprises typically constitutes the core area with the highest number of employees. Consequently, the optimization potential afforded by AI is frequently the most substantial there (Barton et al. 2022). On the other hand, this area often includes the same or very similar activities, making it easier to change something and enable stronger control through key figures. This enhances transparent to the weak points and the success of AI adjustments easier to measure (Karl and Reinhart 2015) (Fig. 3).

Due to the large number for operations, Fig. 4 refines the subdivisions for this activity. Almost half of these papers (12) dealt with the optimization of the quality of the product. Regardless of the size of the company and the specific initial situation, his concern is pertinent to every manufacturing enterprise (Durana et al. 2019).

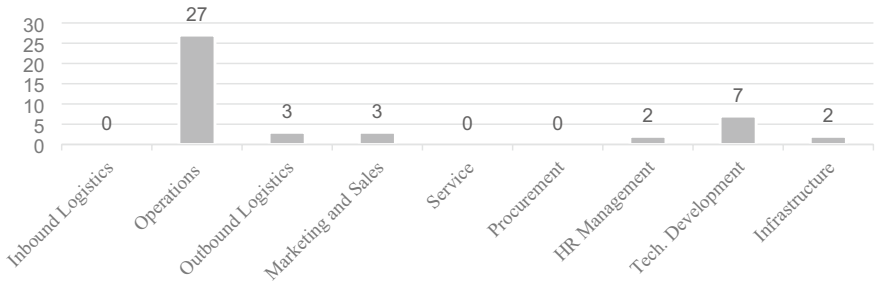

Fig. 3 Distribution of publications across Porter´s Value Chain

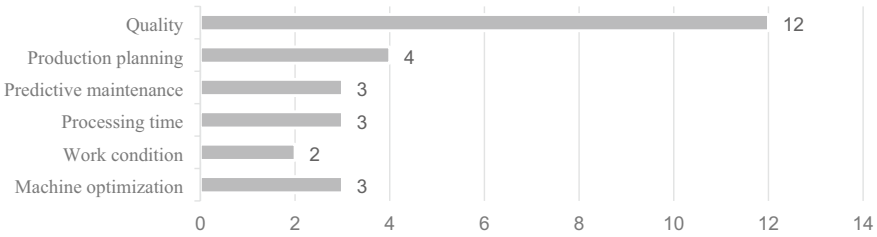

Fig. 4 Distribution of publications with the focus on operations

This is where the quality differs from machine optimization or predictive maintenance, for instance, which is irrelevant for small companies with no or only old machines (Baars et al. 2021). A similar consideration extends to production planning when conducted within the company without the use of technical data. Consequently, quality appeals to a considerably broader target group within the context of SMEs.

4.1.4 Analysis based on the utilized SME definitions

About AI, the different company sizes play a key role in the point of view of this topic and the perceived challenges for implementation. SMEs often have completely different starting conditions, such as a lack of expertise or data availability, than large companies (Agerri et al. 2014). As a result, various scholars see the need or an added value to differentiate by company size regarding AI (Bauer et al. 2020; Hansen and Bøgh 2021). Nevertheless, the customary categorization of SMEs and large companies between distinctive countries substantially diverges owing to distinct definitions. In the EU, for instance, SMEs encompass companies with up to 250 employees, while the United States of America definition extends to companies with twice as many employees (Anastasia 2015).

For this reason, the selected papers were analyzed by the given meanings of the term SME (see Fig. 5). Despite the varying understanding, only a few articles outlined the criteria for their applied definition. Most of them (61) simply used the term without any explanation. When the criteria were explained, the majority (7) of the

articles were based on the regulations issued by the EU. Two more publications defined the limit at 500 employees, and one was orientated at the regulations issued by the Chinese government. The rationale for the absence of the used definition of SME in many of the selected articles is generally not provided.

4.2 Challenges regarding AI implementation in SMEs

This section explains the obstacles for SMEs in the implementation of AI in the industrial sector, see RQ2. In the process, we have identified 27 different challenges mentioned in the papers. This shows the diversity of the challenges and the associated complexity of removing these obstacles. It is not merely one challenge that requires addressing but, rather, an interplay of many different factors. For a better overview, the barriers are summarized and structured in line with the PESTEL model. This involves presenting both the number of distinct articles addressing a specific challenge and the number of different articles of each PESTEL category. For the evaluation in categories, each paper is only counted once for a group. The results are presented in Table 2.

The predominant challenge identified across the selected papers is knowledge. In 35 articles, this obstacle is mentioned and thus much more often than all other. Nevertheless, the authors of the selected studies define different challenges as the most important obstacle to the introduction of AI in SMEs. While many researchers go hand in hand with the absolute number and see knowledge as the most decisive hurdle (Kumar and Kalse 2022; Ulrich and Frank 2021), there are also other publications of the review that consider the costs (Barton et al. 2022), the acceptance (Joerg and Carlos 2022), or the data (Bauer et al. 2020) to be the most crucial factor. Concerning knowledge, two principal domains can be delineated. Firstly, the discourse addresses the scarcity of skilled employees (Basri 2020; Brezani et al. 2022), and secondly, it encompasses the general understanding of AI, such as knowledge about the procedure for AI implementation and knowledge about existing AI application possibilities (Brandalero et al. 2020; Welte et al. 2020).

The second most common reason for the hesitation to implement AI in SMEs are the costs (number of articles that addressed this challenge: 24). This is unanimously attributed to the limited financial resources, which are generally much more limited in SMEs than in MNEs (Chen et al. 2019; Willenbacher et al. 2021). Another

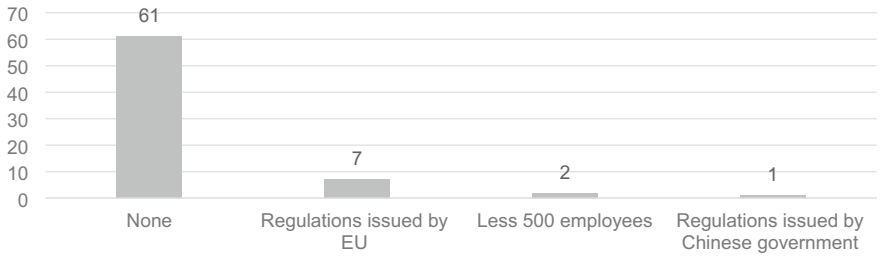

Fig. 5 Number of publications by means of SME definition

Table 2 Challenges for SME (S)

Category	Challenge	Quantity category	Quantity challenge	References
Political	Lack of advice	5	3	S25, S30, S67
	Lack of research		3	S19, S67, S71
	Lack of funding		1	S71
Economic	Cost	38	24	S3, S16, S17, S20, S21, S22, S26, S28, S33, S34, S35, S36, S45, S46, S49, S51, S52, S56, S57, S59, S60, S61, S69, S71
	Productivity evaluation		13	S2, S9, S10, S15, S29, S30, S31, S36, S37, S47, S51, S61, S71
	Risk to fail		10	S15, S26, S31, S35, S36, S39, S60, S61, S64, S69
	Solutions available on the market		8	S10, S13, S33, S35, S52, S56, S60, S66
	Lack of resources / machines		4	S3, S15, S17, S61
	Data exchange		4	S3, S30, S31, S33
	Lack of standardization		3	S17, S22, S30
	Process adjustments		3	S5, S16, S45
	Duration of implementation		2	S60, S71
	Project planning		0	
Social	Knowledge	39	35	S5, S8, S10, S12, S13, S15, S16, S22, S25, S26, S27, S30, S31, S33, S34, S35, S36, S37, S39, S42, S45, S46, S48, S51, S56, S57, S59, S60, S61, S64, S66, S67, S69, S70, S71
	Management		14	S3, S4, S5, S15, S25, S29, S30, S31, S33, S34, S41, S56, S59, S69
	Acceptance		6	S3, S5, S16, S30, S33, S34
	AI corporate strategy		5	S8, S10, S25, S39, S67
	Trust / Ethic		3	S16, S34, S45
Technological	IT-Infrastructure / Digital maturity	35	17	S2, S3, S10, S11, S33, S34, S35, S36, S37, S42, S45, S49, S56, S59, S60, S61, S64

Table 2 (continued)

Category	Challenge	Quantity category	Quantity challenge	References
	Data availability		16	S1, S3, S10, S11, S27, S29, S31, S35, S45, S51, S52, S58, S59, S60, S61, S64
	Data quality		12	S5, S9, S10, S27, S31, S33, S34, S37, S51, S60, S61, S67
	Complexity / Individuality		11	S5, S10, S16, S17, S26, S27 S36, S45, S52, S69, S71
	Data security		7	S3, S10, S22, S30, S36, S37, S57
	Data privacy		4	S2, S5, S30, S71
	Model / AI-Method / application selection		3	S2, S30, S67
Environment	Environmental protection	3	3	S11, S34, S36
Legal	Regulatory compliance	1	1	S33

complicating factor for SMEs lies in their often-limited awareness of their financial capacities or an inability to accurately assess them (Žigiene et al. 2019). This also has consequences for the knowledge challenge, as SMEs are often unable to afford external AI consultants (Szedlak et al. 2020).

The maturity level within their own organization stands out as the third most frequently referenced barrier (17) for SMEs when embarking on AI adoption. Thereby researchers concurred that most SMEs have a substantially lower maturity level of digitalization than MNEs (Bettoni et al. 2021; Teerasoponpong and Sopadang 2021). The great majority of SMEs are only in level one. Mittal et al. (2018) even introduced another maturity level (level zero) to emphasize that some SMEs are at the very beginning of digitalization. As an example, the authors mentioned the lack of wireless fidelity (WiFi). The low maturity level respectively the missing IT infrastructure are therefore an additional challenge for SMEs. Szedlak et al. (2020) pointed out that around 70% of the SMEs without AI ambitions cite the lack of digitalization as a reason.

The particular AI-specific challenge pertaining to data availability (16) is also discussed intensively. Its importance attributed to SMEs is thereby viewed very differently in the selected publications. Some scholars see a clear lack of data in SMEs that needs to be rectified before implementation (Agerri et al. 2014; Putnik et al. 2021) meanwhile other researchers believe that the current level of data in many SMEs is already sufficient (Chen et al. 2019). While the former emphasizes that AI cannot be viewed separately from big data as they only make sense together (Kim et al. 2019a), the latter highlights case studies of successful AI implementations in SMEs that are based on little data at or at least only a small amount of their own data (Kulkarni et al. 2021; Thiagarajan et al. 2018). Thereby they underline the possibility of collecting data together with other companies or introducing AI applications that have been trained on external data.

14 different papers considered management to be a decisive factor for the implementation of AI. In contrast to the predominantly cited barrier of knowledge, fewer than half as many publications identify management as an impediment. Nevertheless, this alignment Barton et al. (2022) survey, underscored management as a significant hindrance to AI adoption in SMEs. Only with their support can the new technology be successfully introduced (Iftikhar and Nordbjerg 2021). The management's hesitation is based on various reasons. According to Bunte et al. (2021), many leaders think that their business is too small for AI. Others cannot imagine any areas of applications (Husson et al. 2021) and others again do not see the need for a change, especially when the enterprise is doing well (Joerg and Carlos 2022).

Besides productivity evaluation is a further often mentioned challenge for SMEs (13). Many enterprises are often unsure about the return on investment (ROI), because they cannot assess the consequences of an implementation (Prem 2019; Žigiene et al. 2019). The given reasons can be categorized into two groups, on the one hand into factors that apply regardless of the size of the company and on the other hand into factors that have a major influence on SMEs in particular. General difficulties in assessing the ROI are the uniqueness and the difficulty of calculating the customization costs of many AI solutions for your own company (Bunte et al. 2021). This complicates the derivation of insights from the experiences of

other companies. Numerous AI solutions also necessitate multiple attempts and approaches before achieving functionality (Hansen and Bøgh 2021). This further complicates the anticipation of the implementation timeline and, consequently, the realization of cost-saving effects. Moreover, for smaller enterprises, there exists the additional challenge that the investment costs of an AI solution often need to be distributed across a lower quantity of sold products. Therefore, each must bear a higher share of it (Husson et al. 2021). Furthermore, the current absence of publications featuring case studies about the introduction of AI in SMEs that calculate the ROI also makes it difficult for these companies to estimate the ROI in advance (Iftikhar and Nordbjerg 2021).

Next to the amount of data, many researchers (12) emphasized the data quality as a demanding requirement as well. This holds particular more importance to SMEs compared to MNEs, given that SMEs often do not have any data collection standards or ways to clean up data trash (Lu et al. 2022). Hence the preparation of the data would be a time-consuming task for many SMEs. For this reason, it is difficult to use these for an AI application, even if enough data are collected (Jain et al. 2021). The importance of data quality should not be underestimated, as redundant and unclear data has already caused implementation projects to fail in selected case studies (Bender et al. 2022).

Compared to other technologies, AI has a much higher complexity. This is another important challenge that is often (11) seen in SMEs regarding an implementation. The perceived complexity results from three causes. First compared to other technologies, AI is considerably more IT-intensive, and there are more prerequisites that must be fulfilled, such as the existence of high-quality data (Bender et al. 2022). Secondly, AI applications are frequently challenging to transfer from other companies or necessitate extensive customization, thereby augmenting the perceived complexity (Kant and Johannsen 2022; Lu et al. 2022). The more the companies differ from each other in their structures or sizes, the greater the effort required to adapt (Seseni and Mbohwa 2018). Thirdly, this perceived intricacy is increased by highly technical case studies on AI in SMEs, for instance, with detailed descriptions of individual algorithms. Only rarely publications simplified to an understandable level for managers without IT expertise (Willenbacher et al. 2021).

As already described, AI implementation is often a trial-and-error process with an unclear outcome at the beginning (Prem 2019). In addition to the resulting difficulty in determining the ROI, many scholars (10) also see the risk of failure as a challenge, especially for SMEs. Since these enterprises are often unaware of their own risk profile and also have fewer financial resources, failed attempts are a major problem that strongly influence the company's performance (Willenbacher et al. 2021). For this reason, those enterprises rely more frequently on mature technologies, which prevents or slows down the adoption of AI in SMEs at the moment (Bettoni et al. 2021).

In addition to the challenges in their own companies, various studies have also identified barriers on the market side (8). The available AI solutions that explicitly focus on the requirements and initial situations of SMEs are very limited (Kaiser et al. 2021; Velmurugan et al. 2021). Most applications are aimed at large companies and are tailored to their structures. Although there are now initial approaches

for SMEs (Marco et al. 2021; Singh and Desai 2022), these are still in the clear minority. This is particularly contradictory to the fact that there are significantly more companies falling under the SME definition than there are larger enterprises (Kaymakci et al. 2022; Perera and Chand 2015). However, one example of an AI solution with an explicit focus on SMEs is developed by Brezani et al. (2022). In this case study, a program was designed to detect objects on camera images with the help of AI. During the development phase, special attention was paid to ensuring that this AI program can be adopted by other SMEs without any major adaptation effort.

Besides the frequently cited challenges, certain impediments to AI implementation in SMEs received limited attention in the selected publications. These include the obstacles of acceptance (6), trust (3), data security (7), and data privacy (4). First acceptance and trust, play a minor role in AI implementation in SMEs in the selected publications, although, Joerg and Carlos (2022) considered acceptance to be the most important challenge for SMEs and Kumar and Kalse (2022) emphasized that the Technology Acceptance Theory (TAM) must be taken into account. Another conspicuousness is the issue of data security and data privacy, but only seldom addressed in the selected articles about SMEs. Scholars attributed this to the generally less attention of SMEs to these topics, given the lower volumes of data and limited data utilization until the present (Empl and Pernul 2021). However, some authors assume that this will also change in SMEs with the introduction of AI and the associated collection and evaluation of large amounts of data. As a result, these challenges will become more important as smaller companies engage more intensively with the topic of AI (Joerg and Carlos 2022).

If the challenges are viewed from a higher level, based on the categories of the PESTEL model, a bisection is remarkable. The categories economic, social, and technological are weighted much higher than the groups of political, environmental, and legal. The category with the most mentions of challenges is economic (68 challenges in 36 different publications). However, the social (58/36) and technological (66/33) barriers are almost identically high. On the contrary, the remaining three categories political (8/5), environmental (3/3), and legal (1/1) are also quite close to each other, but on a variant scale. The observation that the three predominant challenges—knowledge, costs, and IT infrastructure—originate from three separate categories (social, economic, technological) further exemplifies the diversity and complexity inherent in addressing barriers to AI implementation in SMEs.

The political challenges can be split into (i) lack of advice, (ii) lack of research, and (iii) lack of funding. Even if all of them are rather less discussed, Žigiene et al. (2019) highlighted the importance of solving these barriers. Furthermore, within the political context, the lack of advice opportunities (3) and academic research (3) are currently seen as more of a challenge than the lack of funding (1).

In the economic area, the barriers are (i) cost, (ii) productivity evaluation, (iii) risk to fail, (iv) solutions available on the market, (v) lack of resources and machines, (vi) data exchange, (vii) lack of standardization, (viii) process adjustment, (ix) duration of implementation, and (x) project planning. Costs emerge as the most frequently cited economic challenge, with noteworthy emphasis on the fact that the second (ROI) and third (risk of failure) most prevalent obstacles are also intricately

connected to financial considerations. This underscores its meaning for an AI introduction (Bunte, 2021), simultaneously highlighting a disparity with the rare mentions of the necessity for action in political funding.

The two least frequently mentioned challenges in the economic category, project planning and duration of the project can be assigned to project realization. This shows that the concrete execution of an AI project in SMEs is viewed rather uncritically (Teerasoponpong and Sopadang 2021).

The social difficulties in AI adoption are (i) knowledge, (ii) management, (iii) acceptance, (iv) AI corporate strategy, and (v) trust/ethics. In this category, in particular, two challenges are emphasized: the knowledge required and convincing management. However, knowledge is by far the most common social challenge for SMEs (Bauer et al. 2020). In contrast, moral and ethical aspects are rarely seen as an obstacle (Lu et al. 2022).

Besides (i) IT infrastructure, (ii) data availability, (iii) data quality, (iv) complexity/individuality, (v) data security, (vi) data privacy, and (viii) model/method/application selection, there are the technological obstacles. This category is more balanced between the individual barriers than the others. All appeared in at least three different articles. The focus of challenges in the technological domain is more on general barriers that must be met irrespective of specific AI applications (data, IT infrastructure), rather than application-specific challenges such as complexity or the selection of individual AI solutions (Iftikhar and Nordbjerg 2021). Overall, this category is strongly characterized by challenges related to data. More than half of the listed challenges can be assigned to this topic. In this context, the focal point primary centers in data generation (Kim et al. 2019a).

In the environment category, only (i) environmental protection is depicted. Conspicuously, the only perceived hindrance concerning the environment is the high energy requirements of the IT hardware for the procedure of AI solutions (Kant and Johannsen 2022). Other potential environmental barriers remain unaddressed.

The last category is legal with (i) regulatory compliance. Due to the large amount of data collected and used, AI poses new legal challenges for the companies. For many, there is still no satisfactory solution how to deal with it (Lu et al. 2022). As already described, many SMEs have not looked at any or only at uncritical data until now. With the expansion of data collection and analyses that inevitably accompanies the implementation of AI, SMEs must now, in addition to a stronger focus on the acceptance of data use and data security, also increasingly deal with the regulatory requirements (Žigiene et al. 2019).

5 Discussion and future research opportunities

The literature review shows the most important characteristics of the selected studies as well as the challenges of AI implementation for SMEs. These barriers and additional research gaps slow or prevent widespread AI adoption. Therefore, this section identifies and discusses potential solutions, practical implications, and open research questions. A summary of the results is shown in Table 3.

5.1 State of the art of research on AI in the industrial sector regarding SMEs

One of the main results of our analysis of the state of the art research is that the subject area of AI with an explicit focus on SMEs is still underexplored. This can be attributed to various factors. First, there are only a few studies on this topic to date. Despite extensive keyword searching, only 71 publications were found for our SLR. Compared with the number of publications on AI in MNUs (Rathore et al. 2021), it shows that this topic area is still backward, despite the identified increase since 2021. This supports the statement by Hansen and Bøgh (2021) and Brandalero et al. (2020) that the overwhelming focus on AI studies to date has been on larger companies. The lack of studies also has practical impacts on SMEs. Although the effect of AI on a company's competitiveness may not be decisive in most cases today, it is anticipated that this will change in the future. As the implementation of AI is a lengthy process (Prem 2019), it is crucial to initiate action now. Thereby academic research is the first step. Hence, we urge scholars to focus more on the topic of AI in SMEs, taking into consideration its unique characteristics in comparison to MNEs.

Furthermore, the analysis according to the business activities by Porter (1985) underscores the deficiency of AI papers for SMEs. Notably, there is a pronounced emphasis on the operational domain, while there is an absence of publications in numerous other business areas (see Fig. 3). Against this background, it is essential to acknowledge that a comprehensive overview of possible AI applications from different business areas holds great importance for enterprises. The current state of research on AI and SMEs conveys the impression that AI is mainly applicable in the domain of operations, leading to a perception of limited potential for AI development in other areas. Hence, there is a need for additional research papers on AI and SMEs that specifically focus on the underrepresented areas (Dobler et al. 2020; Žigiene et al. 2019). Given the recognition of the prevailing concentration of case studies on the operational domain, practical implications for businesses can also be derived. This provides SMEs that are newly delving into the field of AI with an initial orientation on where to commence within their enterprise. Even though the potential of AI is very company specific, this offers entrepreneurs at least an initial starting point. Alongside the previously highlighted advantages of AI in the operational domain, such as the high number of employees and the frequently repeated activities (Bunte et al. 2021), we therefore recommend that manufacturing SMEs initially focus on operational activities, when starting with AI.

Another reason for the need for additional publications on AI in SMEs are the very technical case studies to date. Most of them described their approaches and results from an IT expert point of view (Kiangala et al. 2022; Lin et al. 2021; Manmohan and Shalij 2022). However, since the focus is on SMEs and they usually have less specialized knowledge in their company, especially in the IT area, it is debatable whether the case studies are too complex for many users. This applies particularly to publications that explain the program code or compare different algorithms (Brillinger et al. 2021; Murphy et al. 2019). We urge future researchers to evaluate the purpose and necessity of including detailed technical descriptions in publications about SMEs, and, whenever possible, to make case studies more comprehensible for a broader target audience or to explain the technical specifications in

Table 3 Implications and research gaps

Research question	Main findings	Implications	Research gaps
What is the current state of the art of research on AI in the industrial sector regarding SMEs?	The vast majority of AI studies to date have focused on big enterprises		More research papers regarding AI with an explicit focus on SMEs are needed. Due to the limited scholarly focus on this topic (up to 2020) and the duration of the implementation process of AI, it is important to lay the foundation in research today
	Some business activities are still completely unexplored, others have a particularly great focus	We recommend manufacturing SMEs who are newly entering the AI domain to initially focus on operational activities	Studies on business activities that have received little attention so far are required. Additionally, a comprehensible overview of potential AI applications for SMEs is needed
	Many studies are very technical	For the target group of SMEs, the papers could be too technical and thus give the impression that AI is unsuitable for SMEs. Therefore, decision-makers within SMEs should prioritize easily comprehensible case studies at the beginning	Scholars should check which technical details are necessary for their studies or present them in separate sections if possible
	Case studies are difficult to transfer	SMEs should be aware that many AI case studies cannot be implemented without modifications. Therefore, they should assess their own starting conditions beforehand, with an expectation of necessary adjustments	In future research, it is recommended to provide a detailed description of the initial situations and it should be stated which aspects of the case studies are transferable to other enterprises
	Often the term SME is not defined, or no information is given on the starting conditions		Complicate in assessing the transferability of the studies. The considered company size and the given starting conditions should be clearly defined in future research

Table 3 (continued)

Research question	Main findings	Implications	Research gaps
What are the challenges for SMEs in the implementation of AI in the industrial sector?	Many distinct challenges when introducing AI	Shows the complexity and individuality of AI solutions. Therefore, SMEs should think from the application outwards. Our identified challenges should be applied to the specific case study, utilizing them as guidelines to ensure comprehensive consideration of potential obstacles. Service providers and government should individualize support to the use cases	
	The most frequently perceived challenges are knowledge, costs, and IT infrastructure/digital maturity	These challenges span across economic, social, and technological domains. Consequently, addressing the hurdles of AI implementation requires a holistic approach. Concentrating solely on individual obstacles or specific areas is inadequate. This should be considered in future policy decisions regarding support initiatives	
	Economic challenges have a focus on financial issues (cost, ROI, risk to fail)	Our SLR identified individual low-budget AI applications that should encourage SMEs to engage with AI despite limited financial opportunities. The discrepancy that financial barriers are a common challenge, but the lack of political funding is rarely perceived as an obstacle, indicates the need to make existing funding supports more visible to SMEs. Companies should become more aware of this opportunity	

Table 3 (continued)

Research question	Main findings	Implications	Research gaps
	Often unclear ROI for AI solutions		The calculation and evaluation of the ROI should be considered in future case studies. SMEs need a framework for assessing AI implementations that is tailored to their requirements
	Frequently the management of a company delays an AI introduction. We identify three main reasons: i) enterprise is too small, ii) no potential use cases, iii) no need to introduce AI	Given the importance of management in SMEs concerning the decision for AI implementation, the conviction and support of this target group should be accorded particularly high priority. Exchanges and collaborations between companies organized by academic institutions could additionally support the management	Managers need concrete use cases to recognize their own possibilities. To counteract the problem that many decision-makers do not know how to start an AI implementation, step-by-step guidelines are needed
	Trust, ethics, and acceptance are not much discussed in publications regarding to AI and SMEs	SMEs should thoroughly examine these obstacles, despite their often-limited relevance for this topic up to this point	It is still an open research question whether SMEs are unaware of these challenges or if they are less relevant to them

a separate section. In this way, more people can be reached, as their openness to AI is not negatively affected by the complexity. In line with Szedlak et al. (2021), we also perceived the risk that it could give otherwise the false impression that AI is only manageable for software engineers or at least IT experts. This would inhibit the acceptance and thus also the spread of AI in SMEs. Nonetheless, our SLR also highlighted examples where the technical aspects are not the primary focus (Seseni and Mbohwa 2018). These can serve as an entry point into the AI topic for entrepreneurs with limited IT expertise.

In the case studies it is important to critically question the extent to which these solutions and their benefits can be transferred to other use cases. In the field of AI in particular, researchers widely agree that it is often difficult to transfer or copy solutions that have been developed (Ersöz et al. 2022; Kant and Johannsen 2022). Rather, the very different initial situations, such as the amount of available data, cause the need for individual requirements and conditions. Consequently, in upcoming research papers utilizing a case study, it is vital to establish a clear and concise depiction of the initial situation. Moreover, researchers should highlight which aspects of their case studies are transferable to other companies and should specify the necessary conditions for such applicability. For businesses, this implies that many AI applications and case studies can be adopted only with often substantial customization efforts. Therefore, it is crucial to influence decision-makers to understand that the presented AI solutions typically cannot be directly adopted in a 1:1 manner. Otherwise, companies may recognize these divergent starting points too late or misjudge their impacts, resulting in a flawed business case for the AI applications.

It has already been stated that the selected papers generally only distinguish between SMEs and other company sizes, whereby the exact term of SME often remains undefined. In other areas of Industry 4.0, this might not be critical, but AI is substantially different compared to other technologies (Jöhnk et al. 2021). A major influence on an AI implementation arises from the initial conditions of the company, including factors such as available data and maturity level. For this reason, companies should always consider these factors in case studies whenever possible, especially when drawing conclusions from the publications for their own business. To enable companies to do this we believe that it is needed to clearly define the company sizes considered and show the starting conditions of the enterprises in the context of AI publications. Only in this way is it possible to differentiate the results. But the right level of detail and the right key figures are questionable, as some researchers have already shown (Loecher 2000). In addition to the widespread option of revenue and/or number of employees, scholars dealing with AI often distinguish according to the maturity level (Bauer et al. 2020; Mittal et al. 2018). Defining the most appropriate key figure for a subdivision still represents a research gap that would have to be investigated in more detail in the future.

5.2 Challenges for SMEs in the implementation of AI in the industrial sector

A main finding of our SLR is the great number of different challenges for an AI implementation by SMEs. The result of 27 identified challenges is surprising, as

many case studies only focus on a few most important barriers (Kim et al. 2019b), and this diversity clearly passes the number of identified obstacles in reviews of AI in MNEs (Arinez et al. 2020; Regona et al. 2022). This indicates, on the one hand, that SMEs perceive substantially more challenges in AI implementations than larger enterprises, and, on the other hand, underscores the complexity and individuality inherent in AI applications. This is further supported by the researcher's disagreement on the definition of the biggest challenge for an AI implementation by SMEs. Depending on the specific use case, different obstacles can be perceived as the greatest barriers to implementation. If, for example, the required data could be the biggest barrier for a complex ML solution (Bauer et al. 2020), acceptance may be the largest obstacle for a simple application that processes personal data. This renders standardization of the challenges and their prospective solutions arduous. Thus, companies should adopt an approach that considers the concrete AI application, evaluating the challenges and prerequisites associated with the specific use cases to be implemented. In this context, we recommend considering our identified challenges as guiding principles to avoid overlooking or underestimating potential barriers. Simultaneously, our SLR shows that due to the individuality of AI applications, there is no necessity for companies to satisfy all 27 identified challenges before an implementation. For companies with low data availability, for example, AI applications that precisely take these initial conditions into account and are designed accordingly can be interesting. Case studies from our SLR present this possibility (Kim et al. 2019b). For SMEs, this implies that even if their own company does not meet all usual prerequisites for an AI implementation, it does not necessarily mean a general unsuitability for AI. Rather, these companies should not be deterred by this and explore what is already achievable given their initial starting conditions.

When considering the challenges, the most common implementation barriers for SMEs are knowledge, costs, and IT infrastructure/digital maturity. It is noteworthy that these three most frequently cited obstacles can be assigned to three different PESTEL categories: (i) knowledge to social, (ii) costs to economic, and (iii) IT-infrastructure/digital maturity to technological. In our opinion, this shows that from an economic and political point of view, the dismantling of challenges for SMEs must take place in a triad. It is not enough to focus on just one category or even on one single obstacle. Instead, the barriers, especially economic, social, and technological, must be viewed and solved as a whole. Future political decisions regarding the support options for SMEs in AI adoption should be made based on these findings. A parallel improvement in the conditions across all these diverse categories is expected to have the most positive impact on the increase in the spread of AI in SMEs.

The three major economic challenges, cost, productivity evaluation, and risk of failure, can all be attributed to the topic of finance. This underscores the importance of financial aspects in the implementation of AI in SMEs. However, there is a disparity to the barely noticed political barriers. The authors of the selected studies see only an occasional need for action about the political obstacles to AI (Basri 2020), even though political support, especially through funding, has proven effective in overcoming barriers and expediting the dissemination of other new technologies (Yang et al. 2022).We assume that many companies perceive the financial barriers

of adoption but may not be aware of the available support options. Therefore, the government should enhance the visibility of existing funding opportunities for SMEs and, if necessary, expand them accordingly. Nevertheless, companies should initially not view the financial barrier as a reason to forego AI solutions. Firstly, they should consider potential support offerings in their deliberations. Furthermore, case studies have already demonstrated that individual and efficient AI applications can be introduced with a budget of less than $500 (Kim et al. 2019b).

Another noticeable aspect, regarding the financial obstacles, is the frequent mention of productivity evaluation (quantity: 13). This suggests that it is not only the absolute costs of implementation, but rather the difficulty of assessing whether an investment in AI may have a good ROI. In all selected case studies, the calculation of the productivity evaluation is completely out of scope without further justification. Only Kim et al. (2019b) listed the exact costs for their case study. Given that the ROI is a crucial factor for SMEs when contemplating AI adoption (Iftikhar and Nordbjerg 2022), future case studies should address this aspect as well. However, since case studies are always very specific, there is also a necessity for additional frameworks customized for SMEs to determine the ROI of an AI solution in a way that is as simple and universal as possible. In the absence of a comprehensive framework for calculating and assessing the potential benefits, numerous companies tend to abstain from initiating AI implementation, or alternatively postpone the decision-making process, pending further experience-based insights. This reluctance is often due to the fact that SME managers without suitable aids lack the capacity to adequately estimate the potential benefits of AI solutions (Bunte et al. 2021). The development of a corresponding framework would enable the calculation of the benefits of AI applications, ultimately fostering greater acceptance and diffusion of the technology within companies.

The challenge of management also holds an important weight in the context of an AI introduction. This is particularly pronounced in SMEs, firstly, because decision-making authority rests especially with management, and secondly, due to the larger impacts of an AI implementation on the financial aspects of a smaller company. Therefore, we consider the conviction of management in AI technology as a prerequisite for the widespread adoption of AI in SMEs. The persuasion of this target group should therefore take priority. Addressing the concerns of management identified in our SLR, namely (i) the own company is too small, (ii) there are no potential use cases for the business, and (iii) there is no need to introduce AI as the company can function without it, is essential. To achieve this, we see an opportunity in enhanced communication and collaboration between businesses. Especially, the fact that many managers think that their companies are too small and that they cannot imagine concrete use cases (Husson et al. 2021), can be eliminated through successful experience reports. Direct exchange, for example with the help of networks, would also be useful here. These could be organized by academic institutions, among others. To help SMEs to understand the potential of AI, scholars should provide in addition a practical overview of possible applications and existing case studies, in an easily understandable manner. Furthermore, to address the challenges arising from the complexity and diverse starting conditions of AI implementation in SMEs, many managers from SMEs already have issues defining the first necessary

steps for an AI introduction in their company (Lu et al. 2022). Thus, very small-scale procedures are needed that explain an AI introduction step by step and address the different starting conditions.

Both at publications on AI in MNUs and in the media, the topics of trust, ethics, and acceptance are frequently discussed in relation to AI applications. But in the articles on AI in SMEs, only limited reference is made to these points (Joerg and Carlos 2022). There is a need to clarify whether trust, ethics, and acceptance are generally less important in the context of AI solutions in SMEs or whether this is mainly because many SMEs are still in the early stages of introducing AI and therefore do not yet perceive these topics as a challenge. If the subject of ethical and acceptance considerations is not sufficiently pronounced in SMEs, it is important to explore the underlying reasons. This includes investigating whether SMEs have not yet fully recognized the consequences of these aspects in the context of AI and if measures need to be taken. One potential solution is to increase the focus on education and awareness-raising initiatives in this area. Regardless, SMEs should critically scrutinize these aspects for their specific use case before implementation to avoid being surprised by their potential implications later on. This is particularly crucial for AI applications.

6 Conclusion and limitation

The aim of our study was to answer our two research questions and to highlight open research areas, considering the limitations. To obtain a comprehensive overview of important search strings on the topic AI for our SLR, we chose a novel approach. Therefore, we determined the most frequent key words from 77 systematic reviews related to AI (see Table 1) and added the most frequent AI terms from the Artificial Intelligence Index Report 2022 of Zhang et al. (2022). With this, we were able to identify 71 relevant publications for our subsequent SLR. Out of these we figured several findings related to our research questions.

6.1 RQ1. What is the current state of the art of research on AI in the industrial sector regarding SMEs?

- In order to address the current imbalance of AI research that predominantly focuses on MNEs, it is necessary to increase the number of studies concerning AI regarding SMEs. Furthermore, the scope of research should encompass the full range of business activities, since current studies often consider only a limited number or none at all in certain areas (see Fig. 3)
- For manufacturing SMEs newly entering the AI domain, we recommend placing initial emphasis on operational activities. This domain exhibits the most advanced research on AI in SMEs, with successful case studies. Moreover, it commonly offers the greatest potential for optimization.
- In the selected case studies the initial situation of an enterprise, such as the data collection process, is frequently unclear, rendering the transferability of the case

study to other companies challenging. SMEs need to be aware of this issue. This can be further complicated by elaborate exposition of technical details, as often the target group of SMEs lacks technical expertise. Therefore, future publications should provide a comprehensive description of the starting situation and carefully consider which technical aspects are necessary and relevant to the topic.

6.2 RQ2. What are the challenges for SMEs in the implementation of AI in the industrial sector?

- We could identify 27 different challenges for SMEs in total (see Table 2). This shows the great complexity and individuality of AI solutions. Henceforth, it is advisable for enterprises to consider embracing an application-oriented approach while integrating AI. Besides, SMEs can utilize the identified challenges to investigate these for their own AI projects, mitigating the risk of overlooking potential obstacles or risks.
- The three most frequent challenges in our SLR were knowledge, costs, and the low maturity level in digitalization. Additionally, a pronounced emphasis on financial risks is evident in the economic domain. Many SMEs consider the lack of ROI assessment as an obstacle to deciding on AI implementation, but none of the selected case studies addressed this aspect. This represents a research gap for future studies.
- For the management, we identified three primary reasons for hesitation: (i) the own business is too small, (ii) lack of AI use cases and (iii) there is no necessity to introduce AI. In response to these concerns, we recommend the conducting of knowledge-sharing rounds with other companies to address these concerns.

However, some limitations must be taken into account when considering the results. First of all, the utilized research method for this article results in certain limitations, as mentioned in other SLRs (Reis et al. 2020). The choice of search strings and exclusion criteria significantly influenced the result of the selected publications. Moreover, many primary studies often considered only a single country, industrial sector, or company (Ha and Jeong 2021; Ushada et al. 2017). This creates a risk of bias in the interpretation of the outcomes. To answer the second research question, the challenges addressed in the individual publications were listed and the number of mentions was counted. For this approach, there is a limit to the extent to which the quantity can be causally linked to the importance of the obstacles for SMEs. Furthermore, there was no different weighting of the challenges based on qualitative criteria.

7 Appendix 1

See Table 4.

Table 4 Summary of reviewed publications—SMEs

Number	Author	Year	Title	Research question/Purpose	Study design
S1	Agerri et al	2014	Multilingual, Efficient and Easy NLP Processing with IXA Pipeline	Describes simple alternatives to NLP that can be used by SMEs	Case study
S2	Aldinucci et al	2018	PC4AI, an AI-on-demand federated platform endeavour	Showing alternatives to large AI platforms for SMEs	Case study
S3	Barton et al	2022	Identification Overview of Industry 4.0 Essential Attributes and Resource-Limited Embedded Artificial-Intelligence-of-Things Devices for Small and Medium-Sized Enterprise	Identify SME attributes for an AI and industry 4.0 strategy	Overview
S4	Basri	2020	Examining the impact of artificial intelligence (Ai)-assisted social media marketing on the performance of small and medium enterprises: Toward effective business management in the saudi arabian context	To identify if and how AISMM impacts the SMEs performance	Survey
S5	Bauer et al	2020	Machine learning in SME: an empirical study on enablers and success factors	What is the current state of ML in SMEs and how does it differ from best practice? What are the success factors?	SLR & survey
S6	Becker et al	2020	Acoustic Anomaly Detection in Additive Manufacturing with Long Short-Term Memory Neural Networks	Recognizing errors in 3D printing with the help of neural networks	Case study
S7	Ben Abdelaziz et al	2020	A multi-objective particle swarm optimization algorithm for business sustainability analysis of small and medium sized enterprises	To determine the influence of sustainability on the performance of SMEs	Case study & survey
S8	Bencsik	2020	Challenges of Management in the Digital Economy	How do the challenges of digitalization differ between company sizes?	Interviews
S9	Bender et al	2022	Benchmarking AutoML-Supported Lead Time Prediction	Can the compared AutoML surpass manual predictions in performance comparison?	Case study

Table 4 (continued)

Number	Author	Year	Title	Research question/Purpose	Study design
S10	Bettoni et al	2021	An AI adoption model for SMEs: A conceptual framework	Development of a framework to check whether SMS are ready for AI adoption	Conceptual framework
S11	Borghesi et al	2021	IoTwins: Design and implementation of a platform for the management of digital twins in industrial scenarios	Analyzing the requirements for a platform to manage DigitalTwins	Framework
S12	Brandalero et al	2020	AITIA: Embedded AI Techniques for Embedded Industrial Applications	Demonstrate how AI theory can be transferred to practice using 4 different practical examples	Case study
S13	Brezani et al	2022	Smart extensions to regular cameras in the industrial environment	Development of a rapid response system for object recognition in SMEs using cameras	Case study
S14	Brillicnger et al	2021	Energy prediction for CNC machining with machine learning	Which factors influence the energy consumption of CNC machines and how can the energy demand be predicted with the help of AI?	Case study
S15	Bunte et al	2021	Why it is hard to find AI in SMEs: A survey from the practice and how to promote it	Is there a clear understanding of what AI is in the context of manufacturing? To what extent is AI being implemented and succeeding in manufacturing? What are the specific advantages of using AI?	Survey
S16	Chalmers et al	2021	Artificial Intelligence and Entrepreneurship: Implications for Venture Creation in the Fourth Industrial Revolution	Investigating the negative impact of AI on the operational practice in small enterprises	Framework
S17	Chen et al	2019	A Low-Cost Add-On Sensor and Algorithm to Help Small- and Medium-Sized Enterprises Monitor Machinery and Schedule Processes	Investigation of cost-effective additional sensors that are integrated with a monitoring AI algorithm	Case study
S18	Chen et al	2021	AIoT module development for automated production	Developing an AI solution to detect production defects from camera footage	Case study

Table 4 (continued)

Number	Author	Year	Title	Research question/Purpose	Study design
S19	Dobler et al	2020	Supporting SMEs in the Lake Constance Region in the Implementation of Cyber-Physical-Systems: Framework and Demonstrator	Which AI algorithm, which can also be used by SMEs, is best suited for predicting production planning	Simulation
S20	Dos Santos et al	2021	Decision-making in a fast fashion company in the Industry 4.0 era: A Digital Twin proposal to support operational planning	Development of an AI-supported dashboard to optimize future production planning	Case study
S21	Ellefsen et al	2019	Striving for excellence in ai implementation: Ai maturity model framework and preliminary research results	Exploring the areas of potential applications of AI in manufacturing and warehousing	Framework & survey
S22	Empl and Pernul	2021	A Flexible Security Analytics Service for the Industrial IoT	Design of a flexible AI security analysis service for the needs of SMEs	Framework
S23	Ersöz et al	2022	Defective products management in a furniture production company: A data mining approach	Using data mining/AI to determine the causes of quality problems in production	Case study
S24	Ha and Jeong	2021	CNN-based defect inspection for injection molding using edge computing and industrial IoT systems	Development of an AI solution for error proofing of injection moulding based on data scarcity in SMEs	Case study
S25	Hansen and Bøgh	2021	Artificial intelligence and internet of things in small and medium-sized enterprises: A survey	Analyzing the spread and opportunities of AI and IoT in SMEs	Review & survey
S26	Hansen et al	2020	Concept of easy-to-use versatile artificial intelligence in industrial small & medium-sized enterprises	Determining the benefits of AI boxes for easy introduction of this technology in SMEs	Case study
S27	Hennig et al	2021	Introduction of a time series machine learning methodology for the application in a production system	Development of a framework to enable employees with limited knowledge of AI to use machine learning methods in 3 steps	Framework

Table 4 (continued)

Number	Author	Year	Title	Research question/Purpose	Study design
S28	Horputra et al	2021	Deep Learning-Based Bottle Caps Inspection in Beverage Manufacturing and Packaging Process	Development of a deep learning solution for the automatic detection of faulty bottle caps	Case study
S29	Husson et al	2021	Analysis and illustration of the practical impact of Artificial Intelligence and Intelligent Personal Assistants on business processes in small- and medium-sized service enterprises	Investigating the benefits of combining AI and IPA features for use cases in SMEs	Interview & survey
S30	Iftikhar and Nordbjerg	2021	Adopting Artificial Intelligence in Danish SMEs: Barriers to Become a Data Driven Company, Its Solutions and Benefits	Analyzing the barriers and benefits of introducing AI	Literature review
S31	Iftikhar and Nordbjerg	2022	Implementing Machine Learning in Small and Medium-Sized Manufacturing Enterprises	Development of a detailed introduction process for ML in SMEs	Framework
S32	Ing et al	2020	Edge-Cloud Collaboration Architecture for AI Transformation of SME Manufacturing Enterprises	Presenting an AI implementation process regarding the specificities of SMEs	Framework
S33	Jain et al	2021	Unlocking technology adoption for a robust food supply chain: Evidence from Indian food processing sector	Analyzing the impact of AI adoptions on the efficiency in companies of the food processing sector	Survey
S34	Joerg and Carlos	2022	Design Framework for the Implementation of AI-based (Service) Business Models for Small and Medium-sized Manufacturing Enterprises	How can AI-based (service) business models be introduced and utilized by SMEs?	Framework
S35	Kaiser et al	2021	Towards low-cost machine learning solutions for manufacturing SMEs	Demonstration of an approach for determining favorable ML solutions for SMEs	Review & framework

Table 4 (continued)

Number	Author	Year	Title	Research question/Purpose	Study design
S36	Kant and Johannsen	2022	Evaluation of AI-based use cases for enhancing the cyber security defense of small and medium-sized companies (SMEs)	Highlighting existing AI case studies with high potential for cyber security for SMEs	Literature review
S37	Kaymakci et al	2022	A Systematic Selection Process of Machine Learning Cloud Services for Manufacturing SMEs	Establishing a systematic ML cloud service selection method for SMEs	Framework
S38	Kiangala et al	2022	An Experimental Safety Response Mechanism for an Autonomous Moving Robot in a Smart Manufacturing Environment Using Q-Learning Algorithm and Speech Recognition	Development of an AI-based robot that finds the nearest exit in manufacturing companies in an emergency	Case study
S39	Kim et al	2019b	A Low-Cost Vision-Based Monitoring of Computer Numerical Control (CNC) Machine Tools for Small and Medium-Sized Enterprises (SMEs)	Demonstrate that cost-effective and easy-to-integrate AI solutions for machine monitoring are also possible, making them particularly suitable for SMEs	Case study
S40	Kim and Ryu	2020	Intelligent process quality management for supporting collaboration of mold manufacturing SMEs	Designing a process to strengthen quality management based on AI between different companies	Literature review & framework
S41	Kulkarni et al	2021	Camelot: AI-Powered Campaign Management System	Development of a process on how AI can be used to create a marketing campaign from text generation to image selection	Framework
S42	Kumar and Kalse	2022	Usage and adoption of artificial intelligence in SMEs	Identification of potential fields of application of AI for SMEs and which influencing factors have a positive effect regarding an introduction	Systematic literature review

Table 4 (continued)

Number	Author	Year	Title	Research question/Purpose	Study design
S43	Lin et al	2021	A general product identification method for mass customization based on deep learning	Individual orders are to be assigned to the correct customer order at the end of the production process using AI instead of RFID	Case study
S44	Liu et al.	2019	Next generation integrated smart manufacturing based on big data analytics, reinforced learning, and optimal routes planning methods	Optimization of transport routes and selection of the optimal wash cycle in a laundry determined by AI	Case study
S45	Lu et al	2022	AI-Enabled Opportunities and Transformation Challenges for SMEs in the Post-pandemic Era: A Review and Research Agenda	To demonstrate the potential areas of application for AI in SMEs and the associated benefits and effects. In addition, the challenges of an introduction will be discussed and how these can be positively influenced by the stakeholders	Review
S46	Manmohan et al	2022	Optimal Prediction of Manufacturing Parameters for Integration of Lean and Sustainability with QMS in SMES	Based on different machine data, the optimal machine settings are to be determined by an AI algorithm regarding the amount of waste and environmental protection	Case study
S47	Marco et al	2021	AI-Powered Curricula Selection: A Neural Network Approach Suited for Small and Medium Companies	An AI algorithm will be used to match applicants with the right jobs based on their CVs	Case study
S48	Marosi et al	2022	Interoperable Data Analytics Reference Architectures Empowering Digital-Twin-Aided Manufacturing	Highlighting existing reference architecture concepts regarding cloud and digital twins. From this, a framework is to be developed explicitly for SMEs	Review & framework
S49	Murphy et al	2019	Machine learning technologies for order flowtime estimation in manufacturing systems	With the help of 16 different input factors, an ML application is designed to better estimate delivery times	Case study

Table 4 (continued)

Number	Author	Year	Title	Research question/Purpose	Study design
S50	Philippe et al	2015	Exploration and design of embedded systems including neural algorithms	Couple different environments of embedded systems with the help of a neural network	Case Study
S51	Prem	2019	Artificial intelligence for innovation in Austria	Does AI innovation require a different management approach than other IT innovations?	Review & interviews
S52	Putnik	2021	Semi-Double-loop machine learning based CPS approach for predictive maintenance in manufacturing system based on machine status indications	Various AI algorithms are to be tested to determine which can best predict the future maintenance requirements of machines	Case study
S53	Qu et al	2021	Research on enterprise business model and technology innovation based on artificial intelligence	Investigation of the influence of technological innovation on business models and on the performance of companies	Survey
S54	Sardis and Varvarigou	2010	Industrial workflows recognition by computer vision and AI technologies	Analyzing the possibilities and benefits of an AI algorithm that uses a camera to detect deviations from the target state in human–machine interaction	Case study
S55	Schuh et al	2020	Using AI to facilitate technology management—Designing an automated technology radar	Creation of a search application for SMEs based on NLP, which automatically collects information on desired technologies and clusters them as required	Case study
S56	Seseni and Mbohwa	2018	The implications of Artificial Intelligence on Soweto furniture manufacturing SMEs	Investigation of whether SMEs in manufacturing are ready for the introduction of AI and thus meet the requirements in terms of finance and knowledge	Review & case studies
S57	Sharma et al	2022	Artificial intelligence framework for MSME sectors with focus on design and manufacturing industries	Demonstrate a framework for an AI implementation based on the challenges, benefits, and potential areas of application	Framework

Table 4 (continued)

Number	Author	Year	Title	Research question/Purpose	Study design
S58	Singh and Desai	2022	Automated surface defect detection framework using machine vision and convolutional neural networks	Development of a low-cost AI application for small companies to achieve an almost 100% error detection rate with machine version	Case study
S59	Szedlak et al	2021	Risks and Benefits of Artificial Intelligence in Small-and-Medium Sized Enterprises	Analyzing the different perceptions of the challenges and benefits of introducing AI in SMEs between a survey in enterprises and interviews with AI experts	Survey & interview
S60	Szedlak et al	2020	Application of artificial intelligence in small and medium-sized enterprises	Investigation of the degree of dissemination and potential areas of AI applications in SMEs	Survey
S61	Teerasoponpong and Sopadang	2021	A simulation–optimization approach for adaptive manufacturing capacity planning in small and medium-sized enterprises	Simulation of optimal capacity planning with ANN in SMEs	Case study & simulation
S62	Thiagarajan et al	2018	Manufacturing flow time estimation using the model-tree induction approach in a dynamic job shop environment	Using supervised learning and ten different input factors to determine the estimated lead time	Simulation
S63	Tosida et al	2020	Optimizing the classification assistance through supply chain management for telematics SMEs in Indonesia using deep learning approach	Exploration of different deep learning approaches to obtain the best possible results for classifications	Simulation
S64	Ulrich and Frank	2021	Relevance and adoption of AI technologies in German SMEs—Results from survey-based research	Which AI technologies are particularly widespread and in which areas of application are they used?	Survey
S65	Ushada et al	2017	Affective Temperature Control in Food SMEs using Artificial Neural Network	Determine the optimum working temperature based on personal data with the help of ANN	Case study

Table 4 (continued)

Number	Author	Year	Title	Research question/Purpose	Study design
S66	Velmurugan et al	2021	SME 4.0: Machine learning framework for real-time machine health monitoring system	Presentation of a framework to determine the optimized failure rate through machine learning	Framework
S67	Welte et al	2020	A Method for Implementation of Machine Learning Solutions for Predictive Maintenance in Small and Medium Sized Enterprises	Description of an optimal procedure orientated towards SMEs for the introduction of ML for predictive maintenance	Case study and framework
S68	Wen	2019	Research and Implementation of Intelligent ERP Platform for SMEs Based on Cloud Computing	Design and detailed description of an intelligent ERP platform that is explicitly tailored to the needs of SMEs	Case study
S69	Willenbacher et al	2021	Machine learning for optimization of energy and plastic consumption in the production of thermoplastic parts in SME	Using machine data and ML to minimize energy consumption and resource waste	Case study
S70	Xie et al	2021	Does artificial intelligence affect the pattern of skill demand? Evidence from Chinese manufacturing firms	Investigating the impact of the use of AI on the demand for employees	Data mining
S71	Žigiene et al	2019	Artificial intelligence based commercial risk management framework for SMEs	How can AI be used to determine and present the own financial risk more transparently	Framework

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Declarations

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