

RESEARCH ARTICLE | MARCH 20 2026

A multiple case study of AI potential in small and medium sized companies (SME)

Jonas Waidringer ✉; Chandadevi Giri; Sven Beiker; Jens Wittsten

AIP Conf. Proc. 3381, 060005 (2026)

<https://doi.org/10.1063/5.0308483>



Zurich Instruments

Freedom to Innovate.

The New VHFLI 200 MHz Lock-in Amplifier.

Orchestrate pulses, triggers, and acquisition as the hub of your experiment. Discover more – run every signal analysis tool, simultaneously.

Order now

A Multiple Case Study of AI Potential in Small and Medium Sized Companies (SME)

Jonas Waidringer ^{1, a)}, Chandadevi Giri ^{1, b)}, Sven Beiker ^{2, c)} and Jens Wittsten ^{3, d)}

¹ *Industrial Engineering and Management, University of Borås, 50190 Borås, Sweden*

² *Graduate School of Business, Stanford University, Industrial Engineering and Management, University of Borås, 50190 Borås, Sweden*

³ *Mathematics, University of Borås, 50190 Borås, Sweden*

^{a)} Corresponding author: Jonas.waidringer@hb.se

^{b)} chandadevi.giri@hb.se

^{c)} sven.beiker@hb.se

^{d)} jens.wittsten@hb.se

Abstract Small and medium-sized enterprises (SMEs) are central to economic development and innovation but often encounter significant obstacles in adopting advanced technologies such as artificial intelligence (AI). This study examines the potential of AI to address these challenges and enhance the competitiveness of SMEs. In a multiple case study, the research integrates a review of the relevant literature, in-depth case analyses, and semi-structured interviews to identify key barriers to AI adoption, including deficiencies in technical skills, organizational inertia, limitations in data infrastructure, and constrained resources. The study critically evaluates the transformative role of AI in improving decision-making processes, operational efficiency, and strategic adaptability in SMEs. Strategies for mitigating adoption barriers are proposed, emphasizing the importance of targeted training programs, fostering an innovation-oriented organizational culture, prioritizing robust data governance, and utilizing accessible AI tools. While the study acknowledges limitations such as the small sample size and the potential for interpretative bias, its findings contribute to the academic discourse on technology adoption in SMEs. The research provides a framework for understanding AI's role in SME contexts and offers directions for future empirical investigations into the intersection of AI and small business sustainability.

INTRODUCTION

Most economies are built on small and medium-sized enterprises (SME) [1]. In Sweden, 99,9% of firms are SMEs, and in the European Union, 99% of firms are SMEs [2]. Reduced lead times and adaptable multipurpose assembly systems are requirements for many SMEs in the current business environment, and a need for production flexibility is one factor that influences the decision to invest in industry 4.0 solutions. To stay competitive in a world where the pace of technological change is continually accelerating, it is becoming crucial for businesses to adopt innovative technologies and processes. This article is based on findings in an ongoing research project at the University of Borås, that involves several small and medium-sized enterprises in southern Sweden.

Many SMEs currently have rigid industrial activity which is difficult to change: innovations can hardly be afforded, process costs are increasing, and therefore profit margins are constantly declining [1]. Typically, there is also high dependence on in-house knowledge and expertise, making these companies more vulnerable to changes in the work force. At the same time, production systems, although already highly automated, do typically not possess self-learning capabilities, which means that they cannot adapt, improve, or diagnose themselves without constant human monitoring. All these impediments point to the need for the next great revolution in industrial manufacturing, which will lead to several enhanced attributes in comparison with actual production activities. This is referred to as industry 4.0 [3].

Because of their size that allows for greater agility, SMEs are renowned for their inventiveness, frequently spearheading the development of new products and services that can alter markets completely. This agility is a great advantage, particularly in industries where time-to-market is a critical factor [4].

But SMEs also have unique difficulties that may prevent them from further expansion and economic stability. Access to capital is a major factor, because of their limited assets and often less predictable revenue streams. SMEs are frequently seen by traditional banks as an investment risk; therefore, they are disproportionately affected by funding challenges due to a regulatory environment that necessitates strict compliance with established financial processes. [4].

Despite the potential benefits, the adoption of AI by SMEs is fraught with challenges. Many SMEs have rigid industrial activities that are difficult to change, with increasing process costs and declining profit margins (Ghobakhloo & Ching, 2019). Additionally, while production systems are often highly automated, they typically lack self-learning capabilities, meaning they cannot adapt, improve, or diagnose themselves without constant human monitoring. These impediments highlight the need for a novel approach to industrial manufacturing, one that leverages the capabilities of AI to create more flexible, efficient, and adaptive production systems.

The primary research problem is the difficulty SMEs face in adopting and implementing AI technologies. Unlike large enterprises, SMEs often lack the technical expertise, financial resources, and infrastructure needed for AI adoption. This results in challenges such as inadequate data management, resistance to cultural change, and limited investment capacity, which hinder effective AI implementation. Given these challenges, the central research question guiding this study is:

How can small and medium-sized enterprises (SMEs) successfully adopt and implement AI technologies to enhance their competitiveness and operational efficiency?

The objectives of this study are threefold: to identify the specific barriers to AI adoption in SMEs and understand their impact, to explore the requirements, potential, and benefits of AI-enabled solutions for SMEs, and to determine key factors that contribute to successful AI implementation in SMEs.

The complete research framework is shown in Figure 1.

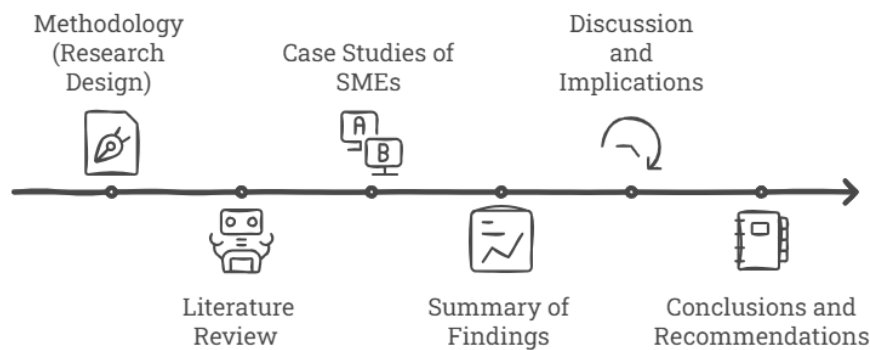


FIGURE 1. Research Framework

The paper is structured as follows: Section 2 outlines the research methodology, data collection methods used in the study. Section 3 provides a comprehensive review of the existing literature on AI adoption in SMEs, focusing on the challenges and opportunities associated with AI implementation in automation and product development. Section 4 presents detailed case studies of two SMEs, focusing on their experiences with AI adoption in automation and value chain. Section 5 summarizes the key findings from the case studies and literature review, highlighting the main challenges and strategies for successful AI implementation in SMEs. Section 6 discusses the implications of the findings for SMEs, including practical recommendations and future research directions.

METHODOLOGY

This chapter outlines the research design, data collection methods, and limitations of the study. By employing a combination of qualitative and quantitative methods, the study aims to provide a comprehensive understanding of the challenges and opportunities associated with AI adoption in SMEs. The use of triangulation ensures that the findings are robust and well-rounded, drawing from multiple data sources and perspectives.

Research Design

The research design for this study employs a combination of qualitative and quantitative methods, also known as triangulation, to provide a comprehensive understanding of the challenges and opportunities associated with AI adoption in SMEs [5-8]. The research has employed a combination of different methods, also known as triangulation. [9]; [10]. The methods used in this study are presented in Table 1. below.

TABLE 1. Overview of research employed methods.

Method	Type	Description	Objectives
Literature Review	Qualitative	Synthesizes findings from multiple studies to draw robust conclusions [11]	- Establish theoretical framework - Gain contextual understanding
Case Study	Qualitative and quantitative	Investigates real-life activities using diverse evidence sources [12]	- Understand complex real-life phenomena - Describe relationships within a specific context (e.g., organizational)
Interview	Qualitative (Semi-structured)	Explores phenomena through human perspective via subject interviews [13]	- Explore complex areas - Gather rich qualitative data

Data Collection Methods

The data collection methods used in this study include literature review, case studies, and semi-structured interviews (see Figure 2). The literature review synthesizes findings from multiple studies to draw robust conclusions and establish a theoretical framework for the study. Searches were conducted in academic databases such as Scopus and Web of Science using keywords like SME, AI, challenge, implementation, automation, and product development. The selected literature serves as a comprehensive background for the study, providing insights into the current state of research on AI adoption in SMEs.

Case studies were conducted to investigate real-life activities using diverse evidence sources [12]. The design of the case studies is divided into two parts: quantitative measures and qualitative measures. Quantitative measures involve collecting existing company data from their operations to understand the current state of quality or throughput. This data helps identify areas where AI solutions may improve reliability and efficiency in corporate operations. Qualitative measures involve gathering insights and experiences from technical staff and management of the companies, as well as observations by the researchers. This qualitative approach allows for a deeper understanding of the underlying processes and challenges these businesses face when implementing AI solutions.

Semi-structured interviews were conducted to explore phenomena through the human perspective via subject interviews [13]. This method allows for flexibility and individual focus, enabling a deeper dive into the participants' different experiences and observations. Multiple representatives from different companies were interviewed to understand the various challenges they observe in their respective companies' daily operations. The goal of the interviews was to capture their ideas and points of view to create an understanding of how they could implement AI in their business and to explore suitable tools.

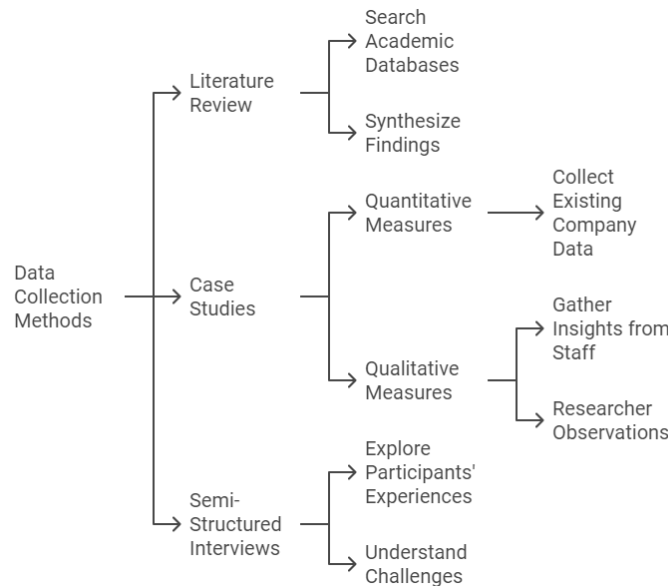


FIGURE 2. Data Collection

Limitations

The study acknowledges several limitations. The sample size for the case studies and interviews may be limited, which could affect the generalizability of the findings. The qualitative nature of the research may introduce subjectivity in data interpretation. Efforts were made to minimize bias through triangulation and rigorous data analysis techniques.

LITERATURE STUDY

The literature study examines the challenges and opportunities of AI adoption in SMEs, focusing AI, automation, and product development. It highlights key factors such as resource constraints, knowledge gaps, and the importance of organizational readiness and cultural acceptance.

Artificial Intelligence

In recent years, the rapid evolution of artificial intelligence and automation technologies has transformed the landscape of manufacturing industries, offering unprecedented opportunities for efficiency, productivity, and competitiveness [14]. While large enterprises have embraced these advancements to streamline operations and gain a competitive edge, small- and medium-sized enterprises face unique challenges in adopting AI solutions due to resource constraints, knowledge gaps, and risk aversion [15].

AI is defined as a system's ability to correctly interpret external data, to learn from such data, and to use those learnings to achieve specific goals through flexible adaptation [16]. This technology offers numerous opportunities for business operations, including improved decision-making, inventory planning, and optimization of manufacturing processes [17].

SMEs often might not see the potential of using AI, while large companies realize the opportunities it creates more easily and therefore are more willing to invest in AI-technology and the necessary skills development. By comparison, SMEs often lack technical competence and have organizational difficulties integrating AI into their operations [3]. Closing the gap by creating an informative model of effectively using AI and its benefits could increase the willingness of SMEs to consider investments and up-skilling [14].

AI was conceptualized in the 1950s and the main research emerged in the 1970s. However, it was through Industry 4.0 that it started to yield more complex and extensive applications in the corporate environment of manufacturing and product development [18]. Although AI can be found in many areas and continues to evolve, it still does not have a commonly used definition. While some use a narrow definition that is mostly centred around machine learning (ML), others consider a wider interpretation for everything performed by computers. Systems for advanced problem-solving methods are usually called artificial intelligence and are often based on machine learning algorithms [19].

The use of AI within manufacturing companies constitutes a relatively new approach, and within that research domain, the development of the necessary programs is ongoing while practical use is still limited [20]. However, the solutions that have been implemented in the manufacturing companies have shown promise in making work more efficient. In Industry 4.0, AI is expected to increase its impact on engineering and operations. The optimization of design-related issues relies more and more on AI with advanced simulation techniques, biology-inspired algorithms, and more [21].

As discussed, AI has the potential to increase productivity, quality, and profitability in future manufacturing systems [22]. To achieve these effects, AI implementation needs to be planned well ahead accounting for key success factors.



FIGURE 3. Factors affecting AI implementation.

Usually, it is not one single factor that is obstructing implementation but rather a combination of multiple different factors [18].

One crucial factor that has been mentioned in previous research is “trust and acceptance.” However, Oldemeyer, Jede and Teuteberg (2024) have identified that it is not a major factor and often not mentioned in previous research.

on the specific topic. But still, it has been found that SMEs are more inclined to adopt AI tools if they believe these technologies could enhance operational efficiency, improve decision-making processes, and provide a competitive advantage. Tangible benefits such as cost savings, increased productivity, and better customer insights play a crucial role in shaping positive attitudes toward AI adoption [23]. It was found that perceived usefulness directly correlates with expected performance improvement, which is a significant factor influencing technology acceptance.

However, the complexity of AI models, especially those that function as black boxes, further exacerbates the issue as these models can be difficult for non-experts to understand and trust [24]. Therefore, the ease of use of AI technologies, including user-friendly interfaces and comprehensive documentation, is critical. Simplifying the integration process and providing accessible support can help mitigate these challenges, making AI more easily available to smaller enterprises [25].

Organizational readiness also significantly impacts AI adoption. This readiness is influenced by existing infrastructure, financial resources, and the technical skills of the workforce. Organizations with a robust IT infrastructure and a culture of innovation are better positioned to integrate AI technologies effectively [25]. Additionally, the availability of financial resources to invest in AI and related training programs is a critical factor. SMEs must consider the initial costs of AI implementation and the ongoing costs of maintenance and training. Without adequate investment, even the most willing organizations may struggle to implement AI solutions effectively [26]. This highlights the importance of strategic planning and phased integration to ensure that AI technologies are adopted in a manner that is sustainable and scalable.

Perceived risk is another important consideration in the acceptance and adoption of AI technologies. Concerns about data security, privacy, and the potential for job displacement could hinder the acceptance of AI. To overcome these barriers, it is essential to address these concerns transparently and proactively. Implementing robust data protection measures and proactively ensuring that AI systems comply with relevant regulations, such as the European General Data Protection Regulation (GDPR), could help alleviate fears about data security and privacy [27]; [28]. Moreover, involving employees in the adoption process could mitigate fears about job displacement. Once employees understand that AI is meant to augment rather than replace their roles, they are more likely to support its implementation [29]. Creating an environment where employees feel secure and valued could significantly reduce resistance to AI technologies.

Skills development and employee involvement are crucial strategies for overcoming barriers to AI adoption. Investing in training programs to enhance the technical skills of the workforce is vital. This includes not only training on how to use AI technologies but also developing a broader understanding of AI’s potential and limitations. By improving the technical capacity of employees, SMEs could ensure that their workforce is equipped to leverage AI effectively [30]. Continuous education and skill development could help employees stay updated with the latest advancements in AI, fostering a culture of learning and innovation within the organization.

Employee involvement is equally important. Engaging employees in the AI adoption process helps to build trust and reduces resistance. Involving staff in decision-making processes, seeking their input on AI initiatives, and clearly communicating the benefits of AI could foster a sense of ownership and acceptance. When employees feel involved and valued, they are more likely to embrace new technologies [31]. This involvement could take various forms, such as forming cross-functional teams to oversee AI projects, organizing workshops to gather feedback, and creating channels for continuous communication about AI developments. Figure 3. illustrates the various elements influencing the adoption of AI in SMEs, including resource constraints, knowledge gaps, organizational readiness, cultural acceptance, and perceived risks.

Automation

Automated machine operation with only little or completely without human presence has been made possible already throughout the last century. Now Industry 4.0 contributes further to this trend, with IoT as a prerequisite to implement the next wave of automation in the manufacturing environment [32]. In that context, automation can be divided into two primary areas: physical and cognitive automation.

Physical automation refers to the technology and equipment that can substitute physical human work. Computer Numeric Controlled (CNC) machines, paint robots for automobiles, and fully automated warehouses are well-known examples. However, a need for close customer orientation with highly customized products may require what is called batch-size-of-one production. But a small volume usually makes it more challenging to defer the cost of automation technology. Now AI may help change the equation and allow automation even for highly customized products [33].

Cognitive automation on the other hand refers to the technology and methods for substituting human thinking and decision-making [34]. This is often applied to situations where the right decision is critical for the safety and operational capacity, in many applications related to the development, production and operation of a product. For example, it is applied in the aeronautical and mining industry to relieve human operators and eliminate human errors by automating certain tasks involving cognitive functions. Focus is primarily on automating complex but repetitive tasks within an anticipated domain where data can be used for instance in a neural network with defined inputs and outputs but a probabilistic relationship in between.

The integration of AI into manufacturing processes represents a transformative shift in the industry landscape. AI can be applied in manufacturing operations, particularly SMEs through cloud computing, robotics, and decision support systems (DSS).

Cloud computing, an internet-based service providing on-demand access to diverse computing resources with high reliability, is a pivotal technology for AI integration in manufacturing. This flexibility allows companies to acquire, scale, and reuse services as needed. Because of their limited resources, SMEs find cloud-based AI services particularly relevant, offering a more accessible alternative to in-house AI implementation. For instance, cloud platforms offer tools for real-time data analytics, predictive maintenance, and supply chain optimization. By leveraging these capabilities, SMEs can enhance their operational efficiency and competitiveness in the market [20]

Robotics integration in manufacturing processes significantly boosts productivity. Robots can be employed in various operations, including repetitive, dangerous, or bottleneck tasks, thereby improving both efficiency and safety. Notably, robotics enhance the quality of production, an essential factor for SMEs reliant on manual manufacturing and assembly lines [35]. Modern robots assist workers by managing repetitive and physically demanding tasks, allowing human workers to focus on more complex activities. These robots are designed to perform multiple tasks using different tools, demonstrating versatility and adaptability in manufacturing environments. Today's manufacturing robots are often designed to operate effectively in unpredictable environments. AI enables them to process sensor data, make decisions, and perform actions based on real-time analysis. This capability is particularly beneficial for object recognition and manipulation, which is crucial in diverse manufacturing processes [36].

The implementation of DSS has significantly reduced the complexity of decision-making in manufacturing. DSS tools, often powered by machine learning, are used for forecasting and decision-making to improve customer satisfaction and operational efficiency. When properly trained, these systems can automate many business processes, although the final decision typically still rests with a human [37] [38]. For example, in supply chain management, DSS can predict demand patterns, optimize inventory levels, and streamline logistics operations, thereby enhancing overall efficiency and reducing costs [38]. Figure 4. Illustrates the application of AI technologies in automating manufacturing processes, highlighting areas such as load-balancing CNC machines, predictive maintenance, and quality control.

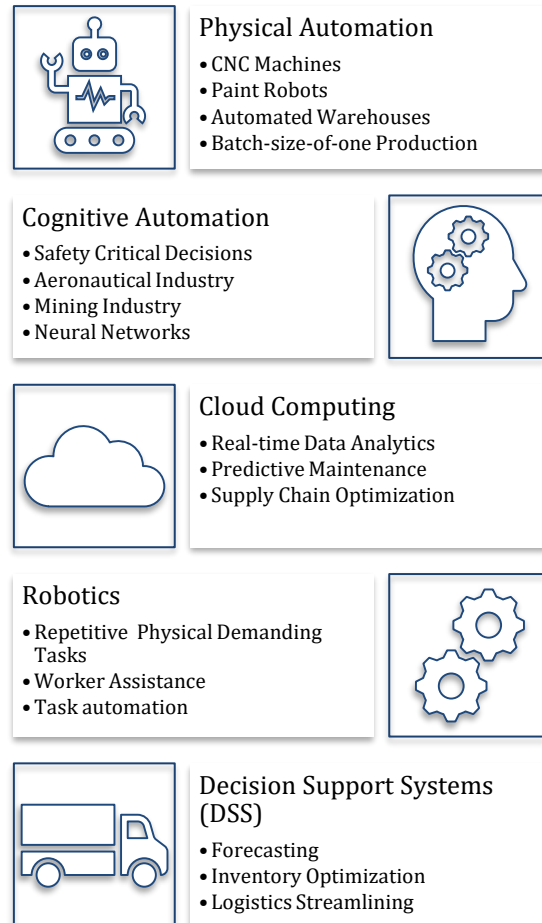


FIGURE 4. AI in Automation

Product Development

Product development (PD) can be defined, according to Karakoylu, Kural and Gulden (2020), as the conversion of market opportunities and technical potentials into objects valuable for commercial production. Market insights are a key factor, as they stand at the beginning of the PD process and therefore directly influence its effectiveness and efficiency.

The approach for PD has changed over the decades. Many manufacturers and brands have historically opted to keep the PD and production in house, which is not the case today. Factors like globalization have resulted in decentralization, where elements of PD and production processes have been spread across many locations [39]. Also, as technology continues to advance, together with a volatile market demand, the products have become more complex which has resulted in PD evolving and adapting to these circumstances [40].

AI has emerged as a transformative force in modern PD, offering unprecedented opportunities for creativity and efficiency, facilitating rapid innovation, and improving results [41]. AI capabilities enhance several aspects of design for sustainability, commercialization strategies, and overall organizational performance [42]. AI systems can assist managers with decision-making and implementing effective strategies throughout all stages of the PD process, particularly during its initial stages [41].

The six most adopted AI technologies in PD are: robotic AI, functional AI, interactive AI, text AI, visual AI, and analytic AI [42]. These types of AI are typically categorized as weak AI, which refers to AI systems that are designed and trained to perform specific tasks or to function in a particular way, rather than possessing consciousness or generative intelligence. By comparison, strong AI is generally characterized by having the capability of thinking and learning like humans [43]. These adopted AI technologies have helped companies conduct engineering assessments, product feature development, prototype evaluation, cost reduction analysis, product design recommendations, and quality improvement initiatives [42].

AI technology can also be utilized to analyse user intentions and trends through big data, providing insights into future PD directions. Inefficiencies in the current design process, such as industrial designers only being able to shape a limited portion of the design while engineers create CAD models and provide feedback, which leads to an iterative but lengthy process with many modifications, can be improved greatly by the use of AI-driven tools that are intuitive to use without the need for a large amount of training [44]. For instance, with advancements in 3D modelling software, AI can generate a wide spectrum of CAD models and assess them based on engineering performance metrics [44]. This enables engineers and industrial designers to identify promising conceptual design candidates and refine the details quickly.

CASE STUDIES

Based on workshops and one-to-one meetings with the industry partners, two case studies were conducted with one focusing on automation and the other taking a broader perspective along the value chain. In this section the main findings from those two studies are outlined.

Case Study 1 – AI in Automation

The first case study tackles automation, asking the question how Company 1, a micro company located in southern Sweden, can automate their small lot manufacturing with the help of AI. The company employs less than 10 employees and has a revenue of less than €1 million. It manufactures diverse kinds of machined metal components for their customers. While they provide high-end machining for several smaller customers, they serve as a supplier to larger original equipment manufacturers (OEMs), and therefore manufacture and ship repair parts directly to end customers. About 40-45% of the company's revenue is gained from just one of these larger OEMs. A substantial portion of their manufacturing is conducted in exceedingly small batches (single unit to a half dozen), on a built-to-order basis. They are looking to implement AI tools to keep up with customer demands and follow EU directives in an evolving and competitive market.

The stakeholders at Company 1 see an increasing need to keep up with environmental policy and regulations. To do so, they would like to become more digitalized and sustainable, realizing that AI is a promising way to help SMEs achieve this goal. One specific application is seen in load-balancing for their CNC machines, which can significantly enhance efficiency and reduce waste in operations. The leadership team is also challenged to get employees to accept AI techniques as they find that new methods need to earn the workforce's trust. However, they assume building trust toward AI may go faster than for instance trusting a new, untrained colleague as technology does not make mistakes like a human would, due to the lack of expertise. They do acknowledge however that a cultural change is needed, which they often find difficult to carry through the organization.

The idea to investigate AI implementation came from one of the workers that present a strong driving force at Company 1, which is one of the reasons why the management decided to investigate AI implementation further. But as they also realized a lack of knowledge regarding AI, a consultant was brought in to help with the implementation. With that support, it was first determined which and how many steps in production could be solved with the help of AI. In that context it is important to note that the fabrication of Company 1's metal parts usually involve many steps that take time and do not require much competence. Therefore, managers and technical staff see AI as a potential aid and not as a threat to replace the workforce. Since Company 1 usually works with diverse types of products in quantities of three or less, they predict implementing AI for their varied product portfolio to be difficult. SMEs often do not work with static production lines to the same extent as larger companies do, since they often have a higher relative diversity of products.

The management at Company 1 also points to their organizational and resource limitations when it comes to implementing novel processes and technologies. Larger companies, by comparison, have dedicated resources solely for IT initiatives, which are often also tasked to enable implementation of AI solutions.

Company 1 wishes to have their measuring tools implemented right into their machines. This would improve today's manual process of reassuring that the machines are cutting correctly, and thus can manufacture further parts with the same settings. Currently they only collect data when the customer asks for a measurement protocol, for which an automated process would be an immense help, both for process efficiency and product quality. Such data could then also be used in further AI-based solutions to improve the entire production process as well as future product design.

Company 1 also lacks sufficient master data of all their products. While product drawings exist, the organization does not have a practical system where product information is collected in one place and easily accessible. This means

for instance when they need to retrieve all products which contain a certain chemical or any other attribute, these products must be found manually, rather than having a straightforward way to search for it in a database. In this context, they point out again that the biggest hurdles might not be to change their business system but rather to change company culture as they are asking themselves how to create reassurance during the change. One of the aspects they find particularly difficult is to know where to begin with such a transformation, so that they would appreciate a list or playbook that is easy to understand and explains the key factors as well as how to start the implementation.

Case Study 2 – AI along the Value Chain

The second case study explores applications for AI more longitudinally along the value chain from engineering to customer service, based on their product development. Company 2 is a medium-sized company located in southern Sweden, employing around one hundred employees, and generating a revenue of about € 25 m. Its business is to manufacture, sell and install automated industrial laundry equipment. The customers are primarily located outside of Sweden with the company being a subsidiary of a larger European corporation. Equipment manufacturing is based on an engineer-to-order / manufacture-to-order (ETO/MTO) hybrid strategy and is mostly low-volume. The work process from the order placement to the installed, ready to use product is mostly a project-oriented work packet. The product development team sees its own proprietary ETO/MTO software as a key strength.

The company has realized the importance of AI solutions for product development, manufacturing, and logistics, considering it imperative to secure its position in the market and an essential part for customer-oriented development and a highly efficient production process. For their global client base, Company 2 would like to improve the process of spare part replacement as they realize the high efforts of related extra work and resources.

The implementation of AI in SMEs like Company 2 requires a comprehensive strategy that aligns AI integration with the company's overall business objectives and core values [45]. The current process for identifying and replacing spare parts components is done manually and prone to errors, resulting in resources and time wasted. AI integration, by comparison, promises great potential to improve operational efficiency. AI algorithms may predict machine failures and maintenance needs, optimize production processes, cut waste, and ultimately improve product quality [46]. Company 2 also hopes that it could help to automate administrative activities like scheduling, payroll, and compliance reporting, which would free up resources for work that contributes to the company's growth more directly. Since SMEs' resources are typically more limited than those of larger companies, these operational improvements might be even more important for them. In that sense, AI implementation could possibly help to employ resources more effectively, saving operating costs and increasing profitability [47].

Summary of Case Studies

The case studies shed light on the challenges and potentials of AI adoption in SMEs. The insights from Company 1 and Company 2 highlight the following key points: Both companies lack expertise in AI, hindering adoption and implementation. A shift in company culture is necessary to embrace AI as a tool for improvement. Proper data collection and organization are essential for successful AI implementation. SMEs face limitations in resources, making investment in AI challenging yet potentially rewarding.

These findings underscore the need for SMEs to invest in expertise, foster a supportive culture, prioritize data management, and manage resource constraints effectively to succeed in AI implementation.

FINDINGS

This section summarizes the key findings from the case studies and literature review, highlighting the main challenges and strategies for successful AI implementation in SMEs. The findings are categorized into challenges and strategies, providing a comprehensive overview of the factors that influence AI adoption in SMEs.

Based on the case studies and the literature study we find that there is significant potential for AI to level the playing field for SMEs, but for that to happen several factors and prerequisites need to be accounted for, which are different from larger corporations.

Both organization types recognize the need for digitalization to remain competitive in the market, as well as attracting the right competencies, especially regarding the first steps of implementing AI. Our work has also shown that AI implementation requires the right expertise and support from management to succeed, which often also necessitates changes in a company's culture. SMEs also need to start collecting relevant data as a prerequisite for implementation.

The case studies shed light on the challenges and potentials of AI adoption in SMEs. Those insights are summarized in Table 2 and Table 3.

TABLE 2. Identified challenges of AI adoption in SMEs

Challenge	Description
Skills Gap	SMEs like Company 1 and Company 2 lack expertise in AI, hindering adoption and implementation.
Cultural Shift	A shift in company culture is necessary to embrace AI as a tool for improvement. Company 1 faced resistance from employees who were concerned about job security and trust in modern technologies.
Data Matters	Proper data collection and organization are essential for successful AI implementation. Company 1 struggled with a lack of centralized systems for product information, while Company 2's project demonstrated the importance of data management in automating workflows.
Resource Challenges	SMEs face limitations in resources, making investment in AI challenging yet potentially rewarding. Company 1 had organizational and financial constraints, while Company 2 benefited from a rapid prototyping approach to explore AI's potential without significant initial investment

These challenges highlighted in Table 2 underscore the need for SMEs to invest in expertise, foster a supportive culture, prioritize data management, and manage resource constraints effectively to succeed in AI implementation. Table 3 provides actionable insights to address these challenges through strategic goal setting, comprehensive training, cultural integration, and continuous evaluation.

TABLE 3. Strategies and recommendations for successful AI implementation in SMEs

Do	Don't
Set clear goals (Define specific objectives for AI implementation to guide the process and ensure alignment with business needs.)	Underestimate the complexity and resources needed for AI implementation.
Invest in training (Develop comprehensive training programs to enhance the technical skills of the workforce and bridge the expertise gap.)	Dismiss the importance of getting the team on board with the changes.
Foster culture change (Promote a culture that values innovation and technological advancements. Engage employees in the AI adoption process and address their concerns.)	Rely solely on tech without addressing underlying cultural barriers.
Start data collection and explore existing technologies (Utilize available AI tools and platforms to minimize initial investment costs. Consider forming partnerships to share resources and expertise)	Neglect to monitor and evaluate in-house AI systems regularly

The findings from the case studies and literature review highlight the significant potential of AI to transform SMEs by enhancing efficiency, productivity, and competitiveness. However, several challenges must be addressed to realize these benefits, including skills gaps, cultural shifts, data management, and resource constraints. By setting clear goals, investing in training, fostering a supportive culture, and prioritizing data management, SMEs can successfully navigate the complexities of AI adoption and leverage its benefits effectively.

DISCUSSION

The findings from the case studies and literature review provide valuable insights into the challenges and opportunities associated with AI adoption in SMEs. The hybrid approach of combining qualitative and quantitative methods yielded significant improvements in understanding the factors that influence AI implementation. The key challenges identified include skills gaps, cultural shifts, data management, and resource constraints. Addressing these challenges is crucial for SMEs to successfully adopt and leverage AI technologies.

Practical Implications

The practical implications of the findings are significant for SMEs considering AI implementation. Investing in skills development is essential for SMEs to bridge the technical expertise gap. Comprehensive training programs should be designed to enhance employees' understanding of AI and its potential benefits. SMEs can collaborate with educational institutions, industry associations, and AI experts to develop tailored training programs that address their specific needs.

Fostering a supportive culture that embraces innovation and technological advancements is vital for successful AI implementation. SMEs should promote a culture of continuous learning and adaptation. Engaging employees in the AI adoption process, addressing their concerns, and involving them in decision-making can help build trust and reduce resistance to change. Leadership plays a crucial role in driving cultural change by demonstrating a commitment to AI and its potential benefits.

Proper data collection and organization are fundamental for AI implementation. SMEs should invest in the necessary infrastructure and processes to collect, store, and manage relevant data. Implementing data governance practices, such as data quality management and data security, can ensure the reliability and integrity of the data used for AI applications. SMEs can also explore cloud-based AI services to enhance data management capabilities without significant upfront investments.

Effective resource allocation is critical for AI implementation in SMEs. Given the limited financial and human resources, SMEs should prioritize AI projects that align with their strategic goals and offer the highest potential return on investment. Exploring existing AI tools and platforms can help minimize initial investment costs. SMEs can also consider forming partnerships with technology providers, industry associations, and other SMEs to share resources and expertise.

Limitations

This study acknowledges several limitations that may impact the generalizability and applicability of its findings. Firstly, the case studies were conducted with a limited number of SMEs, which may not represent the broader spectrum of small and medium-sized enterprises. Future research should include a larger and more diverse sample to validate the findings. Additionally, the study focused on SMEs in southern Sweden, which may have unique characteristics and challenges. The findings may not be directly applicable to SMEs in other regions or countries with different economic, cultural, and regulatory environments. The case studies were specific to certain industries, such as manufacturing and industrial equipment, and the challenges and opportunities identified may differ for SMEs in other sectors. Further research is needed to explore AI adoption across various industries.

Future Research

The research is ongoing, and both the companies have decided to continue their efforts.

As a first step to answer those questions and to map out an AI implementation roadmap for Company 1, the leadership team will take part in the Innovationssprint at the Techarena Borås, which is a unique method for innovation and research in enterprise technology. The sprint combines innovation and research in cross-functional teams consisting of customers, specialists from several companies, researchers, and students. During the six weeks of the sprint, the team of university researchers and company practitioners will explore the identified problem statements together, create one or more solution prototypes and communicate the result. This way, they will get quick feedback and develop their skills by building and testing digital solutions. These will then be used to create new and improved manufacturing processes for Company 1.

To identify opportunities in their customer services and to get more familiar with new technologies, Company 2 launched a first project with the University of Borås to explore how their spare parts ordering process can be improved with the help of AI. In this, a 10-week project was launched during which AI techniques were used to build the entire workflow from training neural networks, uploading customer photos from broken parts, all the way to fetching part numbers automatically from a database and initiating the part order. Such rapid prototyping not only allowed to explore the entire process as a reconfigurable test environment and to optimize technical aspects, but it also showed the decision-makers and technical staff at Company 2 what AI can do for their long-established workflows and what effort it might take to implement AI-based solutions. To that end, Company 2 was put in a much better position to judge if and where it is advantageous to invest in AI.

This article analyses the implication of the AI revolution for SMEs. There is a lack of research into the specifics of small and medium-sized companies, since most studies focus on first movers or larger companies.

As we look to the future, several paths of interest for researchers can help SMEs make the most of artificial intelligence. Based on our case studies, there is a need to develop AI solutions specifically tailored to SMEs' unique requirements. This involves designing systems that are not only effective but also practical and easy to use for smaller organizations. Understanding and addressing the cultural barriers to AI adoption within SMEs is crucial.

Future research should focus on identifying effective strategies for change management to foster acceptance. Businesses need to find ways to make AI feel like a natural part of their work, rather than a daunting change. Additionally, it is essential to determine if AI is genuinely making a difference for them. This necessitates research into the real-world impact of AI adoption, asking whether these businesses see improvements in their bottom line. Understanding this can help SMEs make informed decisions about where to invest time and money.

Sharing ideas and resources might unlock new possibilities for AI in smaller organizations, where collaboration could be a notable change. By teaming up with other businesses or experts, SMEs could overcome the hurdles associated with limited resources and knowledge.

Ensuring responsible AI use is key to building trust and ensuring its long-term success in smaller businesses. As AI becomes more integrated into SMEs, we also need to consider the ethical implications. Topics like data privacy and fairness need to be front and centre.

ACKNOWLEDGMENTS

We would like to express our deepest gratitude to everyone who has supported us in completing this research. Primarily, we extend our heartfelt appreciation to the students whose theses have significantly contributed to this study. Their dedicated work on various aspects of AI adoption in SMEs has provided invaluable insights and data for our analysis. We specifically acknowledge the theses by Hoang & Kochar (2024), Lindqvist & Andersson Bertilsson (2024), Malmfors & Beronius (2024), and Tahiri & Kareem (2024). These theses have been instrumental in shaping our understanding of the challenges and opportunities associated with AI adoption in SMEs. We are also grateful to our industry partners for their cooperation and willingness to share their experiences and insights. Their participation in workshops and interviews has been crucial for the success of this research. Additionally, we extend our gratitude to Åforsk for funding the AI and Automation in SMEs project, which has been a cornerstone of this research. Their financial support has enabled us to explore the potential of AI in SMEs.

REFERENCES

1. M. Ghobakhloo and N. T. Ching, "Adoption of digital technologies of smart manufacturing in SMEs," *Journal of Industrial Information Integration*, vol. 16, pp. 100107, 2019.
2. E. Comission, "'SME definition.'" https://single-market-economy.ec.europa.eu/smes/sme-definition_en, 2024.
3. A. Issa, D. Lucke, and T. Bauernhansl, "Mobilizing SMEs Towards Industrie 4.0-enabled Smart Products," *Procedia CIRP*, vol. 63, pp. 670-674, 2017.
4. H. Degryse, K. Matthews, and T. Zhao, "SMEs and access to bank credit: Evidence on the regional propagation of the financial crisis in the UK," *Journal of Financial Stability*, vol. 38, pp. 53-70, 2018.
5. B. Tahiri and O. Kareem, "Adopting AI in product development: A study on small-to medium sized enterprises," vol. Independent thesis Basic level (degree of Bachelor), 2024.
6. M. Lindqvist and W. Andersson Bertilsson, "AI-enabled automation for SMEs : prerequisites and opportunities for implementation and operation," vol. Independent thesis Basic level (degree of Bachelor), 2024.
7. H. Malmfors and H. Beronius, "Explainable AI and transparency in AI systems for SMEs," vol. Independent thesis Basic level (university diploma), 2024.
8. D. Hoang and B. Kochar, "Optimizing Operations: AI Implementation and Image Recognition in SMEs," vol. Independent thesis Basic level (degree of Bachelor), 2024.
9. V. A. Thurmond, "The point of triangulation," *Journal of nursing scholarship*, vol. 33, pp. 253-258, 2001.
10. C. Karatas-Cetin and G. Denktas-Sakar, "Logistics research beyond 2000: Theory, method and relevance," *The Asian Journal of Shipping and Logistics*, vol. 29, pp. 125-144, 2013.
11. A. Siddaway, A. Wood, and L. Hedges, "How to Do a Systematic Review: A Best Practice Guide for Conducting and Reporting Narrative Reviews, Meta-Analyses, and Meta-Syntheses," *Annual Review of Psychology*, vol. 70, 2019.

12. K. b. Noor, "Case Study: A Strategic Research Methodology," *American Journal of Applied Sciences*, vol. 5, 2008.
13. M. DeJonckheere and L. Vaughn, "Semistructured interviewing in primary care research: a balance of relationship and rigour," *Family medicine and community health*, vol. 7, pp. e000057, 2019.
14. S. Kinkel, M. Baumgartner, and E. Cherubini, "Prerequisites for the adoption of AI technologies in manufacturing – Evidence from a worldwide sample of manufacturing companies," *Technovation*, vol. 110, pp. 102375, 2022.
15. G. Narkhede, S. Mahajan, R. Narkhede, and T. Chaudhari, "Significance of Industry 4.0 technologies in major work functions of manufacturing for sustainable development of small and medium-sized enterprises," *Business Strategy & Development*, vol. 7, pp. e325, 2024.
16. M. Haenlein and A. Kaplan, "A Brief History of Artificial Intelligence: On the Past, Present, and Future of Artificial Intelligence," *California Management Review*, vol. 61, pp. 5-14, 2019.
17. E. Rauch, P. Dallasega, and M. Unterhofer, "Requirements and Barriers for Introducing Smart Manufacturing in Small and Medium-Sized Enterprises," *IEEE Engineering Management Review*, vol. PP, pp. 1-1, 2019.
18. L. Oldemeyer, A. Jede, and F. Teuteberg, "Investigation of artificial intelligence in SMEs: a systematic review of the state of the art and the main implementation challenges," *Management Review Quarterly*, 2024.
19. T. von Hahn and C. K. Mechefske, "Machine Learning in CNC Machining: Best Practices," *Machines*, vol. 10, pp. 1233, 2022.
20. C. Kaymakci, S. Wenninger, and A. Sauer, "A Holistic Framework for AI Systems in Industrial Applications," *Lecture Notes in Information Systems and Organisation*, 2021.
21. Y. P. Tsang and C. K. M. Lee, "Artificial intelligence in industrial design: A semi-automated literature survey," *Engineering Applications of Artificial Intelligence*, vol. 112, pp. 104884, 2022.
22. I. Kovalenko, K. Barton, J. Moyne, and D. M. Tilbury, "Opportunities and Challenges to Integrate Artificial Intelligence Into Manufacturing Systems: Thoughts From a Panel Discussion [Opinion]," *IEEE Robotics & Automation Magazine*, vol. 30, pp. 109-112, 2023.
23. N. A. Norzelan, I. S. Mohamed, and M. Mohamad, "Technology acceptance of artificial intelligence (AI) among heads of finance and accounting units in the shared service industry," *Technological Forecasting and Social Change*, vol. 198, pp. 123022, 2024.
24. A. Adadi and M. Berrada, "Peeking Inside the Black-Box: A Survey on Explainable Artificial Intelligence (XAI)," *IEEE Access*, vol. 6, pp. 52138-52160, 2018.
25. P. Jamshidi, S. Nowaczyk, H. Fanaee-T, and M. Rahat, "A Systematic Approach for Tracking the Evolution of XAI as a Field of Research," 2023, pp. 461-476.
26. S. Kar, A. Kar, and M. P. Gupta, "Modeling Drivers and Barriers of Artificial Intelligence Adoption: Insights from a Strategic Management Perspective," *Intelligent Systems in Accounting, Finance and Management*, vol. 28, 2022.
27. A. Deshpande and H. Sharp, *Responsible AI Systems: Who are the Stakeholders?*, 2022.
28. A. J. Wulf and O. Seizov, "'Please understand we cannot provide further information': evaluating content and transparency of GDPR-mandated AI disclosures," *AI & SOCIETY*, vol. 39, pp. 235-256, 2024.
29. M. Gerlich, "Perceptions and Acceptance of Artificial Intelligence: A Multi-Dimensional Study," *Social Sciences*, vol. 12, pp. 502, 2023.
30. A. Hasija and T. Esper, "In artificial intelligence (AI) we trust: A qualitative investigation of AI technology acceptance," *Journal of Business Logistics*, vol. 43, 2022.
31. D. Vorobeva, D. Costa Pinto, N. António, and A. S. Mattila, "The augmentation effect of artificial intelligence: can AI framing shape customer acceptance of AI-based services?," *Current Issues in Tourism*, vol. 27, pp. 1551-1571, 2024.
32. Z. Papulová, A. Gažová, and E. Šufliarský, "Implementation of Automation Technologies of Industry 4.0 in Automotive Manufacturing Companies," *Procedia Computer Science*, vol. 200, pp. 1488-1497, 2022.
33. Z. Jin, R. M. Marian, and J. S. Chahl, "Achieving batch-size-of-one production model in robot flexible assembly cells," *The International Journal of Advanced Manufacturing Technology*, vol. 126, pp. 2097-2116, 2023.
34. C. Engel, P. Ebel, and J. M. Leimeister, "Cognitive Automation," *Electronic Markets*, vol. 32, 2022.
35. S. Abdunour, C. Baril, G. Abdunour, and S. Gamache, "Implementation of Industry 4.0 Principles and Tools: Simulation and Case Study in a Manufacturing SME," *Sustainability*, vol. 14, pp. 6336, 2022.
36. A. Dzedzickis, J. Subačiūtė-Žemaitienė, E. Šutinys, U. Samukaitė-Bubnienė, and V. Bučinskas, "Advanced Applications of Industrial Robotics: New Trends and Possibilities," in *Applied Sciences*, vol. 12, 2022.
37. A. Prerna, G. Buyu, H. Siyu, R. Prabhat, D. Sampath, O. Yazan, M. Vinod, I. Vatche, and C. Sebastian, "A Process-Aware Decision Support System for Business Processes," in *Proceedings of the 28th ACM SIGKDD*

- Conference on Knowledge Discovery and Data Mining*. Washington DC, USA: Association for Computing Machinery, 2022.
38. X. Li, "Supply Chain Efficiency and Effectiveness Management Using Decision Support Systems," *International Journal of Information Systems and Supply Chain Management*, vol. 15, pp. 1-16, 2022.
 39. M. Senanayake, "Product development in the apparel industry," in *Garment manufacturing technology*: Elsevier, 2015, pp. 21-57.
 40. M. L. Nunes, A. C. Pereira, and A. C. Alves, "Smart products development approaches for Industry 4.0," *Procedia manufacturing*, vol. 13, pp. 1215-1222, 2017.
 41. P. Karakoylu, A. Kural, and S. Gulden, "The Effect of Artificial Intelligence (AI) on New Product Development (NPD): A Future Scenario," *IOP Conference Series: Materials Science and Engineering*, vol. 960, pp. 022026, 2020.
 42. H. Zhang, X. Zhang, and M. Song, "Deploying AI for New Product Development Success: By embracing and incorporating AI in all stages of NPD, companies can increase their success rate of NPD projects," *Research-Technology Management*, vol. 64, pp. 50-57, 2021.
 43. M. V. Butz, "Towards Strong AI," *KI - Künstliche Intelligenz*, vol. 35, pp. 91-101, 2021.
 44. S. Yoo, S. Lee, S. Kim, K. H. Hwang, J. H. Park, and N. Kang, "Integrating deep learning into CAD/CAE system: generative design and evaluation of 3D conceptual wheel," *Structural and Multidisciplinary Optimization*, vol. 64, pp. 2725 - 2747, 2020.
 45. F. Kitsios and M. Kamariotou, "Artificial intelligence and business strategy towards digital transformation: A research agenda," *Sustainability*, vol. 13, pp. 2025, 2021.
 46. R. Chaudhuri, S. Chatterjee, D. Vrontis, and S. Chaudhuri, "Innovation in SMEs, AI dynamism, and sustainability: The current situation and way forward," *Sustainability*, vol. 14, pp. 12760, 2022.
 47. M. J. Sousa and Á. Rocha, "Skills for disruptive digital business," *Journal of Business Research*, vol. 94, pp. 257-263, 2019.