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Antecedents and consequences of social robots adoption for SMEs - Reimaging emerging technologies in the context of the new normal

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ABSTRACT

The study offers a holistic framework for examining the use of social robots in SMEs and subsequently investigates both its drivers as well as implications. The research builds on the Technology-Organization-Environment (TOE) framework using a mixed-methodological approach of surveys, interviews and focus groups to investigate which factors drive small entrepreneurship in adopting social robots with their subsequent impact on business performance. The findings highlight the role of factors that mediate adoption decisions alongside technological compatibility and organizational readiness, which result in operational efficiencies, financial performance improvements and sustainable business practices. We interpret these findings to provide strategic advice for SME managers on the adoption of social robots, that illustrates planning and considering internal and external dynamics are critical with a view to successful integration. This study enriches the body of scholarly research by offering an insight into technology acceptation in SMEs with a specific focus on social robots, and therefore this research has theoretical & managerial contributions.

1. Introduction

COVID-19 has brought unprecedented challenge to SME hence seeking a quick response in order not to run out of business (Chatterjee et al., 2022). The pandemic, however, has introduced a new, changed environment where numerous organizational, technological and financial symptoms are settling in for SMEs (Borghi and Mariani, 2022). The move to remote work and the need to drop overheads as low as possible have certainly highlighted one of those needs — for forward-leaning IT solutions to keep things ticking over smoothly (Rakshit et al., 2022). Given this scenario, the power to act quickly and put short-term preventive measures in place is now a critical factor for SMEs grappling with the contingencies within a post-shutdown era (Ghiglino et al., 2023).

Social robots are one of the most prevalent emerging technologies that usually do not only help forming a business but builds SMEs digitalization into entirely new levels (Letheren et al., 2021). Automation of repetitive tasks in the age of these advanced machines provides a way to minimize costs, time-saving and better resources utilization during crises-guaranteeing company stability (Tojib et al., 2022). Prototypes of social robots are becoming more interactive and robust, making them suitable for frequently used scenarios in industrial environments or everyday human-volume social interactions (Song et al., 2022).

There are several interesting reasons that motivate the focus on SMEs in this work. First, the SME sector is one of the pillars in most economies whereby it contributes substantially to job creation, innovation stimulation and economic growth (Jung and Choi, 2023). However, SMEs often far more challenges as such limited resources; access to capital constrained and low operating scale (Zafrani et al., 2023). Technological advances, in particular the use of innovative technologies such as social robots are one promising solution that attempts to address these challenges (Leeuwestein et al., 2021).

Second, SME technological upgrading refers to the adoption of new technology and its successful transfer into existing business processes (Kim et al., 2022). As a result, the benefits are seen in operational efficiency, increased productivity and potentially even transformational shifts to how SMEs transact with their business (David et al., 2022). By weaving in social robots, SMEs, typically do not have the resources or volume of data to make these massive investments themselves — get a piece of this new way to reduce costs or optimize operations (Hurmuz et al., 2023).

On the other hand, SMEs are often more agile and able to adapt faster

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than their larger counterparts – which makes them interesting test beds whether it comes to adopting new technologies like social robots (Ghiglino et al., 2023). Their size likewise usually enables them to make decisions more rapidly and hence experiment with new technologies faster (Saari et al., 2022). Therefore, by understanding the dynamics related to social robot adoption within SMEs, future work like this can shed light on some benefits and challenges these firms may face from it that are also applicable for technology adoption in different organizational contexts (Islam et al., 2022). This research, thus, explores the possibilities and challenges for SMEs to implement social robots to give an intermediate orientation that could benefit both academic study and business practice within social robot integration.

Several works have been carried out on deploying social robots in different settings including those post-COVID-19, there is still such a gap where comprehensive studies focus SMEs (Astorga et al., 2022). The research study that we present here focuses on investigating the transformative potential of social robots in SME settings by detailing both opportunities and challenges related to their deployment. This study seeks to fill the identified research gap by addressing several related but as yet unexplored research questions from which different models can be developed, including: 1) What are the antecedents of social robot adoption by SMEs? 2) What are the consequences of SMEs' social robot adoption?

This study enables us to provide in-depth insights into the research questions posed for our study using multifaceted research approach with multiple stages which can help to build a better understanding related to social robot adoption within SMEs (Deveci et al., 2023). First, we conducted an exhaustive literature review to build a theoretical base by identifying social robots' adoption research gaps in already existing studies on technology adoption and SMEs (Neerincx et al., 2023). This process was incredibly important to enter the next steps in this research. Next, an extensive empirical study in different SMEs was conducted to understand social robot recognition and utilization trends (Ng et al., 2022). During this phase, a series of qualitative methods including in-depth interviews and focus group discussions with SME owners, managers, and employees were employed to understand their experiences, expectations as well reservations on adopting social robots (Angeles, 2021).

The study also used quantitative methods as well and conducted more general surveys of the SME population to quantify some emergent findings from interviews and focus group discussions (Kuan and Chau, 2001). This hybrid approach offered a comprehensive perspective here incorporating both voices of individual stakeholders as well as aggregated patterns across the wide array that represents SME sector (Kshetri, 2023). The gathered data were analyzed afterwards from the TOE model context which helped in a complete examination of technological, organizational and environmental antecedents that impact SMEs social robot adoption (Dang and Bertrandias, 2023).

Based on the findings from empirical research, we were able to develop and propose a conceptual framework as well. This framework identifies the determinants for SMEs to adopt social robots and reveals their probable influence on SME performance. The empirical validation of the proposed hypotheses helps to shed light on researchers as well as practitioners about how likely is for SMEs that they will see and adopt a social robot in their operations.

This study also offers a distinctive perspective in terms of using social robots as the tool for crisis management, especially under circumstances requiring little human touch and higher safety. The study dissects the following specific functions of social robots: as an agent in institutional logistics, a custodian of minimal risk environments, and a coach promoting psychological wellbeing and clinical wellness.

This paper examines the adoption of social robots in SMEs, in a systematic way. Section 1 contains an introduction of the study. Section 2 reviews the literature, it includes adoption pattern of technology innovation, applying the TOE framework, and pointing to gaps in current studies. In Section 3 we present the development of a social robot driven SMEs model. Section 4 explains the research model and hypothesis. The various consequences of SMEs social robot adoption are discussed in Section 5. The research methodology is discussed in Section 6, and Section 7 discussed the result. In Section 8 discussions, implications, study limitations and future research are illustrated. The study concludes in Section 9, which summarizes the key findings and provides insight into what can be learned about social robots within SME environments.

2. Literature review

2.1. Historical adoption patterns of technological innovations in SMEs

The historical adoption patterns of technological innovations in small businesses make an interesting narrative, demonstrating the intricate relationship between SMEs and technology novelty (Bolodeoku et al., 2022). In the past, SMEs have displayed a mix of both conservative and progressive strategies towards technology (Koban and Banks, 2024). This ambivalence is caused mainly by the limitation of resources and because SME's operations are very sensitive to risk. Academic Studies established that SMEs Technology adoption is dependent on the extent of benefits over costs & risks (Esfandbod et al., 2023). Historically speaking, SMEs have not adopted technology quickly because the challenges associated with it are relatively slow financial resources at their disposal, limited technical expertise available and a possibility of disrupting existing workflows (Chang et al., 2023). But when they see clear benefits, SMEs can be incredibly effective in adopting and exploiting new technologies —often more so than larger companies who are slower to move (Xiao and Goulias, 2022).

There are many factors that have greatly influenced the creation of adoption journeys, internal and external (Bolodeoku et al., 2022). Decisions made from external influences Competitive pressures, market demands and technological advancements (Xiao and Goulias, 2022). The literature gave examples of SMEs that became early adopters in adopting new technology to produce a competitive advantage, suffice operational efficiency or respond rapidly to changing customer requirements (Kshetri, 2023). Some of this often involves opportunistic plays for niche markets differentiation from larger competitors. In addition, the small and lean structure of SMEs often makes decisions much faster than larger competitors in a rapidly evolving technology landscape (Xiong et al., 2021).

However, one key tendency that we must address: over time the adoption pattern of SMEs has change significant and especially when more accessible technologies have entered in force (Skare et al., 2023). The digital revolution — internet, mobile and cloud-based processing technology has come to be known as a new wave that continues wipe onto the coast of possibilities for SMEs (Battistoni et al., 2023). The move reflects SMEs' growing acceptance of technology as a strategic driver for innovation, efficiency and competitiveness (Lestingi et al., 2023). For instance, moving forward including with the emergence of social robots predict that SMEs remain deliberate as well flexible in their technology adoption efforts (Roy et al., 2024).

2.2. Applying the TOE framework in SMEs' technological adoption

The TOE framework is beneficial for the analysis of technological adoption in SMEs due to its richness and emphasis on complexity (Ullah et al., 2021). This framework breaks the adoption process into three separate categories which are interrelated: technology, organization, and environment (Tuomi et al., 2021). The technological characteristics of relative advantage, compatibility, complexity trialability and observability are the key determinant from TOE framework to study factors influencing SMEs adoption decisions (Pollmann et al., 2023). These all sound generic but for SME's this means how easy it is to integrate with their current systems, the time they will need to train staff on new technology and see a return on investment. The TOE framework

dimension helps in deconstructing the essential properties of technologies, for example social robots and it's fit with SMEs operational need (Nguyen et al., 2022).

While focusing on an organizational level, the TOE framework highlights internal characteristics of firms including size, scope, managerial structure and resources (Katebi et al., 2022). These factors help in understanding whether SMEs can adapt to new technologies or not (Hu et al., 2023). SMEs often have idiosyncratic organizational problems, including financial constraints and hiring difficulties, that can affect whether they adopt or resist technology adoption in various ways (Nguyen et al., 2022). The framework indicates that organizational innovativeness, commitment of leadership to change and IT culture in promoting technological adoption is decisive.

Lastly, the TOE framework specifies environmental context to be industry factors and competitive dynamics as well as other higher-level technology dependent macroeconomic aspects relating to both quasi-utility issues and regulatory landscape where SME are embedded (Jo and Bang, 2023). This dimension recognizes that the adoption of technologies by SMEs is not in isolation, but shaped and influenced through market trends, consumer demand and regulatory policies. For social robots, however, industry regulations and polices on product offerings set by the industries in which they service play big roles customer perceptions about interaction with technology drive adoption. The TOE framework hence represents a holistic perspective for the study of technology adoption in SMEs; offering some insights that could be useful to link how many factors combine and evolve together with such decision-making processes.

2.3. Research gap

Given the intensive study on technology adoption in SMEs, a notable gap-deficiency is found regarding adopting social robots. While digital and information technologies have been the primary focus in most studies, far less is investigated about advanced robotics use in SMEs. This gap is particularly important because that automate not just tasks but also socio-cognitive interaction creating new challenges and opportunities for SMEs. Additionally, few empirical studies have explored what different characteristics of a broader set of social robots correspond to the diverse and dynamic needs between industries in SMEs. The second unexplored topic is what the long-term impact of social robot adoption could be on SMEs and may involve changes in how their workforce behaves, overall customer relationships or business model. This lack of empirical studies on the use or potential for social robots in SMEs prevents further exploitation targeting strategies and policies to successfully integrate them. Therefore, filling these gaps is essential for us to learn more from our knowledge about how SMEs can leverage social robots to enhance business operations efficiency but also innovation and competitiveness under such a changing market condition.

3. Development of a social robots-driven SMEs model

The model development for the diffusion of social robots in SMEs is initiated with an understanding that it's a sociotechnical complex issue involving technological, organizational and environmental aspects as barriers to adoption (Ding et al., 2024). We selected the TOE framework for such a relevant and practical model, implemented in these three key dimensions that are covered by this extensive approach. It is a crucial principle for small businesses ready to integrate new technologies since their determining factors are often different from MNC's (Spaccatini et al., 2023).

The TOE framework analyzes the multifaceted aspects of antecedents that affect SMEs' preparedness for using social robots (Basloom et al., 2022). The model intends to provide a realistic depiction of the adoption process, considering example technology capabilities embodied in robots, workplace dynamics around SMEs and enriched contextual factors. It is important to recognize that the deployment of social robots in SME operations represents a substantial technological leap but also an organizational transformation. This new form of social robot is characterized by the many changes with added difficulty, to adapt towards corresponding business processes which mandate shifts in workforce dynamics as well as revisioning strategic applications benefiting from it (Jo and Bang, 2023).

Through illuminating and practically applicable, the model for social robot-based SME adoption is arguably to be considered as a lighthouse with considering further work. It considers the high level of management support, available infrastructure and external market conditions or regulatory frameworks. It is designed as a model of present technology and to further suit the dynamic stage, so that it remains maintainable and in its fitness by producing outputs beyond impacts on SMEs across different industries or sectors.

Social robot adoption giving enough fine-grained detail to understand how SMEs integrate and a broader view or our refined conceptualization. Focused on SMES, the framework visualizes roadmap to opportunities as well challenges for SMEs in adoption of Social Robots that can improve operations efficiency or help drive innovation thereby creating sustainable future growth avenues not just automation-induced dead ends.

3.1. The antecedents of social robot adoption by the SMEs

The antecedents of social robot adoption by SMEs are as multifaceted as the businesses themselves, with each entity bringing its own circumstances to the fore (Ding et al., 2024). Social robots pose a different dilemma for the community SME sector who are phenotypically agile and anatomically compact (Arora et al., 2024). Company factors like culture, employee willingness to adapt and prevailing technological platforms are key players (Hurmuz et al., 2023). Adoption drivers and impediments are dictated by outside forces, such as the market environment, competition from others in a similar field or regulation (Fosso et al., 2023). More important still are technological antecedents. These elements are combined to establish a complicated environment in which the diffusion of social robots happens, driven by how much they fit into both the SMEs' operational and strategic needs (Spaccatini et al., 2023).

The introduction of new technologies such as social robots into SMEs is often compared with the diffusion of innovations, in which an adoption curve illustrates when different types of businesses adopt a product (van Straten et al., 2023). Innovators and early adopters blaze the trail, paving the way for mainstream market penetration (Dang and Bertrandias, 2023). Social Robots — Increasingly evident in public and service spaces — from healthcare to education, customer care and many more. The prospect of losing jobs to social robots may contribute to a sense hesitancy, further necessitating developers to address the complementary approach that these technologies can support human work rather than replacing it. (Roy et al., 2024).

Thinking of a successful integration of social robots in SMEs, these must include socially intelligent dimensions that create the typical human-behaviors and outputs. This involves creating robots that can interact in a way users feel is natural and human-like, improving the interaction experience between man and machine. The adoptability of social robots is significantly related to the extent to which new technologies are adopted by innovative members and other enthusiasts within an organization. These systems must be technically competent and built with trustability criteria that can translate into a greater focus on how businesses use them every day as increasingly essential elements of an SME toolkit (Vishwakarma et al., 2024).

3.2. SME's adoption of social robots in their business

The deployment of social robots in the SMEs has brought technological acceptance and adoption for strategic business discussions (Baudier et al., 2023). Acceptance is a process that takes months or years and represents the last stage of interaction with technology. The process

of acceptance for SMEs involves both the preadoption phase, which includes developing expectations or awareness on technology & post-adoption, where technology becomes a part of everyday business life (Borghi et al., 2023).

This process begins in the critical pre-adoption phase where SMEs develop perceptions for social robots using information-gatherings (Khaksar et al., 2024). This stage is crucial as it incepts the frame of mind towards adoption or rejection. Better matching pre-adoption expectations and real experiences with social robots is hence pivotal for moving closer to acceptance and successful use in practice (Khaksar et al., 2024).

To understand the intention of SMEs for adopting social robots, we investigate motivational factors reported during prescriptive phase. This could be identifying the willingness to engage with technology, wanting to explore it capabilities and being open too adopting innovative business processes. This research shows that even before any direct interaction with a social robot, these factors seem to have an enormous effect on SMEs' intentions to use it in practice (Chang et al., 2023). Thus, this study supported evidence from previous research that SMEs are inclined to have a strong intention of adoption in the field of social robots before they come under practical use (Quenehen et al., 2023). In this light, we explore the specifics of adoption by trying to understand what motivates SMEs to adopt social robots as part of their work. By looking at the pre-adoption period, we will be able to forecast if social robots can really enter the highly heterogeneous SMEs ecosystem or not paving a way for wider and descriptive analysis of this research.

3.3. Proposed social robots-driven SMEs model

The world of SME operations is constantly evolving with tech innovation at the forefront, enabling organizations to change and grow for decades. This research integrates the results of empirical studies and theoretical insights to suggest a social robot-assisted performance model for SMEs. The model is built on the premise that, when incorporated properly within SME settings social robots can bring a host of benefits well beyond mere cost-efficiencies. We thus define the pillars of this models:

The model also focuses on operational cost-efficiency, above all else. SMEs can benefit from cost savings in terms of human labor costs as social robots never take breaks and do not require overtime pay. Many of these robots can be assigned to tasks that are either too repetitive or physically demanding for humans, enabling SMEs to deploy their human resources into more strategic revenue-generating businesses.

Second, we model enhanced organizational efficiency and innovative activity. After all, social robots are not just business process automation. They are change agents for the future of work. This change may help boost employee morale, spur internal innovation and cultivate a culture of continual growth.

Third, the model characterizes that social robots provide a channel of enhanced customer service. Clients experience new and enriched experiences through personalized, consistent interactions with social robots. This unique customer engagement is special only to them, helping in augmenting the satisfaction level and hence helps develop loyalty among customers making SMEs stand out amidst cutthroat competition.

In addition, social robots offer comprehensive solutions for cybersecurity in SMEs. Social robots can be used in many areas such as operating under harsh environmental conditions or handling dangerous substances which are not easy for humans.

The last pillar of the proposed model is Competitive advantage. Such innovative implementation can set SMEs apart in many ways, especially the use of social robots that bring with them a plethora of new opportunity. It is particularly valuable in industries where rapid response to consumer demands and market shifts are necessary pillars of success.

Finally, the model recognizes that social robots make data collection strategically possible. Social robots that feature advanced sensor and data processing capabilities are able to monitor customer activity in real-time, enabling SMEs with relevant information on consumer behaviorisms and preferences. This data-centric approach can provide SMEs with the actionable insights they need to stay ahead of product development and marketing trends, and perhaps more importantly, in tune with a target audience.

The adoption of social robots within SMEs, as envisaged in this model therefore offers a notionally seamless combination of cost reduction, greater safety and strategic innovation. It pulls SMEs into a tomorrow where sustainability, customer-centricity & competitive differentiation is not only an idea but the outcome of accepting the digital revolution.

4. Research model and hypothesis

The objective of this research is to test a proposed model that gathers and highlights the social robot benefits in SMEs. The study defined constructs were drawn from the literature and distilled into twelve key elements that reflect both enablers as well barriers to adoption. The constructs are based on the three critical dimensions, namely technological, organizational & environmental dimensions that make up for the completion of this generic model.

This research uses structural equation modeling (SEM) with AMOS to rigorously test the interrelationships between them. This statistical method can verify the theoretical framework and provides computational information on relationship quality among variables. The study posits intends to identify the routes through which influence is made and measure how influential they are, hence providing actionable insights for SMEs in order to employ social robots as part of their business operations.

The descriptions of the constructs are designed to ground hypothesis testing in a theoretical foundation, clearly establishing how each variable fits into the model. The distinguishing characteristics of each construct and their anticipated outcomes are set out by the research which allows for a high-level look at how social robots can be employed to enhance performance within SMEs as well as flexibility in business change. This comprehensive methodology encapsulates the relevance of a multi-dimensional view when evaluating readiness and capacity for digital innovations with social robots in SMEs (Fig. 1).

The structure enables providing a more holistic view on how these three aspects — technological, organizational and environmental factors respectively interrelate with each other in influencing SME adoption of social robot (Caffaro et al., 2020). This framework has been extensively acknowledged and used in SMEs technology adoption of its detailed segment of social robots (Gao et al., 2022) (Table 1).

To identify the constructs within TOE framework that are related with this study, a comprehensive literature review which concentrates on technology adoption among SMEs is conducted systematic reviews and analysis approach. This review highlighted a range of factors that can impact on the acceptance of social robots in SMEs. The following sections explain the determinants based on each component of TOE to propose multiple hypotheses in exploring this multifaceted phenomenon which is social robot adoption among SMEs (Pap et al., 2022).

4.1. Technological antecedents

The Technological Antecedents section looks at the underlying facilitators that drive new technology acceptance and implementation in SMEs. The section focuses on the role of perceived ease of use, perceived usefulness and compatibility in constructing intention to adopt social robots (Lu and Gustafson, 1994). All three of the preceding antecedents are what underpin TAM and give an indication as to how likely a technological innovation is to be accepted in terms of being absorbed by operational practice within an SME (Xiao and Goulias, 2022). It symbolizes not just the actual burdens of incorporating new technologies, but also an entity's psychological readiness to embrace tech advancements that could realistically transform practice workflows and business models (Yao et al., 2023). These antecedents provide important insights

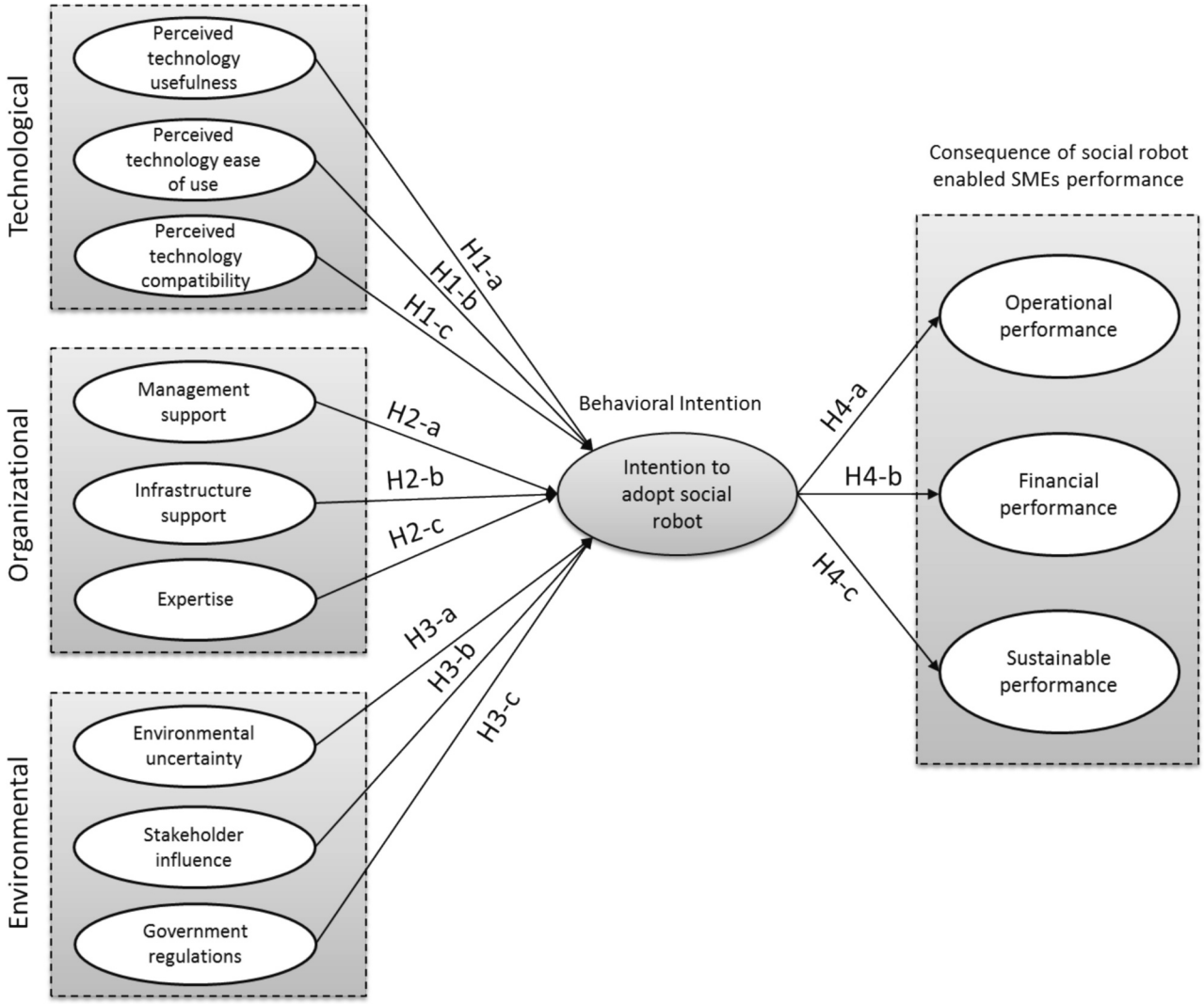

Fig. 1. The research model for SMEs' social robot adoption.

into the decision-making process, helping to contribute towards a successful deployment of social robots in SMEs sector.

4.1.1. *Perceived technology usefulness*

Understanding how the perceived usefulness of technology is related to SMEs' intentions towards adopting social robots can help promote innovation and increase competitiveness in today's business landscape (Oyman et al., 2022). The idea that the perceived benefits of technology can improve its acceptance is well grounded in SMEs since strategic decisions are often influenced by the future-expected advantages from new technologies (Scheper et al., 2019).

In this sense, perceived usefulness corresponds to SMEs judgement on whether social robots are going to lead significantly improve their business processes and services (Arora et al., 2024). For example, social robots can talk to customers and answer questions; they could also automate tasks like simple recycling duty or monitor inventory counts making interaction with the system more efficient (Hurmuz et al., 2023). When SMEs understand these benefits, they are more likely to invest in social robots as efficiency and customer satisfaction will also lead them towards cost savings (Fosso et al., 2023).

Therefore, the business benefits for SMEs of using social robots are not just in theory but a real-world application. The potential for real-life improvements drives the incentive towards adopting these new awesome innovations. The more SMEs experience or anticipate these benefits, the greater a precedent for technology adoption is set and as such helps inform an era in which human-robot collaboration not only becomes real but integral to business-development (van Straten et al., 2023). Thus, the above arguments help to articulate the following hypotheses.

H1-a. Perceived technology usefulness positively influence intention to adopt social robot in SMEs.

4.1.2. *Perceived technology ease of use*

SMEs adoption of sophisticated technologies reflects how they can benefit from it in terms of ease with which technology is absorbed (Eze et al., 2021). For SMEs willing to integrate social robots into their operation, the perceived ease of usage is very important (Caffaro et al., 2020). That is because SMEs are typically resource constrained, both in terms of time and money as well technical expertise (Xiao and Goulias, 2022). The question then is, can the technology be used by SMEs easily.

The easiest of operation is due to the user-friendly nature of social robots — i.e., intuitiveness and simplistic functionality that can be affectionate enough in terms of style & hardware interfaces (Taufik and Hanafiah, 2019). User-friendly technology does not require immense training and can be quicker to roll out, ensuring that SMEs are quick on their feet & crucial for market change (Veflen and Gonera, 2023). In addition, its user-friendliness promotes exploration and evolution across SMEs.

Table 1
Antecedents of SMEs social robot adoption.

Categories of antecedents	Constructs	Characterization	References
Technological	Perceived technology usefulness	The perceived value of technological advancements	(Bolodeoku et al., 2022)
	Perceived technology ease of use	Perceived simplicity of the technological interface	(Caffaro et al., 2020)
	Perceived technology compatibility	Perceptions of how well different technologies work together	(Ozturk et al., 2016)
Organizational	Top Management support	Approval from Upper Management	(Paluch and Shum, 2022)
	Infrastructure support	Help with the infrastructure	(Pap et al., 2022)
	Organizational readiness	The ability and willingness of employees to adapt to new circumstances is what we mean when we talk about organizational preparedness.	(Hradecky et al., 2022)
Environmental	Environmental uncertainty	Environmental uncertainty is the inability to foresee environmental change, reaction choices, and the state of the environment.	(Gao et al., 2022)
	Stakeholder influence	Influence represents a stakeholder's proportionate control over and participation in a project.	(Yadegaridehkordi et al., 2023)
	Government regulations	Regulations issued by the government are, in essence, laws that delineate what constitutes legal action.	(Fleith de Medeiros et al., 2022)

Therefore, the apparent ease of use is a positive trigger for social robots' usage within SMEs. This guarantees decision-makers that the goal of transitioning into automation is reachable and there will not be much to learn or unlearn. The case for adoption by SMEs grows stronger when they realize the ease with which such technologies can seamlessly integrate themselves into their existing infrastructure and support human-robot collaboration. This trend will probably get even more intense as social robots become, through continuous development and design of adaptable easy-to-use features, easier to be operated by reinforcing the positive impact intention to adopt social robot in SMEs. All these arguments lead us to state the following hypotheses.

H1-b. Perceived technology ease of use positively influence intention to adopt social robot in SMEs.

4.1.3. Perceived technology compatibility

While passing through the intricacies of the modern market from inception to establishment, perceived technology compatibility seems like a determinate factor which affects how prepared SME's are when it comes to new technologies like social robots (Drahman et al., 2023). Here, compatibility refers to how much the values i.e., systems of beliefs, past experiences and present needs of a SME overlap with those exclusively fostered by social robots (Fosso et al., 2023). Over time, if the technology is deemed compatible, this too will be perceived to be in perfect harmony with the ecosystem and therefore theory it seems less reasonable that integration has not been obtain (van Straten et al., 2023).

Perceived Technology Compatibility holds a higher statistical power among SMEs because of their lean operational structures (Spaccatini et al., 2023). These are businesses that cannot just absorb the downtime of a technology not integrating properly with their existing systems and operations (Esfandbod et al., 2023). One strategy for deploying social robots is designing them to be interoperable with existing technologies so the integration of these new devices can minimize corporate process changes (Vishwakarma et al., 2024). These results guarantee that new and existing systems are maximally useful by keeping implementation friction minimal.

In sum, perceived compatibility supports the intention to adopt social robots in SMEs. The bottom-line is that if SMEs find social robots culturally congruent with their operational ethos and technical environment, the road to acceptance of such a technology instantly becomes very short. As a result, when social robots become more adaptive and targeted towards the specifics of how SMEs operate, we can expect an increase in their use due to perceived compatibility with organizations' decision-making patterns. All the above valued discussion lead us to formulate the following hypotheses.

H1-c. Perceived technology compatibility positively influence intention to adopt social robot in SMEs.

4.2. Organizational antecedents

Organizational antecedents are a set of important factors that significantly influence the uptake and adoption of technological innovations in SMEs (Ding et al., 2024). These antecedents are the internal factors and conditions that support or inhibit social robot technology integration in business processes. Within the organizational umbrella, factors such as management support, infrastructure, and technical capabilities are important to ensure a move by any organization towards technological change (Arora et al., 2024). The interaction of these components can have significant consequences for an SME in terms of how well positioned it is to invest, deploy and benefit from social robots which in turn impacts not only the innovation pathway or trajectory but by extension also its competitive landscape. A complete picture of internal antecedents leading to the inbound adoption avenues for social robots in SME sector. (Hurmuz et al., 2023).

4.2.1. Management support

The most important aspect for SMEs to adopt in technology is Management Support (Dong et al., 2009). Management support and enthusiasm are vital for the introduction of social robots. Leaders within an SME are pivotal in deciding the strategic aim of the business and they set a culture which defines how open to new techs their organization is likely to be (Paluch and Shum, 2022). Support from management validates adoption, signals to the rest of the organization that this initiative is important and provides assurances for resources need or barriers in getting addressed. This also encourages a climate in which the perceived risks of working with new technology are tempered by faith that leadership is committed to its successful adoption.

The influence of management in technology adoption is way beyond their approval; they have to actively promote it, share the vision and create a change-enabling environment (Hurmuz et al., 2023). This can be especially effective as the management support in SMEs is often less formalized and personal agendas may drive decision-making (Koban and Banks, 2024). Optimistically, it creates a common belief in the merits of social robots and makes people more open to new technology as well invest time into learning how to use them (Paluch and Shum, 2022).

At least a more engaging and personalized version than the aspiration to roll out social robots in SMEs (Ding et al., 2024). This is not only about the investment decision, but also how well we implement and

integrate this technology into our process. Managers who model the way with a well-articulated vision of how social robots can improve organizational competences, create an technology-positive environment that fosters innovation, productivity and future state growth. And, this approach prioritized by leadership can finally tip the scale to make SMEs more amenable and mimic a proactive instrument for adoption of technology. Accordingly, it is hypothesized as follows.

H2-a. Management support positively influences intention to adopt social robot in SMEs.

4.2.2. Infrastructure support

Another critical pillar for social robot adoption success in SMEs is infrastructure support. It refers to the physical and virtual assets that the firm needs to acquire and install to guarantee the ability to assimilate new technologies and optimize their utilization (de Boissieu and Baudier, 2023). On the part of social robots, this support is not confined to having the right equipment and software (Pap et al., 2022). It also comprises the enabling technological environment that sustains and strengthens the potential of the robot. For SMEs, this translates to investing in supportive systems, responsive network operations, and enabling maintenance and repair services to ensure continuous and effective utilization (Esfandbod et al., 2023).

If the current infrastructure is ready to support these advanced technologies in an intuitive manner without a significant need for change, there could be great interest from SMEs globally. This compatibility eliminates the expensive field setup required by most integrators, minimizes downtime during integration and speeds the return on investment — thus making social robots more compelling to adopt (Roy et al., 2024). Even better, a strong infrastructure tells everyone that the organization is ready and willing to go through change (Vishwakarma et al., 2024). It also brings a safety net that allows employees to interact with new technology confidently, knowing they can rely on the system and help is there immediately (Chatterjee et al., 2023).

Hence, infrastructure support is one of the most significant enablers in deciding by SMEs whether use social robots. If the risk of adoption is low, and it appears that systems and appropriate support mechanisms are in place to enable a move towards successful implementation of social robot deployment. This means that investment in infrastructure is an investment for readiness to embrace new technology such as social robots, enabling SMEs success factors. In this context, the following hypothesis is formulated.

H2-b. Infrastructure support positively influences intention to adopt social robot in SMEs.

4.2.3. Expertise

Organizational experience, especially in SMEs is an invaluable asset and a crucial factor to the successful adoption of novel technologies such as social robots (Arora et al., 2024). In fact, this factor is the most significant differentiator that allows an SME to deploy highly developed systems: their in-house expertise (Hurmuz et al., 2023). Having the appropriate technical expertise and experience can give an SME what it needs to understand social robots on a deeper level, including how they might affect different areas of their operating model (Fosso et al., 2023). Knowledge allows for a well-reasoned assessment of the technology, paving the way towards an intention to adopt once benefits become apparent and experience is available in managing it.

Having technical expertise makes it easier to integrate social robots into existing processes. Experts can anticipate and prevent common barriers to integration, adapt solutions for specific business demands, squash any bugs before they become a problem (van Straten et al., 2023). This familiarity removes the intimidation factor many workers have when faced with new or advanced technologies (Dang and Bertrandias, 2023). Having technical specialists will help SMEs in overcoming complexities when it comes to adopting the units.

Therefore, the experience in SMEs works as an accelerator factor of adoption for social robots (García-Martínez et al., 2024). It will also create internal confidence to utilize modern technologies and lower perceived risks from integrating such systems. This study predicts SMEs with a positive foundation in technical knowledge are predisposed to adopt social robots as they take advantage of these technological shifts and manage the market prospects due to been more responsive than their counterparts. Accordingly, it is hypothesized as follows:

H2-c. Expertise positively influences intention to adopt social robot in SMEs.

4.3. Environmental antecedents

External factors that will affect the decision-making process of an SME to adopt new technologies; these are known as environmental antecedents (Saini et al., 2022). For example, things like the overall economy — economic conditions, cultural factors (such as how people perceive a certain product), government regulation in general and industry-specific regulations to keep it compliant with relevant laws are all external reasons that impacted an SME (Sommer et al., 2023). Among these variables, environmental uncertainty, stakeholder influence determining how environmental antecedents shape perception of the risks and benefits associated with adopting innovations like social robots, is also critical (Wang et al., 2023). This context of external pressures and supports in which SMEs exist helps to shape their perception regarding whether large opportunities remain (Atif and Ali, 2021), when employing existing technologies to maintain a competitive advantage (innovation-oriented), as well as sustainment against currently accepted standards and expectations (Netland et al., 2023).

4.3.1. Environmental uncertainty

The complexity of the business environment has made us search for novel solutions to survive in an ever-competitive marketplace (Pacelli et al., 2023). This uncertainty can be caused by rapid changes in technology, changes in the market needs or due to regulatory modifications making it difficult to predict and keep up with business as usual (Chang et al., 2023). Social robots in this unpredictable landscape can be a solution for SMEs to become more agile and adaptive. Social robots open a possible way out for SMEs that fear to be exposed to too much uncertainty if they would hire such humans, as performing various tasks generally involves different functions and positions within an organization (Brogi et al., 2022).

SMEs are a particular example where the adoption of technology arms them against inevitable environmental uncertainties (Salah and Ayyash, 2024). Since they are programmable and can be easily adapted to different conditions, social robots can function under many different circumstances (Baudier et al., 2023). This adaptability shows that SMEs are neither casualty left defenseless on the side lines but all set for the changing times. Because of that, social robots are seen like a guarantee against unexpected elements challenging an SMEs operational continuity on the positive side fostering its intention to adopt (Sommer et al., 2023).

To conclude, environmental uncertainty is the most prominent factor in predicting a firm's attitude to implementing social robots by SMEs. Because the business environment is unpredictable, tools and technologies must provide stability but also adaptability rapidly. SME funding in social robots providing a sense of security during times on uncertainty but markable opportunities for future adaptability. As such adopting these technologies is a strategic initiative to the competitive business scenario covering and ensuring SME's remaining disrupt but robust again external forces. It leads us to formulate the following hypotheses:

H3-a. Environmental uncertainty positively influences intention to adopt social robot in SMEs.

4.3.2. Stakeholder influence

The effects of Stakeholder influence are significant, and they play a very important role in the decision-making process around social robots for example but also when adopting other innovations by SMEs (Ding et al., 2024). The performance and operational efficiency of the SME matter to various stakeholders like customers, suppliers, investors, employees alike (Arora et al., 2024). The input and feedback from these people can dramatically impact the strategic decisions of a company (Hurmuz et al., 2023). When stakeholders are given proper support, technological advancements show they are ready to be directly involved with automated solutions in the company, corporates can see willingness to adopt social robots. The requests from investors are often indicative of wider market shifts and customer demands, indicating that integration of this technology is becoming not just desirable but probably necessary to remain competitive (Spaccatini et al., 2023).

In practice, stakeholder power may exist as customers push for more efficient and technology driven service experience; or supplier pull towards a simpler digital interaction. Public investors can also push social robots by articulating how their installation and deployment could possibly enhance long-run profitability as well market share. The initiative and willingness of employees to work with robots, use these tools more generously is also a key influencer that can help the SMEs in moving forward apprehensively because at last they would know their workforce are willing to welcome this new change. This collective buy-in leads to an open, receptive atmosphere for change and innovation within the SME.

Thus, SMEs are highly motivated to implement social robots because of the effect that stakeholder expectations and pressures have on these organizations (van Straten et al., 2023). This drives home to the point that a business direction in tech must be integrated with its wider stakeholders. In turn, proof of social robots serving stakeholders validates the importance of this technology (Dang and Bertrandias, 2023). It encourages the SME to take its integration forward thereby defining an era in which automated solutions are for business survival and stakeholder happiness (García-Martínez et al., 2024). These inputs suggest formulating the following hypotheses:

H3-b. Stakeholder influence positively influences intention to adopt social robot in SMEs.

4.3.3. Government regulations

The adoption of Social Robots, a kind of advanced technology in SMEs sector is mostly affected by a few crucial roles played by the government policies and initiatives (Neerincx et al., 2023). Favorable government action around the development and integration of automation and robotics can quickly bind this gap for SMEs when it comes to consumer goods set viability (Chatterjee et al., 2023). This support can take many forms, from financial incentives to tax breaks and technology purchase subsidies or even for funding research (Della Corte et al., 2023). Similarly, these measures can help reduce the financial pressure on SMEs and increase their ability to invest in social robots (Chang et al., 2023). Additionally, the government backing these technologies carries a strategic weight and will help to make them more accepted within businesses opposing it (Triantafyllidis et al., 2023).

Government rules and regulations about automation are another entry point for exposure of social robots alongside financial rewards (de Boissieu and Baudier, 2023). The government should set guidelines on how (the use and persuasion authority) the SMEs can integrate robots, and this is a legal side of it (Fink et al., 2023). Such regulatory clarity lowers the perceived risk for SMEs to decide on adopting a certain technology (Koban and Banks, 2024). In addition, governments can stimulate innovation by Creating an enabling environment that includes education and training programs to ensure a workforce with the right skills to work effectively side-by-side in social robots (Abadie et al., 2024).

In summary, all forms of governmental assistance and regulatory regime related to social robots positively enhances the intentions of SMEs towards such adoption by affording these firms financial support, legal mandate as well as innovation-safe atmosphere. SMEs have a higher probability of adopting social robots when they view the government as an ally in their technological ventures. This partnership model between the public sector and SMEs drives technology adoption at pace in a controlled enabling environment as an enabler supporting wider economic growth and societal outcomes within that industry. As established change agents, governments could play an important role in accelerating the uptake of social robots by SMEs and help these businesses handle everything that may come their way with a modern technology landscape. This concept helps to hypothesize as follows:

H3-c. Government positively influences intention to adopt social robot in SMEs.

5. The consequences of SMEs social robot adoption

5.1. Financial performance

The desire to incorporate social robotics in SMEs' workflow is directly associated with the potential for improving finances (Bellandi, 2023). Social robots will help SMEs to save operational cost by performing these functions (Ding et al., 2024). Robots are designed to accomplish high precision work or highly repetitive tasks with little mistakes–meaning less waste and smarter application of materials, as well as labor (Hurmuz et al., 2023). The accuracy of output and repeatability robots bring to the table means lowering production cost but improving product quality (Dang and Bertrandias, 2023), which in turn means more customer satisfaction as well as repeat orders — a lifeline for any SME (Spaccatini et al., 2023).

Social robots are also a strategic asset that can be exploited progressively with time. As an asset class, they offer a day-to-day use case and add directly to the company valuation. They are not fixed — they can be enhanced and upgraded, ensuring the assets keep pace with technology trends. Increased asset values on the financial statements of a SME are one manner by which this adaptability can be reflected, as may an enhanced brand image for appeal to new customers and markets (García-Martínez et al., 2024).

Therefore, the strategic choice of using social robots matches properly with SME earnings creativeness intentions (Neerincx et al., 2023). The direct effects on costs and asset value are expected to improve the financial performance, with some additional income coming from indirect benefits like better branding or a higher market positioning (Chatterjee et al., 2023). With businesses increasingly acknowledging the commercial advantages of social robots, it is clear that adopting these technology platforms will be a key pillar in strategies for SMEs to become innovative and successful players in lean competitive environments. This concept helps to formulate the following hypotheses:

H4-a. Intention to adopt social robot positively influences financial performance.

5.2. Operational performance

The systematic introduction and implementation of social robots in SMEs are closely related to important progress regarding operational performance, especially cost- efficiency but also asset-and liability adjustments (Klaic et al., 2022). First and foremost, social robots are effective in alleviating the budget (Hagiwara et al., 2022). Social robots can eliminate the need for overtime costs, often because of automation in otherwise routine or laborious endeavors — reducing system inefficiency and costly waste due to human error (Kokotinis et al., 2023). A multitude of robots can reduce the waste on raw materials and allow for optimal use of production inputs when compared to conventional industrial processes, therefore actually lowering unit cost substantially increasing financial efficiency. (Della Corte et al., 2023).

In terms of the asset aspect, social robots as an intangible resource are used in measurable performance that improves the operational efficiency for SMEs (de Boissieu and Baudier, 2023). It represents a capital investment, which can go a long way in boosting the overall productive capacity of the business without having to increase labor cost correspondingly (Chatterjee et al., 2023). Social robots can be deployed for long periods of continuous usage to provide a predictable output and consistent performance (Chang et al., 2023). Not only that, but they can also be maintained and updated to add more features, thereby increasing their life as well as ensuring the business stays ahead in technological trends.

Social robots represent a liability which can be financed and structured such that the SME's balance sheet benefits (Koban and Banks, 2024). Rather than making such technology a liability, financing options for purchasing them can be used as an investment in the company's future productivity (Abadie et al., 2024). Furthermore, social robots can also minimize liabilities in labor related injuries and product recall as they improve operational efficiency whilst reducing the risk of workplace accidents or errors which could be costly for a company to payout liability damages that might have detrimental effects on their credibility (Abadie et al., 2024).

Consequently, the desire to deploy social robots in SMEs is not only an operational decision but also a strategic one as it has significant effects on several financial dimensions. Social robots solve the efficiency and effectiveness of SMEs by tackling all three sides of carrying out operations: cost, asset values plus liabilities. However, the use of these technologies is not just a reaction to increasingly modern production processes, but also a vision for positioning business in such a way that it gains or maintains its competitive advantage on the market and achieves financial security as well as gaining sustainable growth. Accordingly, it is hypothesized as follows:

H4-b. Intention to adopt social robot positively influences Operational performance.

5.3. Sustainable performance

The study predicts that the use of social robots in SMEs will not only outperform financial and operational changes, but also improve sustainable performance (Ding et al., 2024). In this regard, a holistic sustainable performance is defined as an additional dimension of organizational activities includes social aspect in addition to environmental and economic aspects (Fosso et al., 2023). The social facet of sustainable performance speaks to an SME's ability to enrich society through caring for the well-being and health of its employees and contributing positively overall within their community. Social robots could supplement the social component by enhancing the work environment (e.g. decreasing related to dangerous or repetitive than arise through undesirable) and thereby make it safer, more pleasant working atmosphere for employees (Dang and Bertrandias, 2023).

From a business perspective, wanting to introduce social robots sustainable in the long run for SMEs (Roy et al., 2024). The efficiency and productivity gains of social robots can drive a more competitive position in the market, enabling companies to imagine better—and create resources into areas that trigger innovation and growth (Vishwakarma et al., 2024). Economic sustainability is also the ability to survive against market fluctuations, and social robots can be flexible enough for SMEs when they need radical changes in economic conditions (Chatterjee et al., 2023).

Being environmentally sustainable matters more than ever to SMEs being under pressure to show environmental stewardship (Della Corte et al., 2023). Social robots help in this regard, as they optimize the use of resources and waste generation, and reducing environmental impact (Chang et al., 2023). Automation offers better material and energy usage control, which in turn fulfills the promise of an SME as a sustainable enterprise (cost saving could be recouped through savings in waste management and energy expenditure) (Neumann et al., 2023).

Thus, the promotion of social robot adoption intention is consistent with an SME's strategic objective to improve its sustainable performance in terms of societal, economic and environmental orientations (Yavuz et al., 2023). The merger of these elements allows a 360 view on sustainability, and all the advantages of technology adoption are spread at every level within business operation. The role of social robots as the harbinger of a future where both businesses remain economically viable and contribute to societal welfare and environmental preservation. This is a small but important step forward for SMEs, marking an alignment with global goals and societal values that position the business as having relevancy and purpose in a future-fit market (Table 2). These discussions help to formulate the following hypothesis:

H4-c. Intention to adopt social robot positively influences Sustainable performance.

6. Research methodology

The study embraced Sequential Exploratory Design, employing a five-phase methodology that commenced with qualitative data collection and culminated in quantitative analysis, as illustrated in Fig. 2.

Data acquisition spanned diverse African nations, leveraging the unique characteristics of African SMEs to illuminate social robot adoption. The rationale behind this choice rests on several factors: the increasing tech integration within African SME operations, their diverse industry engagements fostering varied perspectives on technological implications, their propensity for innovative problem-solving through technology, entrepreneurial spirit encouraging experimentation, and their pivotal role in driving technological advances within emerging markets. The construction of survey projections, crucial for the study's validity, underwent meticulous multistage development drawn from expert insights and multidimensional technology change frameworks.

6.1. Identify the area of the data collection

The data has been collected from different African nations. Social Robots in African SMEs appear to be relevant for several reasons.

1) Technology is being increasingly employed in the operations of African SMEs. Incorporating new technology into their company's workflow forces them to stay up to date with the most recent technological advances and allows them to provide advice on how those technologies can be applied.
2) The African SMEs operate in various industries including agriculture, manufacturing, financial services and healthcare. This allows them to offer different perspectives on how technological advancements can be applied in industries.
3) African SMEs are regularly pressed to come up with innovative ways of doing business due to limited resources and facilities. This could involve using technology to make processes more efficient and get the most value. As a result, they have unique perspectives to offer on the latest technological developments.
4) African SMEs have a track record of being heartland entrepreneurs and risk takers. This makes them more apt to try out newer forms of technology and give feedback on just how effective it is.
5) Africa is a fast growing market and small medium enterprises are leading this transformation. Often the ones that take up new technologies before others, their experience can show how modern technological tools work in real life contexts where they are used.

As such, African SMEs have the potential to help understand what some of this new technology is like (the antecedents and consequences of social robots) how they are used in different industries and contexts.

Table 2
Consequences of SMEs social robot adoption.

Constructs	Parameters	Characterization	References
Operational performance	Operational cost	Operational costs are the expenses incurred to maintain your company's daily operations.	(Chan et al., 2017)
	Operational efficiency	Operational efficiency is an organization's capacity to minimize time, labor, and material waste while providing high-quality goods and services. Financially, operational efficiency is the ratio of the organization's input to its output.	(Boruah and Chandel, 2023)
	Operational time	The time between systems' input state and operation completion.	(Salandri et al., 2022)
Financial performance	Cost aspect	The cost of acquiring, producing, or sustaining something is typically quantified in terms of money, time, or energy; expenditure.	(Saini et al., 2022)
	Asset aspect	A trait or a characteristic is referred to as an aspect. An asset is something that has worth, either for its use or as a commodity that can be exchanged for money.	(Yadegaridehkordi et al., 2023)
	Liability aspect	Loans, accounts payable, debts, deferred revenues, securities, warranty, and accumulated expenses are examples of liabilities. The term 'liabilities' refers to the debts and loans a person owes.	(Rodríguez-González et al., 2022)
Sustainable performance	Social aspect	Social aspects are those facets of life that pertain to other individuals or society as a whole. This encompasses any system or tradition for organizing, cooperating, and getting along with one another in groups, including shared experience aspects.	(Yavuz et al., 2023)
	Economic aspect	Economic Aspect denotes that the party who will utilize the Storage unit must consider, among other things, the rate of return of the owner's economic interests.	(Zhang and Lucey, 2022)
	Environmental aspect	Environmental Factor is a component of a company's activities, products, or services that can impact the environment.	(Adomako and Tran, 2022)

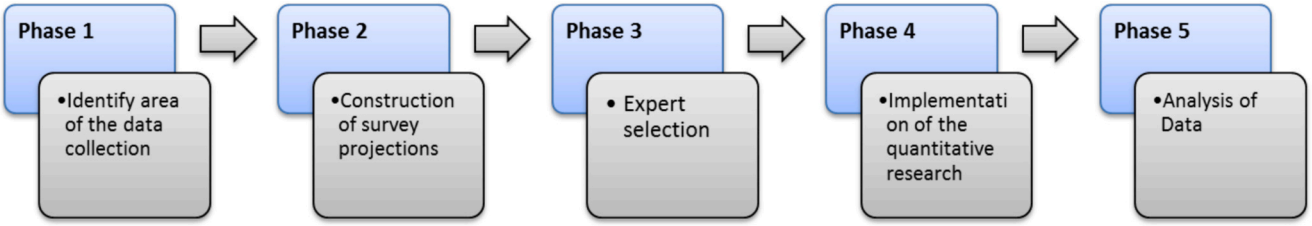

Fig. 2. Research methods.

6.2. Construction of survey projections

The study drew on data collected over the course of four years throughout Africa. To ensure the value, validity, and dependability of studies, the creation of projections and the structure of questions are highly important. Therefore, a thorough and well-established multistage method was chosen to generate concise and stimulating projections (Mitchell, 1996).

Relevant journal articles were reviewed to identify critical factors influencing businesses' potential adoption of Social Robots. Professionals were emailed and requested to provide at least six keywords related to the widespread use of social robots. Additionally, experts and academics conducted interviews on a preliminary basis to find other important variables and reconstruct the selection procedure to guarantee that all pertinent considerations are considered for projection development. The survey continued until significant redundancy and diminishing results from adding new items were found.

According to (Geels, 2004), a multidimensional view of technology change was employed to guarantee that the forecasts extended to more than just the technological qualities of Social Robots. This included societal, natural, economic, accepted practice, and strategic factors. Factors not yet implemented for projection formation and factors associated with the eliminated projections were utilized to build initial pro and contra propositions for the first engaged expert. Thus, no data was wasted through the projection production procedure. The final compilation included 36 projections on the antecedents and consequences of social robot adoption by SMEs.

6.3. Expert selection

The choice of respondents is very important to the accuracy of the survey's data. The panel of experts was systematically selected based on this factor to obtain a high level of heterogeneity and minimize the cognitive biases of diverse respondents, including framing bias, desirability bias, anchoring bias, and the bandwagon effect.

Heterogeneity was accomplished through the involvement of experts from different domains, including Information Technology, robots, and SMEs, as well as the inclusion of designated academic experts and administrators of SMEs. As a result, 782 probable experts with relevant experience in the research field were invited to participate in the panel. To ensure that only specialists have been incorporated in the reliable panel, participants with legitimately professional knowledge of the SME are identified; participants were also informed of the context of the study prior to the survey and had their privacy protected.

The "Mann–Withney *U* Test" was employed to examine the possibility of non-response bias. Here, we compared the late respondent estimate to the early respondent estimate, as it is reasonable to assume that late responders share the traits of people who did not respond (Wagner and Kemmerling, 2010). Comparing the responses to all 36 projections yielded no statistically significant differences ($p > 0.05$) and no evidence of non-response bias.

6.4. Implementation of the quantitative research

This study utilized a questionnaire-survey methodology, and a quantitative assessment of the panelists' ratings was performed immediately. Prior arrangements have been made to enhance the response rate. 782 questionnaires were personally distributed to the chosen experts. Considering the quantitative assessment, every participant was required to evaluate the projections on a measurement scale ranging from 0 to 100 % based on their projected likelihood of occurrence, antecedents, and consequences of social robots' adoption for SMEs. In addition, respondents were given the opportunity to provide qualitative explanations for their quantitative estimates. After removing invalid responses, 342 valid responses remained.

6.5. Analysis of data

Using a two-step methodology, the data were analyzed with IBM SPSS and AMOS. To begin with, a Confirmatory-Factor-Analysis (CFA) was conducted to assess the measures' reliability and validity. Structural paths were then examined to evaluate the hypotheses. Hew et al. (2019) validates the application of SEM as a data-analysis instrument on the premise that these investigations are founded on hypotheses supported by a clear theoretical context. In support of the suitability of the SEM, the collected data also satisfy the multivariate criteria for the purpose of this analysis, ensuring that the data are normally distributed and free of "multicollinearity" issues (Kock and Lynn, 2012). Common method bias (CMB) may be an issue since the data are self-reported (Podsakoff et al., 2012); hence, a "single-factor Harman test" was conducted to rule this out.

7. Results

The results section provides a comprehensive analysis of the empirical data by applying SEM, a robust statistical technique that integrates factor analysis and multiple regression to test complex relationships between variables. The assessment is methodically partitioned into two distinct stages: initially, the measurement model is scrutinized to ensure the validity and reliability of the constructs; subsequently, the structural model is examined to evaluate the strength and significance of the hypothesized relationships. This two-tiered approach facilitates a meticulous validation of the theoretical model, enabling a nuanced interpretation of how each construct interacts within the broader framework of social robot adoption in SMEs. Through this detailed examination, the research delineates the underlying dynamics influencing the successful integration of social robots into SME operations and their subsequent impact on business performance.

7.1. Validation of the measurement model

In the initial phase of model validation, the measurement model was rigorously evaluated to ascertain the accuracy and consistency with which the constructs were measured. This critical process involved CFA, a methodological cornerstone to validate the constructs' structure and ensure the robustness of the research findings. A normality assessment of the data collected from the respondents indicated that all variables fell within the acceptable range for skewness and kurtosis, satisfying the fundamental conditions for normal distribution.

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy returned a value of 0.87, denoting a substantial level of common variance and thus affirming the dataset's suitability for factor analysis. Bartlett's test of sphericity further reinforced this, yielding a Chi-square statistic of 6111.23 with 173 degrees of freedom, which is significant enough to confirm the factors' intercorrelations. Moreover, the constructs demonstrated strong convergent validity, with the average variance extracted (AVE) surpassing the recommended threshold of 0.5 and all factor loadings exceeding the 0.70 benchmark. Composite Reliability (CR) scores for each construct were also above the 0.70 mark. Cronbach's alpha coefficients were consistently above 0.7, indicating high internal consistency across the instruments used.

The goodness-of-fit indices obtained from CFA: $\chi 2/df = 2.39$, RMSEA = 0.067, CFI = 0.961, TLI = 0.963, IFI = 0.947, NFI = 0.949—reaffirmed the model's adequacy, suggesting that the measurement model is well-constructed and capable of capturing the theoretical constructs with a high level of validity. This foundational validation sets the stage for subsequent structural model analysis, providing confidence in the measurement model as a reliable representation of the constructs under study.

7.2. Validation of the structural model

After confirming the validity of the measurement model, the study proceeded to examine the structural model, which represents the expected relationships between the constructs. The structural model was thoroughly evaluated using AMOS software, incorporating insights from a comprehensive literature review and the findings of the CFA. In this stage, the maximum likelihood estimation method was used to calculate standardized regression weights. These weights help us understand the strength and significance of the relationships proposed in the model.

The path coefficients of the structural model were thoroughly assessed to confirm their significance and comprehend the directional influence between variables, as they represent the hypothesized linkages. Validating the structural model is essential to examine the proposed theoretical framework using empirical data. This process ensures that the relationships suggested are statistically significant and meaningful in the specific context of SMEs adopting social robots. The validated relationships are visually represented in the structural path diagram (Fig. 3), and the findings are summarized in Table 3, which provides a detailed overview of the performance of the structural model. This evaluation is crucial in verifying the strength and reliability of the research model and the empirical evidence supporting the proposed relationships.

7.2.1. Assessing the goodness of fit criteria and path coefficients evaluations

In assessing the structural model's fit to the empirical data, several fit indices were calculated to determine the model's adequacy. The Comparative Fit Index (CFI), with a value of 0.971, indicated an excellent fit, exceeding the commonly accepted threshold of 0.95. Similarly, the Goodness of Fit Index (GFI) was found to be 0.951, which is well within the range indicating a good fit, further substantiating the model's robustness. The Root Mean Square Error of Approximation (RMSEA) stood at a commendable 0.060, indicating a close fit of the model with the observed data. The Chi-Square to Degrees of Freedom ratio (CMIN/DF) of 1.661 also suggested a strong model fit, falling well below the maximum accepted value of 3.

Complementing these indices, the Adjusted Goodness of Fit Index (AGFI) achieved a score of 0.961, while the Tucker-Lewis Index (TLI) and the Incremental Fit Index (IFI) both presented excellent fit values of 0.972 and 0.960, respectively. The Parsimonious Normed Fit Index (PNFI) and the Parsimonious Goodness of Fit Index (PGFI) delivered values of 0.832 and 0.893, thus confirming that the model's parsimony did not come at the cost of its explanatory power. These indices collectively affirm that the proposed structural model is statistically sound and provides a reliable representation of the relationships between the constructs.

The SEM technique was instrumental in evaluating the hypothesized relationships, examining twelve paths representing the antecedents and consequences of social robot adoption in SMEs. Table 3 encapsulates the significance of these relationships, presenting the t-values and path coefficients. The results delineate all path coefficients as significant, confirming that the empirical data supports the relationships in the structural model. This comprehensive evaluation underscores the structural model's capacity to accurately capture the dynamics influencing SMEs' intentions to adopt social robots and the subsequent impacts on their performance.

8. Discussion

This study carefully examines the determinants and impacts of social robot acceptance in SMEs, thus making scholarly contributions to knowledge on technology implementation within smaller business contexts. This study aimed to answer two key research questions: What are the antecedents affecting SMEs decision when adopting social robots? How does their adoption influence an effect of SMEs performance during using social robots?

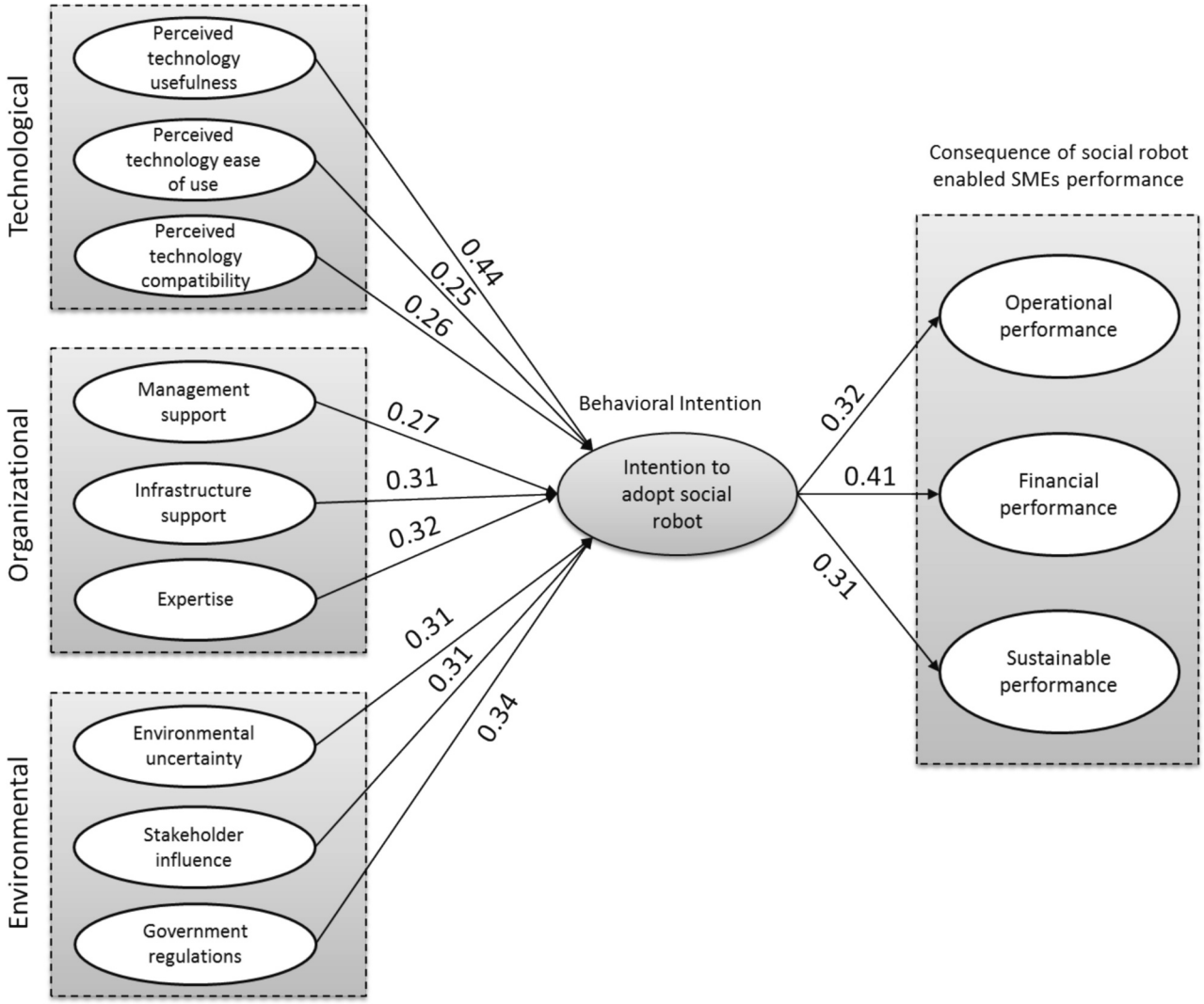

Fig. 3. Evaluation of hypotheses.

Interestingly, the research results show a complex interplay of technological factors with organizational and environmental characteristics that support SMEs in adopting social robots. Among the technological factors perceived usefulness and ease of use were significant predictors for social robots. SMEs prefer technologies that work with their current processes, are easy to implement and help them reduce costs or increase efficiency. How compatible social robots are with existing business practices is another fundamental issue, as SMEs tend to incline for solutions that require minimal disruption of their well-established workflows.

Organizational factors, such as management support and infrastructure readiness are essential as well internal technical expertise. The research revealed that SMEs with leadership support, hardware in place, and internal technical knowhow are more likely to adopt social robotics. This is in line with previous research highlighting how the level of organizational readiness can directly impact decisions regarding technology adoption.

Environmental conditions such as the stakeholder pressure and government regulation also played a vital role. The study also argues that such external pressures, like customer pressure and regulations compel SMEs to redeploy social robots on strategic pathways where the externals align with their overall strategy.

With respect to implications of social robot use, the study reveals several positive outcomes for SMEs. An operational performance improvement is relatively clear, with social robots promoting high efficiency due to low cost and increased productivity. This is consistent with the hypothesis that technology innovation — including implementation of social robots, will reduce dual resource use and operational redundancy. Consequently, the financial performance of SMEs was discovered to be influenced positively by their adoption of social robots.

The results provide evidence for the impact of social robot adoption both on innovation performance and sustainability, thereby reinforcing the role played by low-cost automation in SMEs sustainable development. It includes social, economic and environmental elements of a business operation. The benefits include better business productivity using social robots for more cost-effective operations, and building a greener society by means of reducing waste.

Regarding research questions, this study concludes that the determinants of social robot adoption in SMEs are multi-dimensional and supported by technological compatibility with existing systems, organizational readiness for change as well as environmental pressures.

8.1. *Theoretical implications*

Several theoretical implications have been identified that could encourage more thorough conceptualization of social robots in SMEs to improve understanding technology adoption.

First, this study further generalizes the applicability of TOE beyond

Table 3
Path coefficients evaluations.

Hypotheses	Structural equations	Coefficients β	*t* value	*p* value	Conclusion
H1-a	Perceived technology usefulness → Intention to adopt social robot	0.44	8.02	***	Accepted
H1-b	Perceived technology ease of use → Intention to adopt social robot	0.25	4.49	***	Accepted
H1-c	Perceived technology compatibility → Intention to adopt social robot	0.26	4.72	***	Accepted
H2-a	Management support → Intention to adopt social robot	0.27	4.60	***	Accepted
H2-b	Infrastructure support → Intention to adopt social robot	0.31	6.53	***	Accepted
H2-c	Expertise → Intention to adopt social robot	0.32	6.63	***	Accepted
H3-a	Environmental uncertainty → Intention to adopt social robot	0.31	6.53	***	Accepted
H3-b	Stakeholder influence → Intention to adopt social robot	0.31	6.43	***	Accepted
H3-c	Government regulations → Intention to adopt social robot	0.34	6.32	***	Accepted
H4-a	Intention to adopt social robot → Operational performance	0.32	6.33	***	Accepted
H4-b	Intention to adopt social robot → Financial performance	0.41	8.22	***	Accepted
H4-c	Intention to adopt social robot → Sustainable performance	0.31	6.23	***	Accepted

*** Significance level: $p < 0.001$.

its original system technology concept by deploying it in a context where social robot adoption happens to SMEs. It shows that the framework has wide applicability for modeling more sophisticated and interactive technologies. In so doing, this study contributes to the theoretical debate by offering a more complex view of the forces in SMEs that can spill over into both apparent and less visible choices related to adoption decisions on technology thereby extending TOE framework.

Second, this article extends the theoretical basis of technology adoption models by including detailed functionalities enabled through a social robot's socio-cognitive capabilities and interaction potential. This suggests that future research models of R&D should incorporate dimensions capturing the social and interactive nature involved in using technology, especially when it is being examined for its adoption within contexts where human-technology interaction holds importance.

Finally, the study provides an explanation of what other resources might be necessary by means of identifying indirect pathways and resultant impacts, thus enhancing our theoretical under-sanding on how social robot adoption tilt towards broader organizational impact.

8.2. Managerial implications

The results of this study on social robot acceptance in SMEs carry important managerial implications. They give practical insights especially for SME business leaders and decision makers.

First, businesses looking to adopt social robots should heed the strategic implications of doing so. Managers need to weigh how they can balance the immediate operational upside with long-term impact on their business model and workforce. This work includes figuring out where social robots fit within a company's goals and processes, how they might enhance customer experiences or drive new market opportunities.

Second, the results highlight its impact on organizational readiness for applying social robots successfully. To get ready for social robot adoption, managers must investigate their organizations and ensure they can support the technologies with both capable infrastructure and technical know-how. In this regard, SMEs are constrained by a range of industrial organizational antecedents and their impact on social robot integration.

Finally, it reinforces that technology adoption decisions are influenced by external factors like market trends, stakeholder expectations, and government policies. Managers need to be aware of these external factors and modify their strategies with the same. That might mean talking to customers about their technology needs, monitoring what competitors are doing or keeping up with regulations.

8.3. Limitations and future research direction

Even though the study employs a broad analysis, there are areas which can be scrutinized further in follow-up research. First, the study concentrates on specific SME sectors it may restrict coherence with much other data. The generalizing capability of the results and their applicability to other industries could be further substantiated, in future research by considering a broader range of domains. However, the use of self-reported data may lead to response bias. Subsequent studies could use additional objective outcomes (e.g., performance measures) to validate the present results. A further limitation is that the study design implemented in this research objectification does not consider time, as it has a cross-sectional nature. Longitudinal studies need to be conducted to gain richer understanding of the changing landscape vis-a-vis social robot adoption by SMEs. Lastly, as the development of robot technology is advancing so quickly there is need for continuing research that follows on new trends in social robots and their consequences at SME level by extending to a variety type of social robots which affect different parts within an organization across services.

9. Conclusion

In conclusion, this study makes significant strides in understanding the adoption of social robots in SMEs, a subject of growing importance in the contemporary business landscape. By systematically exploring the antecedents and consequences of this adoption, the research provides a nuanced perspective on how SMEs approach and benefit from integrating advanced robotic technologies. Key findings reveal that technological, organizational, and environmental factors influence SMEs' decisions to adopt social robots. The study also demonstrates that the adoption of social robots can lead to enhanced operational efficiency, improved financial performance, and contribute to sustainable business practices.

Applying the TOE framework in this context offers a comprehensive lens to understand the multifaceted nature of technology adoption in SMEs. This study extends the theoretical understanding of technology adoption models and provides practical insights for SME managers. These insights emphasize the importance of a strategic approach to technology adoption, the necessity of organizational readiness, and the influence of external factors.

While insightful, the study acknowledges limitations, including its

sector-specific focus and the reliance on self-reported data, highlighting areas for future research. As technology evolves, ongoing research will be essential to keep abreast of emerging trends and their implications for SMEs. This study, therefore, stands as a foundational contribution to the field, offering a springboard for further exploration and understanding of the dynamic relationship between SMEs and social robots in an ever-changing business environment.

CRediT authorship contribution statement

Nazrul Islam: Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Conceptualization, Writing – original draft. **Sandip Rakshit:** Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization, Investigation. **Tripti Paul:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Data curation, Conceptualization.

Data availability

Data will be made available on request.

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