Drivers of Acceptance in Human-Robot Collaboration: Interpretative Insights from Healthcare Manufacturing

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Candidate declaration

I hereby declare that:

1. I have not been enrolled for another award of the University, or other academic or professional organisation, whilst undertaking my research degree.
2. None of the material contained in the thesis has been used in any other submission for an academic award.
3. I certify that this thesis is my own work. The use of all published or other sources of material consulted has been properly and fully acknowledged.
4. The work undertaken towards the thesis has been conducted in accordance with the SHU Principles of Integrity in Research and the SHU Research Ethics Policy, and ethics approval has been granted for all research studies in the thesis.
5. The word count of the thesis is 69,268.

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Abstract

Collaborative robots (cobots) are transforming healthcare manufacturing, offering better working conditions and greater productivity. Yet, most studies remain confined to lab settings, providing limited insight into how these robots perform in real-world settings. This gap calls for research that explores their practical application, challenges, and impact within actual organisational contexts. This thesis fills this critical gap by exploring how factors influencing the acceptance of collaborative robots shape system performance in healthcare manufacturing. It does so through three key objectives: (1) identifying critical factors influencing acceptance in collaborative robot applications, (2) developing a conceptual framework, grounded in empirical findings, that associates acceptance-related factors with system performance, and (3) offering actionable recommendations to create conditions that support favourable user responses to collaborative robots.

The research draws on a real-world case study at a leading global healthcare company in Germany, combining document analysis, eight participant observations, and 27 semi-structured interviews with employees and managers. Guided by reflexive thematic analysis, the study developed a holistic conceptual framework for understanding human-robot collaboration. This framework maps critical factors influencing the acceptance, and consequently system performance of collaborative robot applications to the input, process, and output dimensions across the individual and organisational levels. These factors include elements at the input dimension—such as human, robot, and environmental aspects—that shape attitudes towards collaborative robots. In turn, these input factors influence key dynamics at the process dimension. Ultimately, acceptance of collaborative robots is determined at the output dimension, which is directly reflected in system performance. Notably, emotional responses emerged as critical to the acceptance of these robots. Addressing employee concerns and supporting positive attitudes must be the central foci of any successful collaborative robot implementation strategy.

This study advances theoretical understanding at the intersection of human-robot collaboration and technology acceptance research by introducing a novel conceptual framework for analysing the acceptance of collaborative robots and how it shapes system performance. At the same time, it delivers practical insights for managers seeking to foster employee acceptance of collaborative robot integration and drive better outcomes in healthcare manufacturing. Derived from the conceptual framework, actionable recommendations tailored to specific employee groups are provided to inform the enhancement of existing collaborative robot applications and the strategic planning of future implementations.

Keywords: Collaborative robots, cobots, system performance, technology acceptance, healthcare manufacturing, reflexive thematic analysis, human factors, robot factors, organisational and environmental factors

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AJG	Academic Journal Guide
ANT	Actor-Network Theory
Cobot	Collaborative Robot
C-TAM-TPB	Combined Technology Acceptance Model and Theory of Planned Behaviour
DOI	Diffusion of Innovations Theory
ISO	Organization for Standardization
MM	Motivational Model
MPCU	Model of PC Utilisation
SCT	Social Cognitive Theory
SJR	Scimago Journal Rank
TAM	Technology Acceptance Model
TOE	Technology-Organisation-Environment Framework
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
UTAUT	Theory of Acceptance and Use of Technology
VET	Vocational Education Training (Apprenticeship)

Chapter 1: Introduction

1.1 Background to the thesis

Over the past centuries, the four industrial revolutions have each introduced transformative technological advancements that have fundamentally altered the nature of work in the manufacturing sector, steering it towards greater automation. In this context, the emergence of Industry 3.0 marked a turning point wherein robotic technology became integral to industrial operations, driving a paradigm shift towards automating manufacturing processes (Gasparetto & Scalera, 2019). The importance of this technology is further substantiated by its steadily growing adoption, with an annual growth rate of over 20% expected in 2025 (The Business Research Company, 2025a). Initially, these robots were housed within cages and primarily employed in production lines in large-scale manufacturing processes (Probst et al., 2024). Subsequent rapid technological advancements precipitated the development of successive generations of advanced robotic systems with enhanced flexibility and functionality (Kakade, Patle, & Umbarkar, 2023).

The notion of the fourth industrial revolution, commonly referred to as Industry 4.0, was first introduced at the Hannover Messe in 2011, which served as a critical juncture for its subsequent popularisation and adoption within industrial spheres (Musarat, Irfan, Alaloul, Maqsoom, & Ghufran, 2023). This phase of the industrial revolution is characterised by the integration of advanced technologies to facilitate the development of smart factories, wherein interconnected machines and equipment communicate autonomously and make data-driven decisions, with the overarching aim of optimising manufacturing efficiency and flexibility (Özköse & Güney, 2023).

Following the introduction of Industry 4.0, significant progress has been witnessed in the scale of implementation, the level of technological maturity, and the adoption trajectories of these advanced technologies within the manufacturing landscape (Enrique, Marodin, Santos, & Frank, 2023). However, the full-scale adoption of Industry 4.0 across all manufacturing sectors remains an ongoing challenge and has yet to be fully achieved. Thus, the concept of Industry 4.0 remains a prominent priority not only for many manufacturing enterprises worldwide but is also a matter of political significance on the agenda of the European member states (Carolis et al., 2025). In this context, the latest generation of robots, namely collaborative robots, or cobots, is recognised as one of the most promising technologies driving the transition towards Industry 4.0 in the manufacturing sector (Gualtieri, Fraboni, Marchi, & Rauch, 2022). Collaborative robots are designed to operate safely in close proximity to human operators without the necessity for physical safety barriers, offering greater flexibility and adaptability than previous generations of robots (Kakade et al., 2023).

Despite ongoing efforts to fully realise the potential of Industry 4.0 implementation, the advent of the fifth industrial revolution has been observed in recent years. Industry 5.0 builds on the technological foundation of Industry 4.0 by emphasising synergistic collaboration between humans and machines, aiming to achieve more personalised, sustainable, and socially responsible manufacturing outcomes (Musarat et al., 2023). The concept of Industry 5.0 was formally introduced by the European Commission a decade after the introduction of Industry 4.0 through collaborative efforts of researchers and industry practitioners to reorient industrial development (Breque, Nul, & Petridis, 2021). In the context of manufacturing processes, the Industry 4.0 approach is distinguished by a system-centric paradigm that focuses on technological efficiency and autonomous operations (Lu et al., 2022). In contrast, the Industry 5.0 approach is characterised by a human-centric orientation, emphasising the symbiotic collaboration between humans and advanced technologies to foster innovation, well-being, and sustainability (Lu et al., 2022). Within the trajectory toward Industry 5.0, collaborative robot technology is increasingly recognised as a decisive enabler, facilitating seamless human-machine interaction and supporting the paradigm shift toward human-centric, flexible, and sustainable manufacturing systems (Mukherjee, Raj, & Aggarwal, 2023).

The emergence of Industry 5.0 has led to the coexistence of two distinct industrial revolutions (Xu, Lu, Vogel-Heuser, & Wang, 2021). Both of these revolutions emphasise the critical importance of collaborative robots, primarily due to their unique technological capabilities to enhance the work conditions of human operators and the performance of manufacturing processes (Gualtieri et al., 2022). The enhancement of working conditions is predicated on the utilisation of collaborative robots for physically demanding, monotonous, or highly repetitive tasks, thereby enabling human workers to focus on more complex, intellectually stimulating, and value-adding tasks (Heinold, Funk, Niehaus, Rosen, & Wischniewski, 2023). Furthermore, the deployment of collaborative robots has been identified as a strategic approach for enhancing productivity while simultaneously reducing manufacturing expenses by optimising process efficiency and reducing reliance on human labour for repetitive tasks (Arents et al., 2021; Javaid, Haleem, Singh, & Suman, 2021).

While implementing novel technologies, such as collaborative robots, has the potential to deliver significant advantages, it is crucial to acknowledge that these innovations can concomitantly engender several challenges that require strategic consideration (Basile, Tregua, & Giacalone, 2024). For instance, collaborative robots facilitate novel forms of human-robot interaction, catalysing transformative processes within organisations that extend beyond task automation to reshape work structures, hierarchies, and organisational dynamics (Fraboni, Brendel, & Pietrantoni, 2023). Concurrently, it is vital to recognise that collaborative robots are no longer conceptualised solely as instrumental technologies to enhance productivity. Instead, they are now increasingly perceived as social agents within organisational contexts, functioning in ways analogous to human coworkers and actively shaping team dynamics and workplace interactions (Cascio & Montealegre, 2016; Jacob, Grosse, Morana, & König, 2023). In this context, social refers to the robot's capacity for interaction with employees and relationship-building within the workplace. This evolution necessitates a more nuanced and strategic approach to their integration than is typically required for conventional technologies (Wang, Lim, Cheah, & Lim, 2025).

Given the challenges previously outlined and the multifaceted implications associated with implementing collaborative robots, it is vital to examine their implementation in the context of technology acceptance research. The integration of such novel and advanced technological solutions into organisational structures exerts a substantial influence on their effective utilisation, which, in turn, plays a vital role in shaping the overall performance and adaptability of the organisational system (Hopko, Wang, & Mehta, 2022). In this context, employee acceptance of collaborative robots is considered an important factor, as it is likely to have a noticeable impact on organisational performance (Lambrechts, Klaver, Koudijzer, & Semeijn, 2021; Liang, Rasheed, Cai, Wibranek, & Awolusi, 2024; Prassida & Asfari, 2022). This gives rise to the central research problem and purpose: to explore the critical factors influencing the acceptance of collaborative robots and how these factors shape system performance in organisational settings. As such, the present study is intended as a stepping stone towards the broader goal of understanding system performance, defined here as the combined effectiveness and efficiency of all key elements—including employees, robots, processes, and organisational structures—in achieving manufacturing objectives.

1.2 Research problem and purpose

The motivation for this research stems from the increasing implementation of collaborative robots in manufacturing settings (The Business Research Company, 2025b), coupled with persistent organisational challenges and a growing demand for practical guidance among industry practitioners. Notably, literature from comparable contexts—such as the introduction of advanced manufacturing technologies—indicates that a substantial number of implementation efforts fail, not due to technological shortcomings, but rather because of organisational and human factors that impede successful adoption (Charalambous, Fletcher, & Webb, 2015; Kopp, Baumgartner, & Kinkel, 2021; Sukathong, Suksawang, & Naenna, 2021).

In addition to insights from the literature, the researcher's own experience with technology implementation projects has repeatedly underscored both the complexity and prevalence of these challenges in real-world settings. This direct exposure to implementation obstacles and practitioner concerns further highlights the need for focused research in this area, aiming to address widespread issues and support successful adoption of collaborative robots in manufacturing environments.

Gambao (2023) identified low employee acceptance as one of the most significant barriers to the successful implementation of collaborative robots. The relevance of investigating collaborative robot acceptance is further underscored by the consensus among study participants—including stakeholders from academia, robot manufacturers, and industry practitioners—that this issue constitutes a critical research problem. The impact of collaborative robot technology on production performance in the European Union has been rated as notable for the entire manufacturing sector, whilst highlighting the scope for even greater impact in specific enterprise contexts (Gambao, 2023; Liu & Son, 2024). Thus, understanding how factors influencing the acceptance of collaborative robots shape system performance constitutes a research problem of considerable scope and practical significance for the manufacturing sector.

However, as previously outlined, improving productivity and performance is not the sole goal of human-robot collaboration within the framework of Industry 4.0. Enhancing production performance is intrinsically linked to improving product quality and operational flexibility (Enrique et al., 2023). Furthermore, integrating this technology serves broader strategic purposes, including reducing dependency on manual labour, enhancing working conditions, and retaining skilled workers (Dornelles, Ayala, & Frank, 2023). Collectively, these factors significantly influence the performance and resilience of organisations.

In the context of human-robot collaboration, it is imperative to consider the performance of both the human and the collaborative robot as an integrated system, given their close interdependence during joint task execution. Consequently, the analysis of human-robot collaboration requires the consideration of the human, the collaborative robot, the work system, and the organisational context (Tomidei, Guertler, Sick, Paul, & Carmichael, 2024). This perspective posits that introducing a collaborative robot involves organisational change beyond mere reconfiguring work processes (Meissner, Trübswetter, Conti-Kufner, & Schmidtler, 2020). Following the same line of thinking, Hopko et al. (2022) emphasise the necessity to introduce a multidimensional assessment of human-robot collaboration, encompassing (1) human factors, (2) robot-specific capabilities, and (3) organisational and environmental determinants.

To the best of the researcher's knowledge, no empirical qualitative study has, to date, holistically explored the interrelated roles of the three critical dimensions—human factors, robot-specific capabilities, and organisational and environmental determinants—in understanding how the acceptance of collaborative robots influences system performance within real-world healthcare manufacturing settings. This points to a substantive research gap in the extant literature. Moreover, the necessity to conduct further analysis on the performance dynamics of human-robot teams is consistently highlighted by Di Pasquale et al. (2024), Rinaldi, Caterino, and Fera (2023), and Hopko et al. (2022). Additionally, the importance of drawing on empirical data from real-world industrial contexts is widely recognised across the literature (Liao, Lin, & Chen, 2023; Parvez, Arasli, Ozturen, Lodhi, & Ongsakul, 2022; Rossato et al., 2021). Therefore, it is essential to deliberately design the participant sample so as to mirror the diversity typically observed among employees in actual work settings, including aspects such as age, gender, educational background, job position, and other relevant demographic characteristics.

Identifying this research gap provides a compelling rationale for conducting the present study and serves as the foundation for the aim and objectives articulated in this thesis.

1.3 Aim and objectives of the thesis

This thesis can be placed in the intersection of human-robot collaboration and technology acceptance research. The central aim of this thesis is to understand employee acceptance of collaborative robots within real-world manufacturing environments and to elucidate the implications of this acceptance for system performance enhancement. In pursuing this aim, this thesis thus seeks to address the following research question:

How do factors influencing the acceptance of collaborative robots (cobots) shape system performance in the healthcare manufacturing sector?

To systematically address the research question, the thesis focuses on three objectives as follows:

1. ***To explore and identify the critical factors that influence the acceptance of collaborative robots (cobots) in the healthcare manufacturing sector.***
2. ***To develop a conceptual framework that illustrates how acceptance-related factors are associated with system performance, grounded in empirical insights and contextualised within existing theoretical perspectives on human-robot collaboration and technology acceptance.***
3. ***To derive actionable recommendations to create conditions for favourable user responses to collaborative robots (cobots) within the context of healthcare manufacturing.***

The aim and objectives outlined above establish the foundation for delineating the scope and boundaries of this thesis, which are presented in the following section. This ensures that the investigation of the research question is approached in a focused and methodologically coherent manner, thereby enhancing the study's conceptual clarity and analytical precision.

1.4 Scope and delimitations

The empirical and analytical focus of this study is on the healthcare manufacturing sector. This sector comprises companies manufacturing pharmaceutical and diagnostic products that comply with the requisite regulatory standards, ensuring the safety, efficiency, and quality of medical treatments and in-vitro diagnostic reagents. Integrating collaborative robots is particularly relevant to this sector for three key reasons, each underscoring the critical importance of targeted research in this field.

Firstly, the healthcare manufacturing sector is characterised by an increasing demand for efficient small-to-medium-sized manufacturing operations, primarily driven by the growing emphasis on personalised medicine and diagnostics (Horgan et al., 2020). Unlike traditional industrial robots, collaborative robots exhibit enhanced flexibility and adaptability, making them well-suited to manufacturing environments involving frequent product variations and reduced batch sizes. Secondly, collaborative robots can perform tasks involving hazardous materials and ergonomically strenuous tasks, reducing human exposure to occupational risks and mitigating repetitive strain injuries (Bi et al., 2021). This issue is of particular significance in the production of diagnostic products, where handling hazardous materials is commonplace and repetitive tasks such as packaging are routine. Finally, implementing collaborative robots enhances process reproducibility and precision while concurrently mitigating the potential for human error (Di Pasquale, Simone, Giubileo, & Miranda, 2023). This capability is paramount in highly regulated environments, such as the healthcare manufacturing sector, where compliance with strict quality and safety standards is mandatory. Thus, the implementation of collaborative robots holds the potential to support organisations in the healthcare manufacturing sector across multiple aspects.

However, it is imperative to note that any initiative about automation is typically preceded by a meticulous analysis of the most suitable technology to employ and the optimal configuration of the automated manufacturing process, which collectively inform the development of a robust business case for automation (Goh et al., 2020). However, the present thesis does not aspire to engage in such a decision-making process nor provide guidance. Instead, it is based on the assumption that the decision to implement collaborative robots has already been made following a thorough evaluation of the specific circumstances and requirements of the manufacturing context under consideration.

The defined scope and delineation of boundaries of this thesis provide the foundation for assessing its academic and practical significance and novelty. The following section further elucidates the relevance and distinctiveness of this research by presenting a detailed overview of its key contributions and unique features.

1.5 Significance and novelty of the research

Collaborative robots are increasingly recognised as one of the most salient technological advancements in the context of Industry 4.0, improving worker well-being and production performance (Cherubini et al., 2023; Gualtieri et al., 2022). Moreover, it is anticipated that this technology will play a pivotal role in the emerging paradigm of Industry 5.0, with scholars highlighting its potential to reshape human-centric production processes (Hassoun et al., 2024; Mukherjee et al., 2023).

In recent years, collaborative robots have become increasingly prevalent across diverse industrial manufacturing contexts (Weidemann et al., 2023). As Selvam, Aggarwal, Mukherjee, and Verma (2023) argue, implementing collaborative robots represents a significant advancement in industrial manufacturing, particularly in sectors such as healthcare manufacturing, where they are leveraged to enhance productivity, cost-effectiveness, and operational flexibility. Complementing this, Mathew, McGee, Roche, Warreth, and Papakostas (2022) reveal that integrating collaborative robots into drug manufacturing processes significantly enhances production performance, mainly by automating routine tasks. Further, supporting this perspective, a case study conducted by Rossi et al. (2020) demonstrates the benefits of collaborative robots in manufacturing biomedical products, emphasising their role in optimising process efficiency and product quality.

Furthermore, the significance of this research is reinforced by the growing recognition of the need for a holistic perspective when examining the complex, multifaceted implications of human-robot collaboration, as emphasised by Gervasi, Mastrogiacomo, and Franceschini (2020). Responding to this scholarly call, the present study adopts an integrated approach to exploring the critical factors influencing acceptance and system performance. Such a perspective advances academic understanding and yields practical implications for industry practitioners seeking to enhance operational efficiency, workforce adaptability, and system resilience amidst rapid digital transformation.

In addition, this research presents a series of actionable recommendations to create conditions for favourable user responses, positive attitudes towards, and acceptance of collaborative robots. As Fraboni et al. (2023) noted, when collaborative robots are thoughtfully implemented, they can simultaneously enhance productivity and worker satisfaction. The recommendations developed in this thesis are designed to support managers in successful human-robot collaboration, making the research highly relevant for industry practitioners seeking to optimise their operations using collaborative robots. Thus, the present thesis directly responds to the concerns articulated by Selvam et al. (2023) regarding the complexities of implementing collaborative robots within healthcare manufacturing settings by offering contextually grounded strategies that address both technical and organisational barriers to adoption.

Beyond its significance, this research is distinguished by several novel contributions. Firstly, it presents an in-depth analysis of technology acceptance in the context of collaborative robots. By systematically investigating the critical determinants of acceptance and how they shape system performance, this study addresses a notable gap in existing research, particularly within industrial settings where collaborative robots are increasingly being implemented. This contribution is supported by the findings of Hopko et al. (2022) and Di Pasquale et al. (2024), who both highlight the relative neglect of technological, organisational, and environmental dimensions in studies of human-robot collaboration. In response, this research adopts a holistic perspective, integrating multilevel influences to extend the current understanding of system performance beyond the conventional scope of human factors, which, as outlined by Nobile, Bibbo, Russo, and Conforto (2024), has been the primary focus to date.

By doing so, this research advances theoretical discourse by moving beyond the individual-centric paradigm and incorporating a more nuanced exploration of the complex, interdependent factors influencing the successful adoption of collaborative robots. This multidimensional approach is critical for capturing the full spectrum of influences on collaborative robot adoption, allowing for a more detailed and context-sensitive foundation for both academic inquiry and practical implementation.

Secondly, the present research makes a significant contribution through its empirical investigation of the determinants of acceptance and system performance in collaborative robot deployment. Based on the empirical data, this study proposes a conceptual framework that offers a nuanced and structured lens to understand how the integration of collaborative robots in manufacturing settings can be evaluated and optimised to ensure that the potential benefits of this technology are fully realised. This study not only introduces new knowledge but also strengthens the contextual applicability of established theories by drawing on them in the discussion, specifically in relation to the complexities of collaborative robot adoption in manufacturing contexts.

Finally, the study's sector-specific focus on healthcare manufacturing adds a layer of contextual specificity and relevance that enhances the practical applicability of the findings. As noted by Mathew et al. (2022), the healthcare manufacturing sector stands at a pivotal juncture where the integration of collaborative robots could substantially shape the industry's future landscape. The urgency of this investigation is further reinforced by Borboni et al. (2023), who observe that collaborative robot adoption in the pharmaceutical industry remains markedly lower than in more automation-intensive sectors such as automobiles, electronics, and food and beverage. By grounding the analysis in a real-world manufacturing setting, this study generates evidence-based and actionable insights regarding the performance implications of collaborative robot implementation. These insights are particularly valuable for industry stakeholders aiming to overcome adoption barriers and align technological advancements in the healthcare manufacturing sector.

Moreover, the empirical analysis of collaborative robots within an actual manufacturing context also constitutes a core dimension of this study's originality and scholarly contribution. Liao et al. (2023) emphasised that research grounded in real-world industrial settings provides a deeper and more authentic understanding of the socio-technical dynamics influencing the adoption of collaborative robots. This methodological choice is particularly significant given the observation by Picco, Miglioretti, and Le Blanc (2024), who posit persistent challenges in recruiting participants from industrial manufacturing settings due to operational sensitivities, confidentiality concerns, and resource constraints. In light of these challenges, the ability to secure access to a functioning manufacturing site actively deploying collaborative robots emerges as a distinctive feature of the present study.

Following the preceding discussion of the research's significance and novelty, the next section introduces the qualitative approaches to technology acceptance research, closely aligned with the main objectives of the thesis. Given the focus on human-robot collaboration and technology, particularly regarding the complex, context-dependent nature of collaborative robots, a qualitative research design is considered highly appropriate.

1.6 Qualitative approaches to technology acceptance research

Four arguments support the suitability of the qualitative research approach, each aligned with the overarching aim and objectives of the thesis. Firstly, qualitative research is inherently exploratory in nature and particularly effective in generating a deep, nuanced understanding of a phenomenon through detailed, context-rich data (Lim, 2024). This approach is congruent with one of the research objectives of the thesis, which aims to explore and identify the critical factors influencing employee acceptance when deploying collaborative robots. Moreover, the emphasis on human-robot collaboration necessitates an approach that accounts for users' experiences, perceptions, and interactions with these robots (Veling & McGinn, 2021). Further, a review of existing studies in the field reveals that qualitative methods, encompassing interviews and observations, are particularly well-suited for capturing the multifaceted nature of human-robot interactions in organisational settings (Veling & McGinn, 2021).

Secondly, another key objective of the thesis is to create a conceptual framework grounded in the insights derived from the collected data. By exploring how these factors are associated and interact, the research aims to construct a coherent and theoretically informed representation of the technology acceptance dynamics and contextual influences shaping system performance. Shah and Corley (2006) posit that qualitative research is particularly well-suited for developing conceptual frameworks, as it facilitates the synthesis of rich, contextually embedded insights that are often essential for theory building.

Thirdly, to formulate actionable recommendations aimed at fostering favourable user responses to and attitudes towards collaborative robots, it is necessary to have a deep, context-sensitive understanding of the phenomenon under investigation, which captures the subtleties of users' experiences, concerns, and expectations. These detailed insights enable the development of specific, contextually relevant, and practically applicable recommendations rather than generic or superficial solutions (Braun & Clarke, 2013).

Demonstrating functional reflexivity, the researcher recognises that the choice between qualitative and quantitative approaches is not merely a methodological decision. Instead, as Veling and McGinn (2021) assert, it is inherently linked to the epistemological and ontological assumptions underpinning the research. In this research, the qualitative approach is consistent with the constructionist worldview of the researcher, which recognises the subjective and socially constructed nature of human experience—particularly relevant when investigating the multifaceted nature of human-robot interactions.

Having established the rationale for adopting a qualitative research approach, it is equally important to consider the role of the researcher within this interpretive framework. In qualitative inquiry, the researcher is not merely a neutral observer but an active participant in the research process, whose positionality and background can shape data collection, interpretation, and analysis (Braun, Clarke, & Hayfield, 2022). The following section provides insight into how the researcher's background may influence the research process and the interpretation of the findings.

1.7 Role of the researcher

Before and during the preparation of this thesis, the researcher held a managerial role in one of the manufacturing departments of the healthcare company that serves as the focal context of this research. Possessing nearly two decades of professional experience across various positions in the healthcare manufacturing sector, the researcher has gained a deep and nuanced understanding of operational processes, organisational dynamics, and the integration of new technologies, including collaborative robots.

It is important to acknowledge that the researcher's perspective is shaped not only by extensive practical experience but also by a strong scientific foundation in natural sciences. This fosters a clear preference for structured processes and an analytical approach in the researcher's professional practice and thinking. Despite philosophical commitments to a qualitative and constructionist paradigm, the wording used in this thesis may at times reflect influences arising from the researcher's disciplinary background. An example of this is the deliberate use of third-person references to the author of this research throughout the thesis. While this is not standard practice in all qualitative approaches, it serves to foster reflective neutrality rather than full subjectivity, ensuring a balanced and transparent presentation of the research process and findings. The researcher remains mindful of these disciplinary influences stemming from a natural science-oriented healthcare manufacturing background, and promotes transparency and rigor by actively acknowledging this disciplinary context.

Another important aspect is that the researcher's insider perspective offers distinct advantages that enhance the depth and relevance of the study. In particular, the researcher's organisational position facilitated privileged access to key data sources and research participants with specialist knowledge and direct experience using collaborative robots in the healthcare manufacturing sector. This insider access facilitates a more nuanced understanding of the practical challenges, contextual dynamics, and organisational implications of deploying collaborative robots. Consequently, the findings of this study are grounded in real-world application, thereby contributing both theoretically and practically to the emerging discourse on human-robot collaboration in complex manufacturing environments.

Despite the advantages mentioned above, the researcher acknowledges the potential for personal bias to be inherited when conducting insider research. Several procedural safeguards were implemented during the data collection process to mitigate this risk and enhance the credibility of the findings. First, the interview protocol was piloted and subjected to critical review by peers and supervisory committee members to ensure clarity, neutrality, and relevance (Majid, Othman, Mohamad, Lim, & Yusof, 2017). This step helped to refine the questions and minimise the influence of researcher assumptions. Furthermore, participants were allowed to review their interview transcripts for accuracy, provide feedback, and clarify or elaborate on their responses as necessary. This process of respondent validation (also known as member checking) contributed to the trustworthiness and confirmability of the data by ensuring that the participants' perspectives were accurately represented (Motulsky, 2021).

In addition, the researcher has adopted a reflexive stance throughout the study, critically examining the potential influence of personal biases on the research process and outcomes. This approach aligns with Cunliffe's (2003) argument that researchers must participate in constituting knowledge and shaping the research context. To support this view, the researcher maintained a systematic record of reflexive thoughts and experiences in the form of memos throughout the research process. This practice fostered self-awareness and enhanced the transparency of the analytical process, as advocated by Attride-Stirling (2001). This approach was instrumental in contributing to the credibility of the findings, particularly in instances where participant perspectives diverged significantly from the researcher's. Moreover, the researcher's theoretical orientation and positionality were explicitly acknowledged, following Braun and Clarke's (2006) guidance on the importance of situating the researcher within the interpretive process. To maintain ongoing awareness of potential biases, regular reflective discussions were held with peers and supervisors, ensuring that critical scrutiny informed each stage of the research.

Moreover, to fully capture the context and implications of this research, it is imperative to define the key terms central to the study. Establishing this clear conceptual vocabulary is fundamental to ensuring consistency, precision, and coherence throughout the research.

1.8 Definition of key terms

Specifically, these key terms include "collaborative robot", "collaborative manufacturing setup", and "system performance". The following subsections provide detailed definitions of each term within the scope of the study.

Collaborative robot

Collaborative robots, commonly called cobots, are programmable machines capable of interacting physically with their environment and executing complex tasks by manipulating objects alongside human operators (Gervasi et al., 2020; Nichols, 2020). Unlike traditional industrial robots, typically isolated in fenced-off areas for safety reasons, collaborative robots are specifically designed to interact closely with humans, enabling direct and safe human-robot interaction. The notion of collaborative robots was initially proposed in 1996 (Colgate, Wannasuphoprasit, & Peshkin).

Even though the concept of collaborative robot technology was first introduced almost 30 years ago, the first commercially available collaborative robot was not launched until 2004 (Kakade et al., 2023). Furthermore, it was not until 2015 that a broader range of collaborative robots from various manufacturers became widely available in the commercial market (Kakade et al., 2023).

In response to the growing adoption of collaborative robots in industrial environments, the International Organization for Standardization (ISO) has published a series of standards to govern their safe and effective utilisation. Specifically, ISO 10218 outlines the general safety requirements for industrial robots, including provisions for their integration into work processes, and addresses key considerations pertinent to collaborative operations (International Organization for Standardization, 2011). Building upon this, ISO/TS 15066 was introduced as a supplement to the standard above, providing a comprehensive set of specific requirements and guidelines that are particularly relevant to collaborative robots (International Organization for Standardization, 2016). These guidelines emphasise the critical aspects of risk assessments and safety requirements, ensuring human operator safety when working with collaborative robots. Consequently, it is imperative to recognise the significance of these standards in the practical implementation of collaborative robots within industrial contexts, as they provide a framework for the safe and effective integration of such robots into diverse industrial applications.

Collaborative manufacturing setup

The advent of collaborative robotics provides a valuable technological option for manufacturing companies. However, it simultaneously necessitates a series of strategic decisions. One of the primary considerations is selecting the most appropriate manufacturing setup for a given operational context. Broadly, these setups can be classified into three categories: fully manual setups, in which all tasks are performed exclusively by humans; collaborative setups, where humans and collaborative robots work alongside one another; and fully automated setups, typically involving traditional industrial robots operating autonomously.

The selection among these alternatives depends on several key selection criteria identified in the literature: (1) production volume, (2) batch size, (3) flexibility needed, and (4) number of variants required to produce (Heilala & Voho, 2001; Malik & Bilberg, 2017; Rosati, Faccio, Carli, & Rossi, 2013). Based on these criteria, manufacturing units can decide which manufacturing setup is most appropriate for their particular situation, as shown in Figure 1-1. Aligning the manufacturing setup with these criteria is essential for operational efficiency and effectiveness.

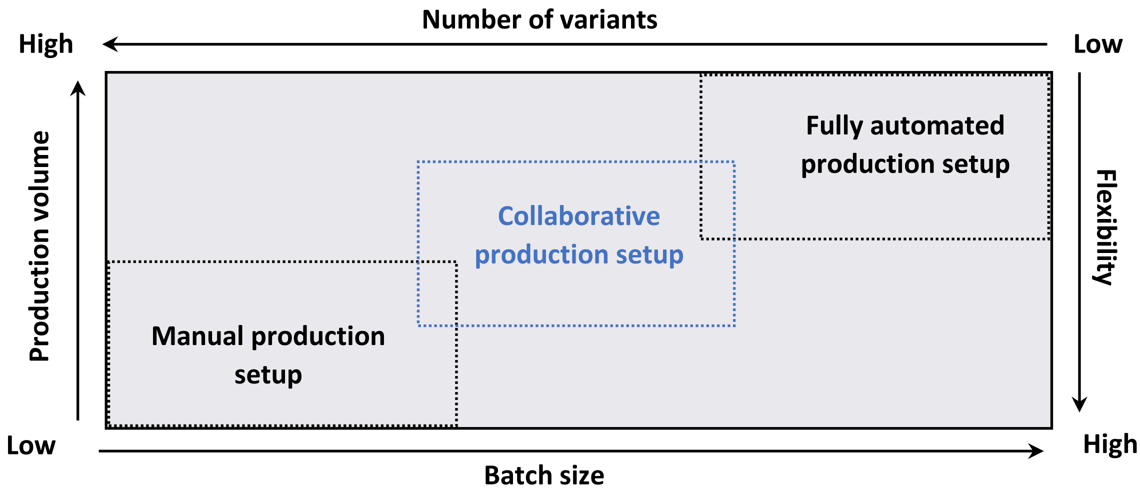


Figure 1-1: Criteria for manufacturing setup (Sources: Heilala & Voho, 2001, p. 23; Rosati et al., 2013, p. 9)

Once it has been established that a collaborative manufacturing setup utilising a collaborative robot is the most suitable approach, the organisation must then determine the nature and extent of interaction between human operators and the collaborative robot. According to ISO/TS 15066, collaborative operations are defined as "a state in which a purposely designed robot system and an operator work within a collaborative workspace" (International Organization for Standardization, 2016, p. 1). This definition is particularly significant because it highlights a critical distinction: not all collaborative robots are necessarily utilised in collaborative operations. While a collaborative robot is designed with collaborative capabilities, it may still operate in isolation from human workers, depending on the specific task requirements.

Both decisions—the selection of the manufacturing setup and the level of interaction within the collaborative operations—are presented in this thesis to provide an overview of the context in which the usage of collaborative robots may be appropriate.

System performance

Following the decision to implement a collaborative robot, questions concerning the productivity and performance of the manufacturing system become central, particularly from a management perspective. Accordingly, the term system performance needs to be defined. However, it is important to acknowledge that neither the assessment criteria nor the boundaries of system performance are universally fixed. In practice, the definition and assessment of system performance depend on the priorities of key stakeholders—such as direct managers and employees—and may encompass a variety of dimensions. Where these boundaries are set—and which elements are included as part of the system—is thus a critical question that determines both the scope and interpretation of performance outcomes.

Drawing on the concept of human-robot team productivity as proposed by Chen, Yang, Gu, and Hu (2022), system performance is understood not solely in terms of the immediate performance of the collaborative robot but more broadly as the outcome of the interaction and synergies between human operators and the entire manufacturing process. This integrative perspective emphasises the synergies between humans and collaborative robots within a shared workspace, reflecting a holistic approach to evaluating performance (Tomidei et al., 2024).

Accordingly, the concept of system performance necessitates a holistic perspective, evaluating the interconnectivity and reciprocal influence of all system components on the overall manufacturing process output (Hopko et al., 2022). This conceptualisation moves far beyond the conventional understanding of performance, which is often narrowly defined in terms of productivity metrics—typically calculated as the output-to-input ratio (Coronado et al., 2022). While such quantitative assessments remain relevant, they fail to capture the nuance involved in human-robot interaction in a collaborative manufacturing setup, where dynamic interactions between human operators, collaborative robots, and the broader organisational and physical context shape performance. Therefore, a nuanced understanding of system performance requires an integrative approach that recognises collaborative robots not as isolated technological tools but as embedded and interactive elements within the socio-technical fabric of the manufacturing process (Hopko et al., 2022).

As the present thesis focuses primarily on acceptance factors in collaborative robot deployment, its findings should be regarded as a stepping stone towards a more nuanced understanding of system performance in human-robot collaboration—underscoring the importance of human factors while acknowledging that further insights will depend on the integration of additional dimensions. In this context, the meaning and boundaries of system performance are collaboratively defined by the study's participants—namely, employees and managers—whose perspectives illuminate which facets of performance are considered most salient within their operational environment.

Following the definition of the key terms, the next step in this thesis is to outline the research strategy roadmap. To lay the foundation for the research strategy, the contents of each chapter are subsequently presented.

1.9 Research strategy roadmap

The research strategy roadmap is designed to guide readers by providing a concise overview of the thesis structure, as illustrated in Figure 1-2. This roadmap has been instrumental in shaping the structure of the thesis to address the research question and objectives systematically. It outlines a coherent and logical progression of topics, ensuring that each chapter builds upon the preceding one and facilitates a cumulative and in-depth appreciation of the study's findings and their broader implications. The arrows from the introduction and the literature review to the discussion and conclusion chapter highlight how this chapter draws on the study's original objectives and theoretical background.

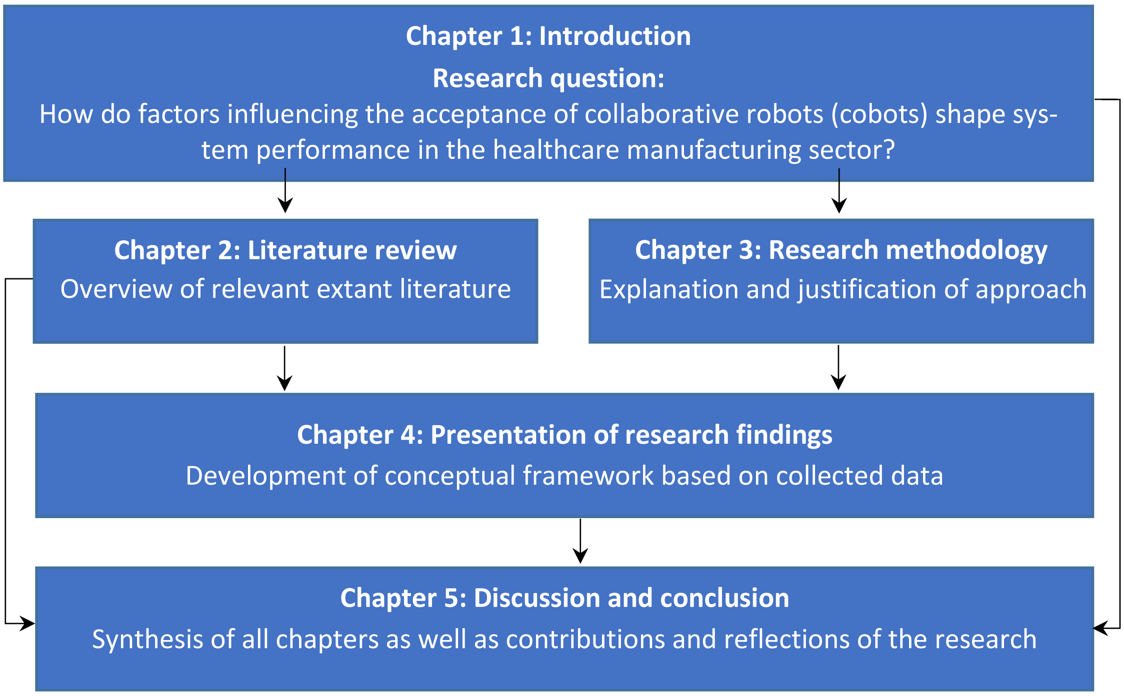


Figure 1-2: Research strategy roadmap

Building on this roadmap, the thesis is structured into five chapters; each contributes incrementally and significantly to the overarching narrative of the study.

Chapter 1: Introduction

Firstly, the background of the research, the research problem, and the purpose are outlined. Subsequently, the aim and objectives of the thesis are delineated while clarifying its scope. The thesis's significance and its novelty are then discussed. Furthermore, the rationale for adopting a qualitative research approach is presented alongside a critical reflection on the researcher's positionality and its potential influence on the study. Finally, the key terms are defined, and the overarching research strategy employed to achieve the stated aim and objectives is presented.

Chapter 2: Literature review

In this chapter, a comprehensive review of the extant literature is conducted, offering a critical overview of the current state of knowledge about the substantive focus of the study. This review thus provides the conceptual and theoretical foundation for the research by positioning the study within the broader scholarly discourse.

Chapter 3: Research methodology

The chapter outlines the philosophical foundations underpinning the study, including its ontological, epistemological, and axiological assumptions. The research design is then presented, including the mode of enquiry, sampling strategy, and data collection and analysis procedures. In addition, ethical considerations are addressed, alongside a critical reflection on the methodological strengths and limitations of the study, thereby establishing the trustworthiness of the research approach.

Chapter 4: Presentation of research findings

This chapter presents the research findings derived from the qualitative data collected. It includes identifying and examining critical factors influencing acceptance and thus shaping system performance when deploying collaborative robots in the healthcare manufacturing context, using reflexive thematic analysis as the analytical approach. Drawing on these findings, a conceptual framework is proposed to advance the understanding of technology acceptance in the specific context of collaborative robotics.

Chapter 5: Discussion and conclusion

The chapter synthesises the key findings of the study and situates them in relation to existing literature, highlighting areas of convergence and divergence with prior research. The subsequent discussion addresses the study's contribution to knowledge and business practice, demonstrating its theoretical and practical relevance. Finally, the thesis concludes with personal reflections on the research process and the insights gained, followed by a critical discussion on the study's limitations and proposing directions for future research.

Chapter 2: Literature review

2.1 Introduction

As indicated in the research strategy roadmap, this chapter provides a comprehensive review of the literature on human-robot collaboration and technology acceptance, focusing on the manufacturing sector, through the critical examination of key concepts and theories, as well as conceptual and empirical studies related to the implementation of collaborative robots. In doing so, it underlines the significant gaps in the existing literature, thereby justifying the relevance and necessity of the present study.

The research gap addressed in the study stems from the insufficient investigation of how factors influencing technology acceptance shape system performance in human-robot collaboration. While existing studies often focus on isolated technical or human dimensions, there remains a lack of multifaceted analyses that integrate human, robotic, organisational, and environmental factors as interdependent components influencing performance outcomes (Hopko et al., 2022). Moreover, the research gap is compounded by the scarcity of empirical research grounded in real-world industrial manufacturing contexts involving collaborative robots.

In addition, the literature review provides a more detailed examination of the previously identified research gap through critically analysing the selected publications. A structured literature review was carried out to achieve these objectives, reflecting the importance of a trustworthy and credible knowledge base as highlighted by Tranfield, Denyer, and Smart (2003).

2.2 Literature review process

The literature review was conducted following a structured literature review process, as suggested by Denyer and Tranfield (2011). This approach entails a systematically preplanned and transparent process that involves the identification of available literature, establishing explicit inclusion and exclusion criteria, and structuring and synthesising selected studies. Its objective is to comprehensively understand what is currently known and identify gaps in the existing body of knowledge (Denyer & Tranfield, 2011). This process is particularly well suited to the present research, as it provides a systematic method to assess the literature rigorously.

In the present study, the structured literature review is organised into three phases: (1) planning the review, (2) conducting the review, and (3) reporting the findings, as outlined by Tranfield et al. (2003). The following sections provide a detailed account of the three phases, encompassing the criteria for selecting pertinent literature and the analytical procedures used to synthesise and present the results in the literature review.

2.2.1 Planning the literature review

The initial step in the planning phase of the literature review involved deriving the guiding questions from the research question and the stated research objectives to direct the current literature review. These guiding questions, which are illustrated in Table 2-1 below, structured the current literature review and ensured that conceptual coherence was maintained throughout the process.

Research question	
How do factors influencing the acceptance of collaborative robots (cobots) shape system performance in the healthcare manufacturing sector?	
Literature review's guiding questions	**Research objectives**
Which theoretical perspectives and models are relevant for studying the implementation of collaborative robots?	To develop a conceptual framework that illustrates how acceptance-related factors are associated with system performance, grounded in empirical insights and contextualised within existing theoretical perspectives on human-robot collaboration and technology acceptance. (Objective 2)
What are the key components of system performance when using collaborative robots in manufacturing environments?	To explore and identify the critical factors that influence the acceptance of collaborative robots (cobots) in the healthcare manufacturing sector. (Objective 1)
Which aspects of human perception and attitude hinder or promote the utilisation of collaborative robots?	To derive actionable recommendations to create conditions for favourable user responses to collaborative robots (cobots) within the context of healthcare manufacturing. (Objective 3)

Table 2-1: Overview of literature review's guiding questions

Following the formulation of the guiding questions, a scoping study of relevant scholarly articles was conducted to identify the keyword usage in the existing literature, as Vrontis et al. (2022) recommended. This preliminary analysis facilitated the derivation and refinement of search terms tailored to the thematic focus of the literature review, as informed by the guiding questions.

The identified keywords and search terms were subsequently grouped into five categories, collectively streamlining the literature search process. These categories include the research area, the research field, the technology, the activity type, and the results. The structure of the literature review, developed on the basis of these categories, keywords, and search terms, is delineated in Table 2-2.

The literature review commenced with a broad scope, which was then progressively narrowed to encompass the most pertinent extant literature, as suggested by Creswell and Plano Clark (2018). The balance between comprehensiveness and precision was considered when developing the search strategy, as recommended by Alderson, Green, and Higgins (2004). This recommendation was operationalised in the present literature review by carefully selecting and structuring search terms within each category.

Category	Keywords	Search terms
Research area	**Human-robot interaction**	HRI Human-robot interaction Human-robot collaboration Human-robot cooperation
Research field	**Technology acceptance**	Technology acceptance Technology adoption Technology utilization Technology diffusion
Technology	**Collaborative robot**	Collaborative robot Cobot Human-centric robot Cooperative robot
Activity type	**Production**	Production Assembly Manufacturing
Result	**Performance**	Performance Productivity Efficiency Effectiveness

Table 2-2: Search terms

The search terms are defined as direct synonyms of the keyword within the given category, morphological variants, or semantically related terms capturing similar conceptual meanings. Such a strategy is particularly salient in interdisciplinary research areas where standardised terminology is lacking (Grames, Stillman, Tingley, & Elphick, 2019). A relatively new and rapidly evolving interdisciplinary research area, such as human-robot interaction focusing on collaborative robots, exemplifies such a situation (Gualtieri et al., 2024). By accounting for terminological diversity, this search strategy enhanced the comprehensiveness of the literature review while simultaneously improving precision through the use of contextually relevant queries.

The initial category delineates the research area, encompassing human-robot interaction as a broad concept. This category is comprehensive in scope, encompassing a wide spectrum of human-robot interactions, including both cooperative and collaborative dynamics. It is acknowledged that these interaction settings are deemed most relevant in the context of interaction between humans and collaborative robots where they share a workspace (Heo, Putri, Kim, Kwon, & Kim, 2024). The second category is the research field, which resides at a more specific level within the broader research area. The research field focuses on technology acceptance, thereby narrowing the scope of inquiry to studies that investigate cognitive, behavioural, and organisational responses to accepting technological innovations. In the context of the implementation of collaborative robots, the terms technology adoption and diffusion are found to be relevant, as they offer frameworks for understanding how individuals and organisations perceive, adopt, and utilise novel technologies within the existing workflows.

The third category focuses on the technology under investigation, namely collaborative robots. The fourth category pertains to the activity type, further refining the literature to studies within production, assembly, and manufacturing environments. Finally, the results category concentrates on the outcomes associated with integrating collaborative robots into work systems. By structuring the literature review through these hierarchical categories, the research is systematically guided toward addressing the research questions.

The five categories were combined during the structured search using the Boolean operator "AND" to ensure that retrieved publications covered all distinctive dimensions of the research scope. Within each category, synonymous or related search terms were combined using the Boolean operator "OR" to capture relevant literature comprehensively. The search string was thus configured as follows: (("human-robot interaction" OR "HRI" OR "human-robot collaboration" OR "human-robot cooperation") AND ("technology acceptance" OR "technology adoption" OR "technology utilization" OR "technology diffusion") AND ("collaborative robots" OR "cobot" OR "human-centric robots" OR "co-operative robots") AND ("production" OR "assembly" OR "manufacturing") AND ("productivity" OR "efficiency" OR "effectiveness" OR "performance")). Combining several alternative keywords with Boolean operators aligns with the best practices recommended by Vrontis et al. (2022). Moreover, following the guidance of Andresen and Bergdolt (2017), no temporal restrictions were imposed on the search to ensure a longitudinal understanding of the scholarly discourse on implementing collaborative robots in industrial settings.

Moreover, using Boolean logic further facilitates flexibility in capturing a diverse range of terminologies and concepts within each category, thereby mitigating the risk of omitting key studies due to inconsistent terminology. The following figure illustrates the structured search strategy, with the blue outline delineating the subset of the literature identified as relevant based on the applied inclusion criteria and Boolean logic.

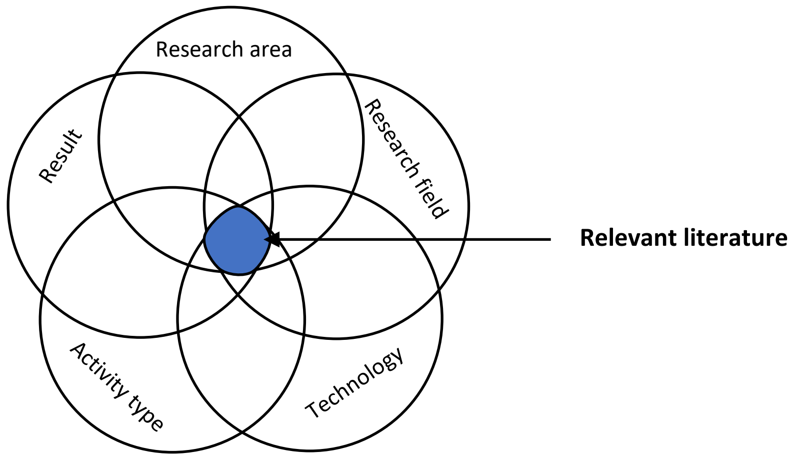


Figure 2-1: Identified relevant literature

The structured search strategy ensures the identification of relevant literature that comprehensively addresses the subject area. However, it is important to acknowledge the potential limitations associated with this process. According to Tranfield et al. (2003), these limitations can be attributed primarily to the fact that the review process is mainly informed by the judgments of an individual researcher rather than by a panel of experts in the field of human-robot collaboration and technology acceptance. To enhance methodological robustness, suggestions from supervisors and peers were taken into account during the planning phase. This provided critical external perspectives, helped to identify potential blind spots and contributed to reducing selection bias, thereby strengthening the thoroughness of the review process.

2.2.2 Conducting the literature review

The next phase of the structured literature review, the conducting phase, commences with selecting relevant academic databases (Piccarozzi, Aquilani, & Gatti, 2018). This step is of critical importance as the selection of databases directly influences the breadth and depth of the literature available for review. Following the selection of databases, the subsequent step involved the systematic selection of relevant publications. Predefined inclusion and exclusion criteria ensured alignment with the research question and objectives (Piccarozzi et al., 2018). The selection criteria were guided by scholarly quality and topical relevance, emphasising studies that substantively contribute to the discourse on human-robot collaboration and technology acceptance. After selecting relevant publications, a comprehensive analysis was undertaken, extracting and synthesising key findings, as proposed by Tranfield et al. (2003). These synthesised insights were organised and presented in the literature review. The sequence of steps outlined in the conducting phase adheres to the structured methodology proposed by Piccarozzi et al. (2018), as shown in Figure 2-2.

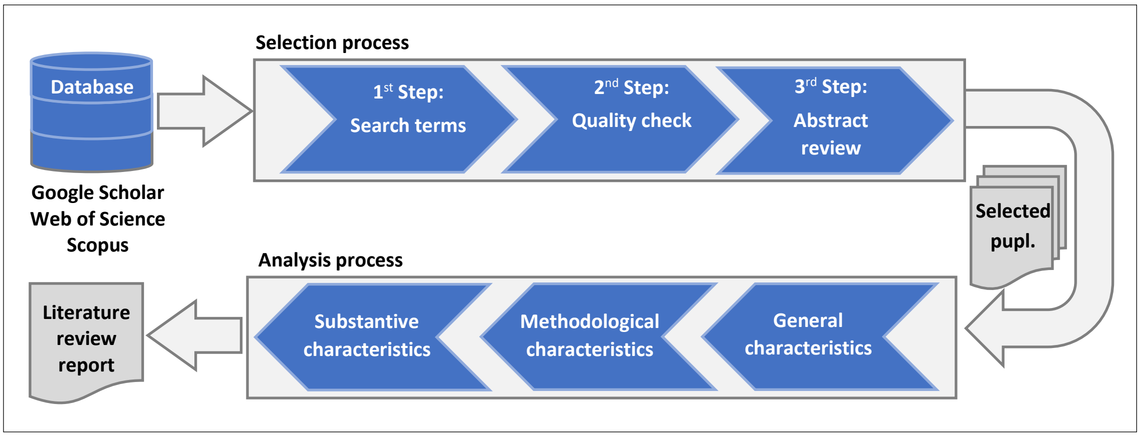


Figure 2-2: Conducting phase: Process steps of structured literature review (Source: Piccarozzi et al., 2018, p. 3)

Each stage is delineated below to facilitate a comprehensive understanding of the literature review process, commencing with the selection of databases. The current literature review draws upon multiple sources, including one academic search engine and two multidisciplinary bibliographic databases: Google Scholar, Web of Science, and Scopus.

Google Scholar was selected as it is the most thorough repository of academic data, providing broad coverage across disciplines and publication types, as emphasised by Gusenbauer (2019). Furthermore, Web of Science and Scopus were utilised to enhance the quality and breadth of the literature review. Both databases are recognised for their extensive indexing of peer-reviewed journals. Further, they are classified by Gusenbauer (2019) as among the largest and most comprehensive bibliographic data sources available for academic research.

After identifying the relevant databases, the process of selecting publications for the literature review was initiated. The initial step in this process involved formulating and refining keywords and search terms. The present literature review employed keywords such as "human-robot interaction", "technology acceptance", "collaborative robot", "production", and "performance", along with their corresponding synonyms, as previously defined during the planning phase and illustrated in Table 2-2. The search was conducted across all selected databases and was finalised on January 2, 2025, marking the date of the most recent update. The outcomes of the search process, including the number of publications retrieved from each database, are summarised in Table 2-3.

	Google Scholar	**Scopus**	**Web of Science**	**Total**
1st Step: Search terms based on Table 2-2	890	226	8	**1,124**

Table 2-3: 1st Step literature review–search terms

The results obtained from the initial step, as shown in Table 2-3, were subsequently refined through a quality assessment of the pre-selected publications. This step aimed to ensure the inclusion of only high-quality, peer-reviewed literature by excluding all non-peer-reviewed publications. Following the recommendations of Piccarozzi et al. (2018), the selection process excludes monographs, editorial notes, books, and conference proceedings, as these may lack the methodological rigour typically required in scholarly research. The Scopus and Web of Science databases facilitated this filtering process by allowing the application of the filter option "document type" criteria to isolate articles and reviews. In the case of Google Scholar, which lacks equivalent filtering capabilities, the metadata of selected publications was manually reviewed and filtered based on source and publisher credibility to ensure alignment with expected academic standards.

The selection process was further refined by restricting the scope of publications to those written in English. Subsequently, duplicate records in multiple data sources were identified and excluded. The table below illustrates the final number of unique publications retained after eliminating duplicates. Furthermore, for transparency, the total number of publications retrieved before deduplication is also given in parentheses.

	Google Scholar	Scopus	Web of Science	Total
2nd Step: Quality check	417	56 (167)	1 (7)	**474 (591)**

Table 2-4: 2nd Step literature review–quality check

The last step in the selection process involved a detailed screening of abstracts. All 474 previously selected publications were assessed based on the content of their abstracts to determine their substantive relevance to the research topic. Only those publications that explicitly aligned with the research objectives and addressed the core questions guiding this literature review were retained for further analysis.

Consequently, publications that did not meet these criteria were excluded, particularly those focused on domains outside the manufacturing sector, such as travel and tourism, retail, agriculture, clinical settings, and construction. Moreover, the scope of the review was exclusively limited to studies on physical collaborative robots, thereby excluding research related to digital assistants or purely virtual agents. The number of publications remaining after this screening process is presented in Table 2-5.

	Google Scholar	Scopus	Web of Science	Total
3rd Step: Abstract review	57	6	0	**63**

Table 2-5: 3rd Step literature review–abstract review

A summary of the publication selection process, encompassing the three steps described above, is depicted in Figure 2-3. For instance, the figures presented herein highlight the number of publications initially identified, the number of publications excluded based on the predefined inclusion and exclusion criteria, and the final number of publications retained for in-depth analysis following the abstract review. This visual depiction facilitates comprehension of the adopted structured approach and underscores the rigour applied at each process step.

1st Step: Search Terms	2nd Step: Quality Check	3rd Step: Abstract Review
Search terms: **Based on Table 2-2** **Keywords** Human-robot interaction Technology acceptance Collaborative robot Production Performance (plus, listed synonyms)	**Requirements:** Peer-reviewed journal English publication (duplicate publications were excluded)	**Requirement:** Abstract with substantive relevance to the research question
Total results of publications (data source: Google Scholar, Web of Science, Scopus)		
1,124	**474 (591)**	**63**

Figure 2-3: Literature review process at a glance

2.2.3 Reporting the literature review

The 63 publications selected for inclusion in the literature review are listed in Appendix A.1. These publications thus establish the literature-based foundation for the reporting phase of the structured literature review. Following the framework proposed by Piccarozzi et al. (2018), each publication was systematically analysed.

The characteristics of the selected publications were subsequently consolidated into a structured knowledge base designed to provide a holistic overview of the research landscape related to the topic under investigation. This knowledge base captures a range of essential bibliographic and methodological attributes for each publication, including (1) author(s), (2) title of the paper, (3) source and document type, (4) year of publication, (5) research type, (6) research design, and (7) research methodology. Further, it includes key findings from each publication and directions for future research, thereby enhancing its utility for both synthesis and gap analysis. The overarching objective of this step was to consolidate these characteristics into a cohesive analytical framework, enabling a detailed, structured, and critically informed perspective on the current state of the scholarly discourse.

2.3 Literature review report

The literature review report is grounded in the previously developed knowledge base and is structured in alignment with the analytical framework outlined in Figure 2-2. Following the guidelines given by Piccarozzi et al. (2018), the review is organised into three distinct sections: (1) general, (2) methodological, and (3) substantive characteristics. The content and focus of each section are detailed in the following parts.

The general characteristics of the literature review include the scope of the research area and the temporal distribution of the selected publications, offering insight into the evolution and breadth of scholarly interest over time. The methodological characteristics of the literature review encompass the research designs, approaches, and methods employed across the reviewed studies, thereby facilitating an assessment of the methodological rigour and diversity within the field. The substantive characteristics of the literature review include key themes, theoretical insights, and empirical findings identified in the literature and proposed directions for future research.

This structured approach facilitates a coherent and systematic exploration of the complex and multidimensional landscape of human-robot collaboration, particularly tailored to the needs of the study. The detailed examination that follows provides a transparent and methodologically rigorous foundation for drawing informed conclusions for the present study.

2.3.1 General characteristics

In the first step, the temporal distribution of the selected publications was analysed and presented in Figure 2-4. The analysis highlighted a pronounced trend: a substantial increase in publications in recent years, particularly from 2022 onwards. This upward trajectory is evident not only in the aggregated total of selected publications but also across the different stages of the conducting phase of the structured review process, which are outlined in Figure 2-2. The consistent year-over-year growth in the number of publications identified as meeting the selection criteria in the initial and secondary stages of the selection process reflects a mounting scholarly interest and accelerated development within the research area. However, this year-over-year increase in the number of publications is not uniformly reflected in the final set of publications, as depicted in the following figure. This discrepancy may be ascribed to the distinct research focus of the thesis and the application of strict quality and relevance criteria, which may have led to the exclusion of several more recent studies that did not meet the predefined thresholds.

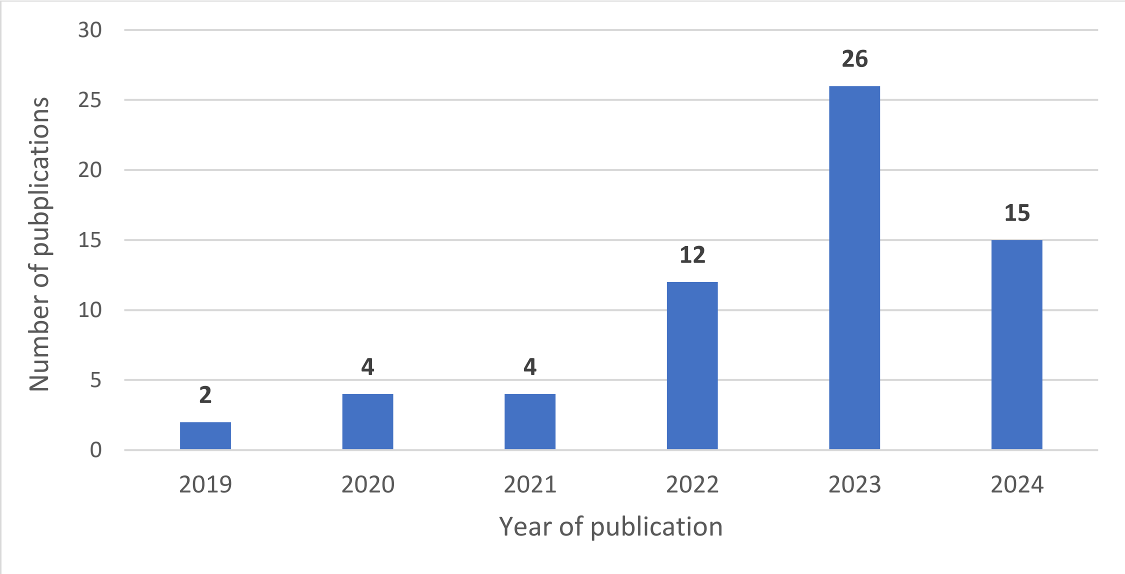


Figure 2-4: Temporal distribution of the selected publications

The observed trend of the growing number of publications is of crucial significance for several reasons. First and foremost, this growth reflects the broadening of the research scope and emphasises the increasing importance of this research domain. This assertion is supported by Rahman, Khatun, Jahan, Devnath, and Bhuiyan (2024), who posit that collaborative robots' rapid development and refinement led to a growing interest in their application across various sectors. The enhanced capabilities, improved safety features, and greater affordability of these collaborative robots have rendered them increasingly accessible and particularly relevant for a broader range of industries, leading to increased scholarly engagement in this field (Karuppiah, Sankaranarayanan, Ali, & Bhalaji, 2023). Furthermore, the accelerated adoption of collaborative robots in production, assembly, and manufacturing environments has generated substantial empirical data, facilitating more sophisticated and context-specific analyses (Javaid et al., 2021; Picco et al., 2024). As the body of research has expanded, it has deepened theoretical understanding and opened new avenues for exploration, enabling scholars to investigate novel applications within the evolving field of human-robot collaboration.

Secondly, recent years have witnessed a notable increase in research focusing specifically on technology acceptance in the context of collaborative robots. This emerging field of enquiry involves the examination of how individuals perceive, accept, and adopt collaborative robotic technologies in their workplace, often employing established theoretical frameworks such as the Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT), and related models (Apraiz, Mulet Alberola, Lasa, Mazmela, & Nguyen, 2023; Sinha, Singh, Gupta, & Singh, 2020). The mounting body of research in this field indicates an increasing awareness of the human factors influencing the acceptance of collaborative robots. This trend is evidenced by studies such as those conducted by Muller, Subrin, Joncheray, Billon, and Garnier (2022) and Hopko et al. (2022). These scholars focused on variables such as trust, usability, workload, and stress, examining their impact on the acceptance of collaborative robots and, in turn, how this acceptance influences human operator performance (Di Pasquale et al., 2023). This increased scholarly attention to technology acceptance research is essential to ensure that collaborative robots are technologically effective and socially acceptable to end users, in terms of their ability to interact meaningfully with employees in the workplace.

Furthermore, the recent surge in publications suggests that collaborative robots are gaining significant momentum, attracting growing interest from scholars and practitioners alike (Du Plooy et al., 2024). This heightened interest is likely driven by rapid technological advances, the increasing integration of collaborative robots across various sectors, and the increasing importance of understanding the dynamics of human-robot interaction. Consequently, research in this domain equips practitioners with the knowledge and tools to effectively implement and leverage collaborative robots in their operational settings (Baumgartner, Kopp, & Kinkel, 2022; Charalambous et al., 2015). This development underscores the practical relevance of the research domain, ensuring that organisations in the manufacturing sector can achieve competitiveness by enhancing operational efficiency, worker safety, and technological advancement within an increasingly automated and dynamic landscape.

Overall, understanding the temporal pattern of publications offers valuable insights into the evolution and current state of the research domain. Following this temporal analysis, the subsequent step was ensuring the quality and credibility of the selected sources.

The selected journals were subjected to a quality check to assess the academic standard based on the Chartered Association of Business Schools' Academic Journal Guide (AJG) ranking from October 2024, which was delineated by Harzing (2024). The AJG provides a tiered ranking system to classify journal quality: 4* - world elite journals, 4 - top journals, 3 - highly regarded journals, 2 - well-regarded journals, and 1 - recognised journals (Harzing, 2024). The distribution of selected publications across these quality categories is illustrated in Figure 2-5.

Of the publications selected for review, 25% (16 publications) were published in journals ranked in the AJG, while the remaining 75% (47 publications) appeared in journals not included in the AJG. The AJG-ranked journals primarily span the disciplines of operational research, management science, production and operations management, organisational behaviour, human resource management and industrial relations, reflecting the broad thematic scope of collaborative robotics research. However, it should be noted that the remaining unranked journals, though they have not received a rating from the AJG, were still subjected to a peer-review process and fulfilled the methodological and quality standards established for inclusion in the literature review.

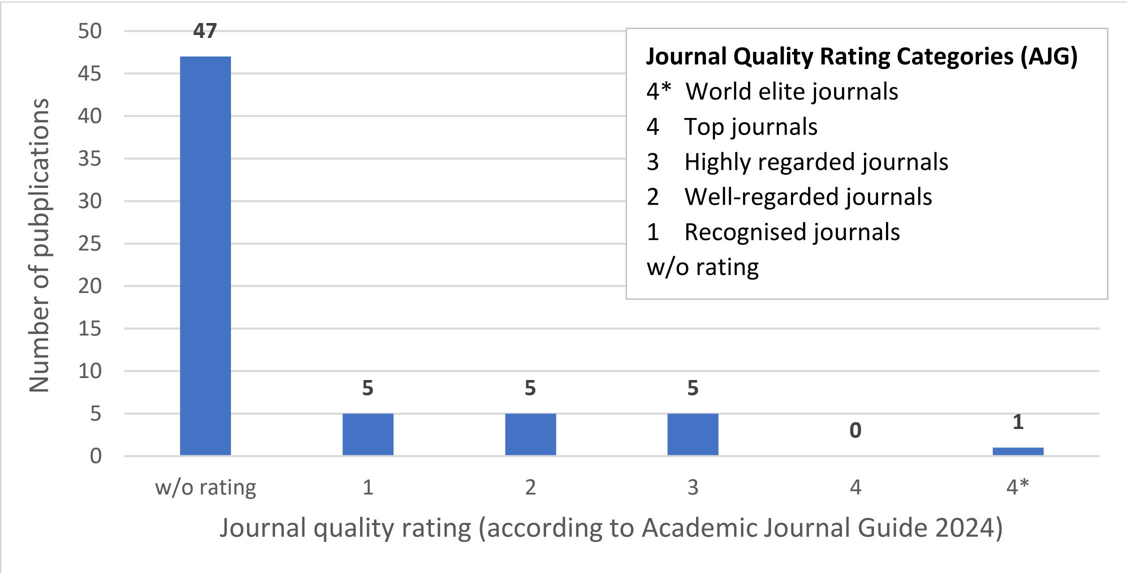


Figure 2-5: Distribution of the selected publications by journal quality rating (AJG)

The distribution of the journal quality rating carries several vital implications for interpreting this literature review. It is important to note that publications from lower-ranked or unranked journals may not necessarily possess the same academic rigour and methodological robustness as those from higher-ranked journals (Jiang, Zhou, & Zhou, 2024). Therefore, these quality differences should be interpreted cautiously. A lower or absent AJG ranking does not inherently indicate a lack of scholarly merit. Instead, it may reflect differences in disciplinary focus, journal scope, or geographical reach. Moreover, Leichtmann, Nitsch, and Mara (2022) describe the research domain as interdisciplinary—which thus includes fields such as robotics, engineering, organisational behaviour, sociology, and psychology. As a result, many relevant publications appear in journals outside the core business and management disciplines covered by the AJG.

To provide a more extensive assessment of journal quality across disciplinary boundaries, the Scimago Journal Rank (SJR) is utilised as an additional metric. The SJR is particularly well-suited for interdisciplinary research areas such as collaborative robots, as it encompasses journals from a wide array of academic fields, including engineering, computer science, and the social sciences (Aguilar-Velázquez, Herrera, Boyer, & Ramos-Fernández, 2023). The SJR is a metric used to evaluate the relative standing of academic journals within their respective disciplines, with the ranking being determined based on quartiles (Newell, 2023). Accordingly, Quartile 1 (Q1) represents the top 25% of journals in a given field, Quartile 2 (Q2) corresponds to journals ranked between the top 25% and 50%, Quartile 3 (Q3) encompasses journals in the 50% to 75% range. Quartile 4 (Q4) includes the bottom 25% of journals within a specific discipline. The distribution of the selected publications across these SJR quartiles is illustrated in Figure 2-6.

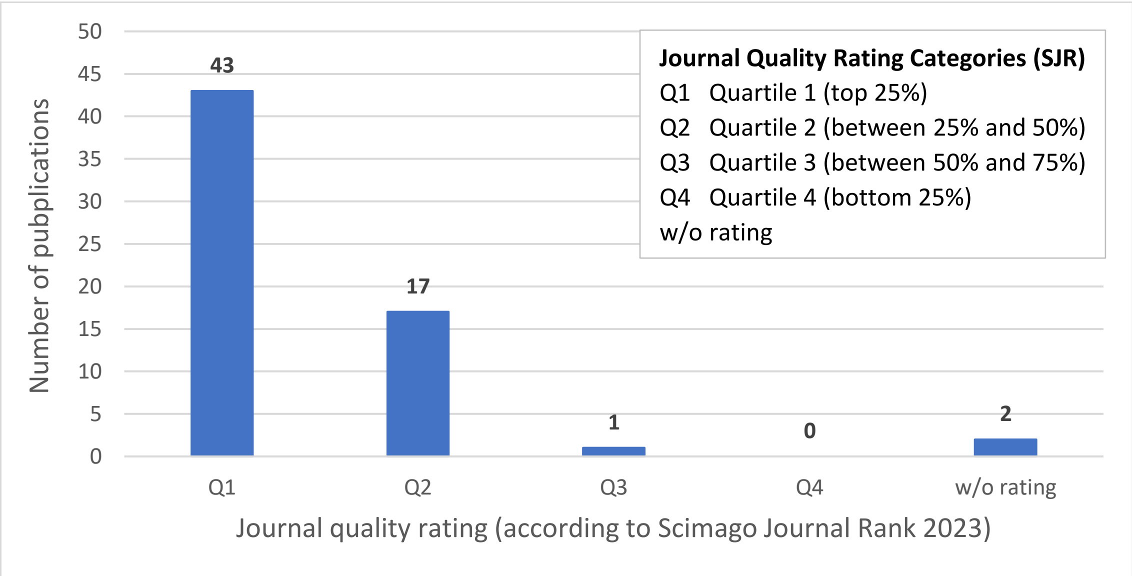


Figure 2-6: Distribution of the selected publications by journal quality rating (SJR)

The distribution of the selected publications, as presented in Figure 2-6 and classified according to the SJR, reveals that 95% of the journals are positioned within the top two quartiles (Q1 and Q2) of their respective discipline. This finding serves as a strong indicator of the overall quality and academic standing of the publications included in the literature review. To ensure transparency and facilitate further assessment, the relevant journals are listed in Appendix A.2, which provides a detailed overview of each journal's SJR classification, the corresponding disciplinary category, and, where applicable, the journal's AJG ranking.

Building on the analysis of the general characteristics of the selected publications, it is essential to investigate their methodological characteristics to generate a deeper understanding of the research designs, approaches, and methodologies employed in current human-robot collaboration research.

2.3.2 Methodological characteristics

As posited by Piccarozzi et al. (2018), a key methodological characteristic of publications pertains to the nature of the research contribution, which may be broadly categorised as either conceptual or empirical. Conceptual contributions involve the development of new theories, frameworks, or concepts that engender an enhanced comprehension within a specific domain (Piccarozzi et al., 2018). These contributions are inherently theoretical and aim to offer novel interpretations or reconceptualisations of existing phenomena, problems, or relationships. A vital subset of conceptual contributions includes literature reviews, synthesising existing knowledge, identifying gaps, and suggesting new perspectives or theoretical developments. In contrast, empirical contributions are grounded in systematic data collection and analysis, providing factual information regarding how a particular phenomenon occurs or behaves in practice (Helfat, 2007).

The 63 selected publications can be categorised into these two primary research contributions: conceptual and empirical. Of these, 25% (16 publications) are classified as conceptual contributions, while the remaining 75% (47 publications) represent empirical studies. This distribution is visually presented in Figure 2-7. The predominance of empirical research within the human-robot collaboration research domain, particularly about technology acceptance in manufacturing contexts, reflects the field's emphasis on generating practical insights. Nevertheless, recent years have witnessed a noticeable increase in conceptual publications, suggesting a growing focus on theoretical advancement.

A more detailed examination of the conceptual contributions shows that their research designs are primarily based on literature review methodologies. Of the 16 conceptual contributions, six publications (38%) contain literature reviews with the development of conceptual frameworks or models, either by constructing novel theoretical structures or by extending existing theories. Conversely, the remaining 10 publications (62%) comprise pure literature reviews, systematically synthesising prior research and formulating conclusions grounded in existing knowledge.

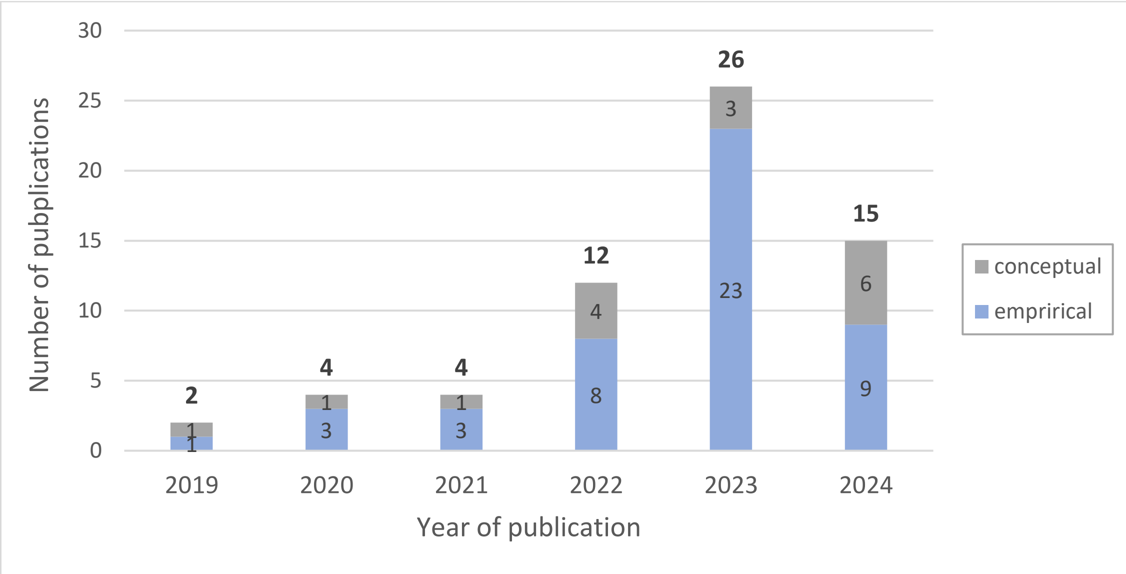


Figure 2-7: Temporal distribution of the selected publications by research types

The 47 empirical contributions were further characterised based on the research design employed. The majority of publications employed a quantitative approach (31 publications, 66%), while a smaller portion of publications adopted either a qualitative approach (7 publications, 15%) or a mixed-method approach (9 publications, 19%). A closer analysis of the quantitative studies reveals that most utilised survey-based methodologies, often supplemented with experimental designs to test hypotheses and gather data. By contrast, the qualitative studies primarily employed interviews, observations, and other interpretive techniques to explore complex, context-dependent phenomena. The studies adopting a mixed-methods design combined both quantitative and qualitative methods to enhance the breadth and depth of the analysis.

A thorough analysis of the methodological characteristics of the selected publications yields several key insights. Primarily, the predominance of empirical contributions signifies a pronounced emphasis on data-driven inquiry within the domain of human-robot collaboration. Moreover, methodological diversity observed across the reviewed studies underscores the multifaceted nature of the field, emphasising the pivotal role of both quantitative and qualitative insights in fostering a comprehensive understanding.

Nevertheless, a closer examination of the quantitative and mixed-method studies demonstrates a pronounced emphasis on laboratory-based research designs, wherein collaborative robots are examined within controlled and simulated environments. Concurrently, the rise in conceptual studies, including systematic literature reviews and the development or extension of theoretical frameworks, strengthens the theoretical foundation of the field. However, it is important to note that the selected conceptual contributions do not rely on primary data. Instead, they draw upon and synthesise existing literature to advance theoretical understanding and provide valuable insights that can inform the design, execution, and interpretation of future empirical investigations (Corley & Gioia, 2011).

After examining the methodological characteristics of the selected publications, the focus now shifts to an analysis of their substantive characteristics. Thus, the next phase of the analysis examines key themes, theories, concepts, and practical implications that emerge from literature on human-robot collaboration, mainly focusing on technology acceptance in manufacturing contexts.

2.3.3 Substantive characteristics

Finally, the substantive characteristics of the selected publications are examined to illustrate the extant literature in relation to the questions guiding the literature review, as outlined in Table 2-1. However, before addressing these questions, it is necessary to provide an overview of the different forms of human-robot interaction and the appearance of the collaborative robot. Since these topics have been frequently discussed in the reviewed publications, it is critical to contextualise subsequent discussions in manufacturing settings.

Different types of human-robot interactions

Recent research in the field of human-robot interaction has differentiated various classifications of interaction modalities between humans and collaborative robots. Notable contributions to this area include studies by Heo et al. (2024), Dornelles et al. (2023), Liu, Caldwell, Rittenbruch, Müge, Burden, and Guertler (2024), and Lu et al. (2022). These classifications are grounded in several factors pertinent to the workplace configuration, such as workflow, workspace, proximity awareness, counterpart awareness, and interaction mode, particularly concerning the physical presence of the human operator and the collaborative robot (Liu, Caldwell, Rittenbruch, Müge, Burden, & Guertler, 2024; Montini et al., 2024).

Despite the absence of a universally accepted definition for the classifications of human-robot interactions, three aspects have been identified as significant. These aspects include (1) the workspace configuration shared between the human and collaborative robots, (2) the sharing of tasks between them, and (3) the sharing of a workpiece during the execution of tasks (McGirr et al., 2022). This classification is critical to accurately ascertain the nature of the interaction between a human and a collaborative robot, given that deployment of collaborative robots does not inherently imply a collaborative work setting.

Dornelles et al. (2023) posit that one of the most frequently cited and applied interaction classifications in the field of collaborative robotics is the model proposed by Bauer, Bender, Braun, Rally, and Scholtz (2016). This classification is based on the three aspects of particular significance in defining human-robot collaboration: the sharing of workspace, tasks, and workpieces (Bauer et al., 2016). The following figure presents this classification system of Bauer et al. (2016), comprising four segments: (1) coexistence, (2) synchronisation, (3) cooperation, and (4) collaboration.

As illustrated in Figure 2-8, the coexistence segment is characterised by the complete absence of shared elements between the human operator and the collaborative robot; neither the workspace, the tasks, nor the workpiece are shared. Similarly, in the synchronisation segment, the workspace is not shared simultaneously, as the human and the collaborative robot operate in a temporally coordinated and thus spatially separated manner. This is because the human operator and the collaborative robot focus on different tasks. In contrast, the cooperation and collaboration segments are marked by simultaneous workspace sharing. Within the cooperation segment, the human and the collaborative robot perform their tasks in the same physical environment, but do not work on the same workpiece. Finally, in the collaboration segment, the highest degree of integration is observed, wherein the human operator and the collaborative robot share the workspace and collaborate on tasks, including workpiece sharing, thus achieving a fully integrated human-robot interaction.

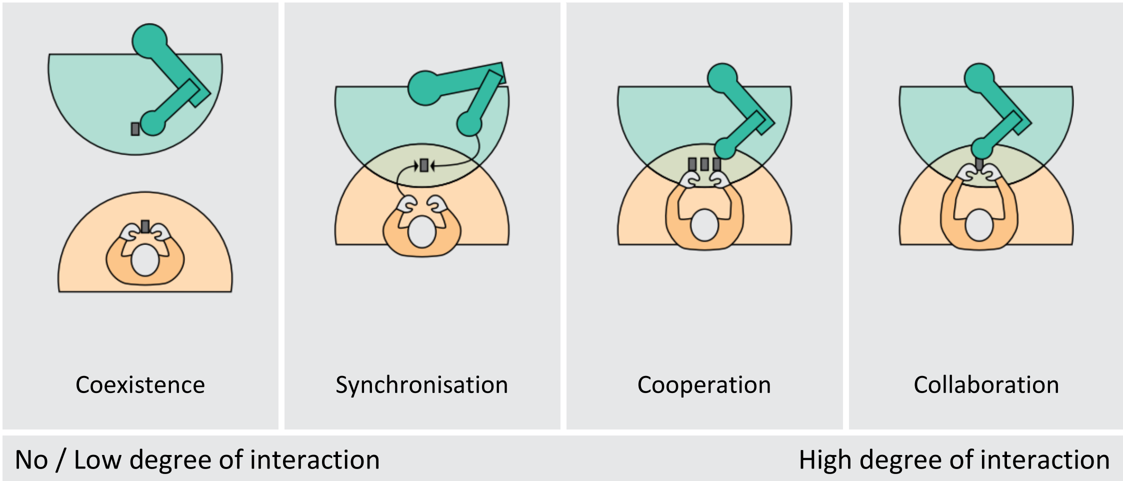


Figure 2-8: The level of interaction between humans and collaborative robots (Source: Bauer et al., 2016, p. 9)

As outlined by Liu, Caldwell, Rittenbruch, Müge, Burden, and Guertler (2024), the classification schema of human-robot interaction that focuses on collaborative robots explicitly excludes fully automated robots that operate at maximum speed and are typically confined within safety cages. These traditional robots, emblematic of the third industrial revolution, enhanced manufacturing precision and productivity (Heo et al., 2024). Conversely, collaborative robots are more closely aligned with the principles of the fourth industrial revolution and, in some contexts, even the emerging fifth industrial revolution, depending on their application and degree of human-centric integration. These robots are designed to work safely and flexibly in close proximity to human operators without physical barriers, thereby supporting more dynamic and adaptable manufacturing environments (Lu et al., 2022).

Appearance of collaborative robots

In addition to classifying human-robot interaction, several publications have focused on the type and form of collaborative robots, with particular attention to the degree of anthropomorphism in their appearance (Liao et al., 2023; Liu, Zou, & Greene, 2024;

Sinha et al., 2020). Anthropomorphism can be defined as the tendency to ascribe human-like characteristics, including motivations, intentions, and emotions, to the behaviour of non-human agents such as collaborative robots (Epley, Waytz, & Cacioppo, 2007).

The degree of anthropomorphism in collaborative robots, reflected in both their appearance and movements, may not only shape the immediate human-robot interaction but can also have far-reaching implications for how these technologies are perceived, accepted, and integrated within organisational settings. Thus, the design and functional capabilities of these robots have the potential to influence the nature and quality of human-robot interaction (Liu, Zou, & Greene, 2024). Within the manufacturing environment of organisations, two distinct forms of collaborative robots are predominantly observed: single-arm and dual-arm robots (Liu, Zou, & Greene, 2024). Single-arm robots are designed to execute specific, repetitive tasks precisely, while dual-arm robots can perform more complex operations that demand coordination between two arms. For single-arm robots, anthropomorphism arises primarily through their movements, as their appearance remains relatively simple. In contrast, dual-arm robots, with their two arms and more complex motion patterns, can more strongly evoke human-like associations.

The results concerning the impact of anthropomorphic attributes on human operator acceptance or behaviour intention remain equivocal. Several studies indicate that such effects are present (Liao et al., 2023; Sinha et al., 2020), while others do not support this claim (Liu, Zou, & Greene, 2024). This divergence in findings indicates that anthropomorphism's impact may be context-dependent, influenced by a combination of robot-specific characteristics and external contextual factors. The contextual factors may include the nature of the task, cultural influences, and individual work preferences.

Building on the foundational understanding of human-robot interaction classifications and the role of anthropomorphism, it is crucial to explore theoretical perspectives that relate to technology acceptance and adoption in the context of collaborative robots. The following subsection of this literature review is guided by the question: Which theoretical perspectives and models are relevant for studying the implementation of collaborative robots?

2.3.3.1 Theories and frameworks

Although a wide range of typologies and conceptual frameworks exist for analysing changes at the intersection of people, processes, and technology (Sovacool & Hess, 2017), the following subsections are concerned solely with those deemed most central based on the literature review. The majority of theories and models identified in the selected papers can be categorised into two main groups: individual-level technology acceptance frameworks and organisational-level adoption frameworks. The former focuses on individual users' perceptions, attitudes, and behavioural intentions in relation to their interaction with new technologies (Ajzen, 1991; Davis, 1989; Venkatesh & Bala, 2008; Venkatesh & Davis, 2000; Venkatesh, Morris, Davis, & Davis, 2003). These models seek to explain how and why individuals decide to accept or reject a particular technology. Conversely, the latter group focuses on the broader organisational context and the factors that influence the adoption of new technologies at the organisational level (Rogers, 2003; Tornatzky, Fleischer, & Chakrabarti, 1990). These models consider the technological, organisational, and environmental factors that collectively impact the decision-making process of implementing technological innovations within an organisation.

Individual-level technology acceptance frameworks

In a substantial proportion of the selected publications (exceeding 50%), frameworks relating to individual-level technology acceptance were either referenced or explicitly applied. Among these, the most frequently cited models include the Technology Acceptance Model (TAM), the Unified Theory of Acceptance and Use of Technology (UTAUT), and the Theory of Planned Behaviour (TPB).

The TAM, developed by Davis (1989), posits that perceived ease of use and perceived usefulness are the primary determinants of an individual's intention to accept and use a given technology. This model has been extensively validated and applied across various technological contexts to understand the factors influencing user acceptance of particular technologies (Leesakul, Oostveen, Eimontaite, Wilson, & Hyde, 2022). Its applicability is also evident in the domain of collaborative robotics, where a substantial number of the selected studies either reference TAM or explicitly use it as the theoretical foundation for examining individual-level technology acceptance. Notable examples include the studies by Pluchino et al. (2023) and Rossato et al. (2021), which utilise TAM to investigate user perceptions and acceptance of collaborative robots in manufacturing environments.

Since the initial development of the TAM, several extensions have been proposed to enhance its explanatory power by incorporating additional contextual and cognitive factors. These extensions are referenced in several publications included in the literature review. Two prominent extensions are TAM2 and TAM3. TAM2, introduced by Venkatesh and Davis (2000), represents an extension of the original TAM by integrating social influence processes, conceptualised as the impact of perceived expectations and assessments from individuals or groups within a given setting. It incorporates the moderating variables of experience and voluntariness, as well as subjective norms, image, and cognitive instrumental processes, including job relevance, output quality, and result demonstrability (Venkatesh & Davis, 2000). These additional factors provide a more comprehensive understanding of the determinants of technology acceptance and usage at the individual level. Building on TAM2, TAM3 was introduced by Venkatesh and Bala (2008) to further refine the model by incorporating determinants related to both individual differences and system characteristics (Venkatesh & Bala, 2008).

Another widely cited theory in the selected publications is the UTAUT. This theory is a comprehensive model developed to explain a user's behavioural intention to use a particular technology and the subsequent usage behaviour. UTAUT comprises performance expectancy, effort expectancy, facilitating conditions, and social influence, which describes the perceived expectations of others regarding technology use (Venkatesh et al., 2003). The model synthesises core elements from eight previous models of technology acceptance, thereby offering a unified theoretical perspective. It includes the TAM and its subsequent extensions (TAM2, TAM3), the Theory of Reasoned Action (TRA), the Motivational Model (MM), the Theory of Planned Behaviour (TPB), the Combined Technology Acceptance Model and Theory of Planned Behaviour (C-TAM-TPB), the Model of PC Utilisation (MPCU), the Diffusion of Innovation Theory (DOI), and the Social Cognitive Theory (SCT) (Venkatesh et al., 2003). Due to its robust explanatory power and empirical validity, UTAUT has been widely adopted across various domains, including studies on human-robot collaboration. For instance, recent empirical investigations by Jacob et al. (2023) and Picco et al. (2024) have applied the UTAUT framework to examine the determinants of user acceptance of collaborative robots in industrial settings.

Furthermore, the TPB, developed by Ajzen (1991) as an extension of the TRA, is referenced in several selected publications. The TPB has been employed across various contexts, including studies on human-robot collaboration (Sinha et al., 2020). As a general behavioural framework, the TPB focuses on the psychological and social determinants of individual behaviour. In TPB, social refers to the role of subjective norms, meaning the perceived expectations and pressures from others regarding a specific behaviour (Ajzen, 1991). Specifically, the model incorporates three core constructs: attitude toward the behaviour, subjective norms, and perceived behavioural control (Ajzen, 1991). This theoretical distinction is particularly noteworthy when comparing the TPB to technology-specific models, such as TAM and UTAUT.

The following table presents a synthesis of the most frequently referenced theories concerning technology acceptance at the individual level, drawn from the selected publications. Table 2-6 categorises each theory by its core constructs and moderating variables, facilitating a rigorous comparison of their configurations. The highlighted (blue) cells illustrate the specific factors within each model. This overview aims to clarify the conceptual distinctions and overlaps among the various theoretical frameworks applied in the published literature on human-robot collaboration.

Factors	**TAM**	**TAM2**	**UTAUT**	**TPB**
Main factors				
Perceived usefulness / performance expectancy				
Perceived ease of use /effort expectancy				
Attitude toward the behaviour				*
Behaviour intention				
Usage behaviour				
Subjective norms / social influences				
Image				
Job relevance				
Output quality				
Result demonstrability				
Facilitating conditions / perceived control				
Moderating variables				
Experience				
Voluntariness				
Age				
Gender				

*Attitude: is influenced by factors such as perceived usefulness and perceived ease of use or performance expectancy and effort expectancy

Table 2-6: Comparison of TAM, TAM2, UTAUT and TPB (Sources: Ajzen, 1991, p. 182; Venkatesh et al., 2003, p. 447; Venkatesh & Davis, 2000, p. 188)

Despite the extensive utilisation of the aforementioned theoretical frameworks, it is imperative to acknowledge the critical stance of scholars who question the adequacy of these models within the domain of collaborative robotics. For instance, Liao, Lin, Chen, and Pei (2024) argue that conventional individual-level technology acceptance models such as the TAM and UTAUT are insufficient for capturing the complexities of human-robot collaboration. The classical individual-level acceptance frameworks were initially developed in information systems research (Omol & Ondiek, 2021; Piçarra & Giger, 2018), thus overly emphasising cognitive determinants of acceptance while neglecting the social and emotional aspects that emerge in human-robot interaction (Liao et al., 2023). This limitation is of particular importance, given that collaborative robots are increasingly conceptualised not merely as utilitarian tools but as social agents that engage in teamwork and influence human behaviour like coworkers (You & Robert, 2017).

In summary, previous research has predominantly concentrated on the individual-level models of technology acceptance, as Liu and Cao (2022) stated. However, beyond this individual-centric perspective, several selected publications also referenced theoretical frameworks that apply to the organisational level, addressing broader systemic, structural, and contextual factors that influence technology adoption.

Organisational-level technology adoption frameworks

While the significance of individual-level factors in technology acceptance research has long been recognised, the organisational level is equally critical in understanding the broader dynamics of technology adoption (Liu & Cao, 2022). However, within the selected publications, only two primarily emphasise organisational-level analysis: Simões, Soares, and Barros (2020) and Liu and Cao (2022). These studies employ two well-established theoretical frameworks, the Diffusion of Innovations (DOI) and the Technology-Organisation-Environment (TOE) framework, to investigate the determinants influencing the adoption of collaborative robots at the organisational level.

The DOI theory was initially proposed by Rogers in 1962 and later refined in subsequent editions (Rogers, 2003). He defined innovation as an idea, practice, or object regarded as being new to an individual or a group of people (Rogers, 2003). By proposing the DOI theory, he provides a theoretical framework for understanding how innovations spread over time within a social system, which comprises interconnected individuals or groups who influence each other's adoption decisions (Rogers, 2003). Aligning with Rogers (2003), Simões et al. (2020) noted that collaborative robots can also be considered an innovation, particularly within industrial and organisational settings. The DOI theory seeks to explain the mechanisms by which innovations are diffused through social systems and the rate at which this diffusion occurs. It highlights five core attributes of innovations that influence their diffusion: relative advantage, compatibility, complexity, trialability, and observability (Rogers, 2003). In the context of collaborative robots, Liu and Cao (2022) identify several specific technological characteristics, such as safety, cost-effectiveness, and ease of use, that align with these attributes and significantly affect adoption decisions.

The TOE framework, proposed by DePietro, Wiarda, and Fleischer (1990), offers a comprehensive lens through which the adoption of technological innovations within organisations can be analysed. This framework identifies three broad contextual dimensions that influence adoption decisions: the technological, organisational, and environmental contexts (DePietro et al., 1990). In the technological context, factors related to the technology itself—particularly its availability and characteristics—are considered (DePietro et al., 1990). In this regard, the specific technology-related variables of Rogers' DOI theory, such as relative advantage, complexity, and compatibility, can be viewed as detailed constructs that operationalise the broader technological dimensions of the TOE framework (Liu & Cao, 2022). The organisational context encompasses internal characteristics of the organisation, such as size, managerial structure, communication processes, available resources, and organisational culture, all of which affect readiness and capacity for innovation adoption (DePietro et al., 1990). Finally, the environmental context pertains to the external environment in which an organisation operates, including industry characteristics, market structure, competitive pressure, and regulatory influences (DePietro et al., 1990). Thus, in the TOE framework, internal social factors such as interaction and communication processes are included in the organisational context, whereas external social influences form part of the environmental context.

The above theoretical frameworks (i.e., DOI theory and TOE framework) are well-established and widely employed in technology adoption literature (Oliveira & Martins, 2011). Their widespread utilisation is primarily attributed to their analytical robustness and explanatory power in identifying the factors influencing the diffusion and adoption of technological innovations, particularly at the organisational level (Simões et al., 2020). Table 2-7 presents a side-by-side overview of their principal factors to provide a structured comparison of these frameworks and highlight the core dimensions they encompass. The blue-shaded cells visually indicate which factors are explicitly addressed within each framework, facilitating a clearer understanding of their respective scopes and points of convergence.

A comparison between the DOI theory and the TOE framework reveals a fundamental distinction in analytical focus. The DOI theory concentrates primarily on the intrinsic characteristics of innovations, such as relative advantage, compatibility, complexity, trialability, and observability, as the principal determinants of adoption (Rogers, 2003). In contrast, the TOE framework offers a more extensive contextual analysis by integrating technological, organisational, and environmental dimensions, facilitating a more nuanced understanding of the innovation adoption process within organisational settings.

Main Factors	**DOI**	**TOE**
Technology context		
Relative advantage		
Compatibility		
Complexity		
Trialability		
Observability		
Availability		*
Characteristics		*
Organisational context		
Formal and informal linking structures		
Communication processes		
Organisational size		
Organisational slack		
Environmental context		
Industry characteristics and market structure		
Technology support infrastructure		
Government regulations		

*Availability and characteristics: can be seen as a summary of the specific variables of the DOI framework in the technology context (Liu & Cao, 2022)

Table 2-7: Comparison of DOI and TOE (Sources: DePietro et al., 1990, p. 153; Liu & Cao, 2022, p. 3; Rogers, 2003, p. 37)

Beyond the frameworks discussed above, other theoretical perspectives were identified in the literature review, offering conceptual lenses to explain the phenomenon under consideration.

Network-oriented theoretical perspective

Another theoretical perspective is Actor-Network Theory (ANT), which was developed in the early 1980s by Bruno Latour, Michel Callon, and John Law (Kaasinen et al., 2022). ANT aims to analyse how dynamic networks consisting of both human and non-human actors—such as people, machines, and technological artefacts—emerge and interact within socio-technical systems (Latour, 1996). A socio-technical system integrates people and technology, focusing on their interaction and mutual influence within a shared environment. Key concepts and dynamics of ANT include the principle of symmetry, which holds that human and nonhuman entities are equally significant within networks (Muhle, 2024); the notion of relationality, meaning that the properties and roles of actants are not intrinsic but arise from their dynamic associations; and an emphasis on network dynamics, which highlights that actor-networks are continually enacted, negotiated, and transformed, and are never fully fixed or stable (Rydin, 2018).

The ANT framework was applied in one of the reviewed studies to investigate how agency and outcomes are distributed in practice, highlighting the collaborative construction of social and technical realities through networks of heterogeneous elements (Sinha et al., 2020). ANT thus enables the examination of human-robot interactions, their interconnections, and the ongoing development of these networks (Ioniță, Anghel, & Boudouh, 2025; Kaasinen et al., 2022). Importantly, ANT seeks to provide rich, empirically situated accounts of specific local and dynamic networks, deliberately refraining from generalising its insights—even to similar cases—and instead focusing on the unique configurations and contingent interplay of actants within each instance (Latour, 1996). In ANT, social context is not predefined but is produced by dynamic networks of interactions between human and nonhuman actors (Latour, 1996).

Having considered relevant frameworks for understanding determinants of technology acceptance and adoption, attention now turns to a change curve model, which focuses on the temporality of transformation by mapping typical progression patterns within organisations.

Change curve model

Facer, Siebers, and Smith (2022) observe that time and temporality are often overlooked in research despite their essential role in understanding complex organisational phenomena. This view is echoed by Meissner et al. (2020), who emphasise that implementing collaborative robots is inherently embedded within organisational change processes. Consequently, understanding the organisation's current position within its change trajectory becomes crucial in this context. Situating data within the temporal dynamics of change yields a more nuanced interpretation of the phenomenon under investigation (Breese et al., 2018).

The organisational change process can be effectively described based on the model developed by Kübler-Ross (1969). Originally intended to describe the stages of grief, this model has since been adapted to various contexts, including changes in work settings, based on the premise that individuals exhibit comparable psychological responses whenever a significant change occurs (Chavan & Bhattacharya, 2022; Stephens, McLaughlin, & McLaughlin, 2021). Consequently, scholars such as Chavan and Bhattacharya (2022) have widely adopted and developed this model to analyse employee responses to change initiatives. Figure 2-9 depicts the model in question, illustrating five key stages through which individuals may progress during a change as follows: (1) denial, (2) anger, (3) bargaining, (4) depression, and (5) acceptance (Chavan & Bhattacharya, 2022).

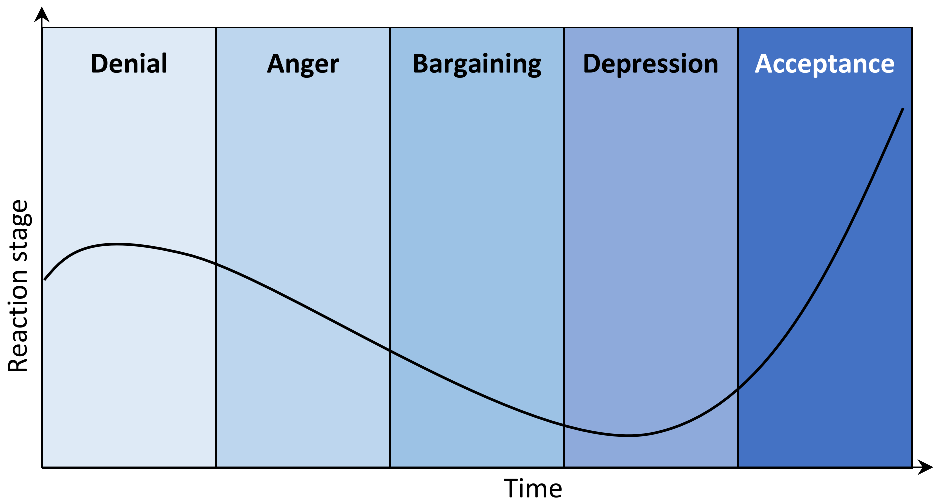


Figure 2-9: Stages of organisational change (Source: Chavan & Bhattacharya, 2022, p. 241 f.)

Figure 2-9 illustrates the sequential progression of individuals through the stages of emotional response delineated by the Kübler-Ross Change Curve model, culminating in a state of acceptance (Chavan & Bhattacharya, 2022). This model is employed in the present study, aligning with the proposition put forward by Sotelo and Livingood (2015), who argue that the Kübler-Ross change curve model provides a valuable foundation for understanding technology acceptance research.

The following presentation delineates the stages of the change process to contextualise the implementation status of collaborative robots within the focal organisation. The stages delineated by Chavan and Bhattacharya (2022) were employed to illustrate the transformation occurring within the workplace environment during technological integration. The following description of the four stages is based on the work of Chavan and Bhattacharya (2022). In the initial stage, employees resist or deny the introduction of collaborative robots. Subsequently, frustration and anger emerge in response to the sudden alteration of the established routine work process. The third stage is characterised by bargaining, wherein employees may attempt to delay the change or negotiate modifications to it. Subsequently, the stage of depression emerges, which is characterised by feelings of uncertainty, fear, and helplessness. In the final stage, the existence of collaborative robots as part of the working environment is acknowledged and accepted. While some individuals may accept the change reluctantly, others may embrace it positively (Chavan & Bhattacharya, 2022). It is imperative to acknowledge that this change trajectory is inherently non-linear and dynamic, with individuals traversing the stages at their own pace (Santos de Souza & Chimenti, 2024). Although these stages describe individual reactions to change, they can also serve as a framework for evaluating an organisation's collective progress during the implementation of collaborative robots.

Having examined the inherent temporality of organisational transformation, it is essential to further deepen the analysis of extant literature by addressing the operational implications of collaborative robot deployment. Specifically, a nuanced understanding of system performance when collaborative robots are deployed in manufacturing settings is essential. Accordingly, the guiding question for this segment of the literature review is as follows: What are the key components of system performance when using collaborative robots in manufacturing environments?

2.3.3.2 Components of system performance

The notions of technology acceptance and adoption refer to the willingness of individuals and organisations to adopt and utilise novel technologies. These concepts assume paramount importance in the context of determining the effective integration and utilisation of technologies such as collaborative robots. Consequently, scholarly attention has increasingly focused on evaluating the performance of collaborative robots in manufacturing environments, reflecting the growing significance of this research area (Özköse & Güney, 2023).

These robots are now frequently deployed to assume repetitive, physically demanding, and error-prone tasks conventionally performed by human workers to enhance efficiency and reduce error rates (Pluchino et al., 2023). Collaborative robots are designed to operate safely alongside humans in shared workspaces, bridging the gap between humans and traditional industrial robots (Pluchino et al., 2023). Despite these advantages, evaluating the performance of human-robot collaboration remains challenging due to the absence of widely accepted assessment frameworks (Arslan, Cooper, Khan, Golgeci, & Ali, 2022). Moreover, prior research indicates that system performance is closely tied to the rate of adoption of collaborative robots, which is contingent upon the level of user acceptance within the workplace (Zemlyak, Gusarova, & Sivakova, 2022).

To ensure the successful implementation of collaborative robots in manufacturing environments, it is essential to consider the core objectives typically associated with their deployment. As posited by Riedelbauch, Höllerich, and Henrich (2023), three primary objectives underpin the introduction of collaborative robotic systems: (1) task productivity, (2) flexibility, and (3) job attractiveness. However, it must be noted that the realisation of these objectives is fundamentally contingent upon the assurance of occupational safety (Riedelbauch et al., 2023).

The task productivity in manufacturing environments with and without the integration of collaborative robots can be evaluated by comparing the time required to complete a task manually and with human-robot collaboration (Riedelbauch et al., 2023). A reduced task duration, indicative of enhanced efficiency, is positively associated with accepting collaborative robots (Meissner et al., 2020). Beyond productivity, flexibility is a critical performance objective, particularly in contexts characterised by small batch sizes, where minimising changeover times is essential for maintaining operational agility (Kopp et al., 2021). Flexibility in this context is reflected in the system's capacity to adapt rapidly to different product variants, including the time and complexity of reprogramming the robot for new tasks (Riedelbauch et al., 2023). In addition to flexibility, another primary objective of implementing collaborative robots is enhancing job attractiveness (Riedelbauch et al., 2023). This is understood as a function of both physical and cognitive ergonomics. Physical ergonomics refers to the physical comfort experienced when interacting with collaborative robots, while cognitive ergonomics involves psychological well-being in the workplace (Di Pasquale et al., 2023).

The goals associated with the integration of collaborative robots exert a significant influence on the overall performance of the system. The efficiency and effectiveness of collaborative robots in enhancing task productivity are closely tied to system performance (Hopko et al., 2022). Flexibility, the capacity to adapt to varying products or production conditions, is a critical determinant of sustained performance in dynamic manufacturing environments (Riedelbauch et al., 2023). Finally, job attractiveness, which encompasses physical and cognitive ergonomics, is vital to employee satisfaction and retention. A motivated and skilled workforce is indispensable to achieving optimal system performance, particularly in settings where human-robot collaboration is central (Kopp et al., 2021). It is, therefore, vital to emphasise that task productivity, flexibility, and job attractiveness represent interconnected dimensions of system performance, shaped by both individual- and organisational-level factors. This assertion is further supported by the studies of Simões, Pinto, Santos, Pinheiro, and Romero (2022) and Di Pasquale et al. (2024), who emphasise the importance of integrating both individual and organisational-level factors in evaluating production performance within human-robot collaborative systems.

Having explored the typical objectives underlying implementing collaborative robots with respect to system performance, it is essential to translate these theoretical insights into practical applications. Accordingly, the following subsection focuses on specific characteristics and attitudes that influence the utilisation of collaborative robots. This part of the literature review is guided by the question: Which aspects of human perception and attitude hinder or promote the utilisation of collaborative robots?

2.3.3.3 Barriers and enablers of collaborative robot utilisation

A growing body of scholarly literature posits that the success of human-robot collaboration is contingent on a multifaceted set of determinants, including human-related factors, robot-specific factors, organisational, and environmental factors (Di Pasquale et al., 2024; Hopko et al., 2022). These factors collectively function as both barriers and enablers, influencing the overall integration of collaborative robots within manufacturing contexts. In light of this, the following subsections thoroughly examine these factors, assessing their impact on human-robot collaboration and system performance.

Human factors

A substantial body of research has been dedicated to examining human factors in the context of human-robot collaboration (Hopko et al., 2022; Nobile et al., 2024). These factors are intrinsically linked to individual acceptance of collaborative robots and are imperative for successfully implementing such robots within work processes. As highlighted by Hopko et al. (2022), a systematic review of the literature identified five human factors that are most frequently discussed about collaborative robots: (1) trust, (2) cognitive workload, (3) anxiety, (4) safety perception, and (5) fatigue.

Trust, in the context of human-robot collaboration, pertains to the extent to which human operators perceive the collaborative robot as either beneficial or potentially threatening (Pluchino et al., 2023). As posited by Hopko et al. (2022), this perception is influenced by prior positive experiences and increased familiarity with the collaborative robot's behaviour and functionality. Furthermore, trust has been empirically shown to have a positive impact on system performance (Rahman & Wang, 2018). When human operators exhibit high trust in collaborative robots, they are more inclined to fully engage with the technology and exploit its capabilities, enhancing system performance.

Cognitive workload, a critical human factor in human-robot collaboration, refers to the mental effort required of a human operator to interact with a collaborative robot (Steijn, van Gulijk, van der Beek, & Sluijs, 2023). This workload is significantly influenced by the degree of control and involvement demanded of the operator, with interaction speed representing a key determinant (Panchetti, Pietrantoni, Puzzo, Gualtieri, & Fraboni, 2023). Furthermore, the perceived reliability of the collaborative robot also plays a crucial role (Steijn et al., 2023). More explicitly, lower reliability tends to increase the operator's need for monitoring and corrective actions, thereby elevating cognitive workload (Hopko et al., 2022). Excessive cognitive workload may cause stress and anxiety in the long term, leading to fatigue, diminished employee well-being, and increased production errors (Riedelbauch et al., 2023), all of which have the potential to adversely impact overall system performance.

Anxiety is a frequently discussed human factor in the literature on human-robot collaboration (Verna, Puttero, Genta, & Galetto, 2023). Human operators may experience anxiety for various reasons, with concerns regarding job security being a common contributing factor (Jacob et al., 2023; Tomidei et al., 2024). The task design, which involves the configuration and setup of the work process carried out in joint operation by the human operator and the collaborative robot, is particularly relevant in this context. As Hopko et al. (2022) observe, poorly designed tasks can exacerbate operator anxiety, especially when individuals feel overwhelmed or insufficiently engaged. These findings emphasise the necessity of addressing operator anxiety through deliberate and inclusive task design. Proactively managing anxiety may foster a more supportive work environment, enhancing the performance of human-robot collaboration (Baumgartner et al., 2022).

In the context of human-robot collaboration, which involves shared workspaces between human operators and robotic systems, safety is of paramount importance. Berx, Decré, Morag, Chemweno, and Pintelon (2022) developed a comprehensive taxonomy of hazards and risk factors specific to human-robot collaboration. It is imperative to acknowledge that these risk factors are not only instrumental in the physical design of the workspace but also significantly impact the acceptance of the collaborative robot (Berx et al., 2022).

Previous research indicated that the deployment of collaborative robots could reduce human fatigue in manufacturing environments (Jacob et al., 2023; Rinaldi et al., 2023). A commonly proposed approach involves allocating repetitive and physically demanding tasks to the collaborative robot, automating monotonous activities and reducing the physical strain on human operators. This contributes to the human operator's well-being and enhances the system's overall performance by sustaining operator engagement and reducing the risk of fatigue-related errors (Lu et al., 2022).

Human factors, such as trust, cognitive workload, anxiety, safety, and fatigue, play crucial roles in successfully integrating collaborative robots in industrial work environments. These human factors can function either as a barrier or an enabler to successful human-robot collaboration, contingent upon how they are managed and integrated into system design and organisational practices. Importantly, these human factors are not isolated but interconnected, and their combined effect influences the effectiveness and efficiency of human-robot collaboration (Hopko et al., 2022). Besides human factors, robot-specific characteristics—referred to as robot factors—must also be taken into account, as they can significantly impact human-robot collaboration.

Robot factors

Robot factors are defined as the physical characteristics and operational parameters that influence the functional behaviour and interaction dynamics of collaborative robots. These factors, as outlined by Liu, Caldwell, Rittenbruch, Müge, Burden, and Guertler (2024), include the robot's role, movement and trajectory, degree of automation, error rate, applied force, speed, and proximity to human workers. These factors determine the technical capabilities of the robot while also shaping user perceptions and affecting the quality of human-robot collaboration. Hence, these factors are aligned with the constructs of established theoretical frameworks such as the DOI theory or the TOE framework.

Probst et al. (2024) asserted that robot factors associated with the operational dynamics of collaborative robots encompass the speed of movement as a particularly salient element. In support of this view, Kopp et al. (2021) suggest that calibrating a collaborative robot's speed to the requirements and pace of the human operators is more conducive to effective collaboration than merely maximising it. This argument is further substantiated by the findings of Hopko et al. (2022), who argue that maximising the performance of collaborative robots does not necessarily lead to enhanced system performance.

Another critical robot factor directly linked to system performance is the ability and performance of the collaborative robot (Hopko et al., 2022). In this context, the error rate is particularly salient, as it significantly influences the perceived reliability of the collaborative robot (Liu, Caldwell, Rittenbruch, Müge, Burden, & Guertler, 2024). Elevated error rates can undermine the reliability level of the collaborative robot, which in turn impacts the cognitive workload of human operators (Hopko et al., 2022). Moreover, the performance of the collaborative robot is closely linked to the development of trust in the collaborative robot, which is essential for successfully integrating collaborative robots into human-centric work environments (Rahman & Wang, 2018).

Consequently, robot factors can shape key human factors, such as perception of trust and anxiety (Hopko et al., 2022). These robot factors substantially shape the human-robot collaboration and directly affect both task performance and, thus, system performance (Di Pasquale et al., 2024; Liu, Caldwell, Rittenbruch, Müge, Burden, & Guertler, 2024). In addition to robot factors, organisational and environmental factors play a crucial role in effectively deploying collaborative robots (Hopko et al., 2022).

Organisational and environmental factors

The analysis of organisational and environmental factors influencing the implementation of collaborative robots aligns with broader studies of technology adoption at the organisational level (Liu & Cao, 2022; Simões et al., 2020). These factors can be effectively contextualised within the TOE framework, which provides a comprehensive lens to analyse the organisational and environmental conditions that shape the adoption of technological innovations.

The TOE framework identifies communication processes as critical factors within the organisational context (DePietro et al., 1990). These processes include leadership behaviour, particularly related to the change process associated with implementing new technology (DePietro et al., 1990). Consequently, management support emerges as a key role in ensuring the successful implementation of collaborative robots (Fraboni et al., 2023; Leichtmann, Hartung, Wilhelm, & Nitsch, 2023; Liu & Cao, 2022).

Another critical factor within the TOE framework is the technology support infrastructure, which falls under the environmental context (DePietro et al., 1990). This factor is intrinsically linked to the availability of technology-related training for employees (DePietro et al., 1990). Gervasi et al. (2020) assert that training human operators utilising collaborative robotic systems is a prerequisite for successful human-robot collaboration. This assertion is further substantiated by the findings of Di Pasquale et al. (2023) and Wolf and Stock-Homburg (2023), who both highlight the importance of equipping operators with the necessary skills and knowledge to maximise the potential of collaborative robots in manufacturing environments.

Overall, factors such as management support and training are considered critical enablers of the successful implementation of collaborative robots (Zemlyak et al., 2022). However, extant literature overly emphasises human and robot-related factors, often neglecting the significant role of organisational and environmental factors (Hopko et al., 2022). This is even though the introduction of new technology, such as collaborative robots, has the potential to precipitate substantial organisational change (Armenakis, Bernerth, Pitts, & Walker, 2007; Wang et al., 2025). This underscores the importance of further support for the necessity of studies that focus on the organisational environment and the related factors when implementing collaborative robots.

The above review justifies the need for a multifaceted analysis of the acceptance and impact of collaborative robots on system performance. Several factors were identified as potentially impeding effective human-robot collaboration. These included a lack of trust, a high cognitive workload, and concerns about job security, leading to anxiety. Poor usability of collaborative robot interfaces and high error rates were also identified as significant barriers. In contrast, reliable performance, user-friendly interfaces, and a supportive organisational culture were identified as success factors fostering human-robot collaboration.

Building upon the research gap outlined in Section 1.2, the comprehensive review of the existing literature reveals a critical need for further investigation into the complex and nuanced interplay of factors influencing the acceptance and adoption of collaborative robots. While numerous studies have offered valuable insights into various determinants of technology acceptance and adoption, there remains a significant gap in research exploring the intersection of human, robot, and organisational-level factors, particularly concerning the specific technologies underpinning collaborative robots.

2.4 Research gap in the context of literature review

The selected publications demonstrate that the analysis of collaborative robots is predominantly conducted at the individual level, with only a limited number addressing organisational-level factors. As previously outlined, this fragmented approach restricts a holistic understanding of the phenomenon. Therefore, a more integrative analysis combining individual and organisational perspectives is essential to capture the multifaceted nature of collaborative robot adoption (Hopko et al., 2022). Furthermore, recent critiques suggest that classical technology acceptance models, such as the TAM and UTAUT, are insufficient for studying individual-level acceptance of collaborative robots (Liao et al., 2024). In particular, these models have been criticised for their limited capacity to account for the emotional aspect of human-robot interaction, a gap that has been explicitly acknowledged by multiple scholars (Çiğdem, Meidute-Kavaliauskiene, & Yıldız, 2023; Hopko et al., 2022; Liao et al., 2024).

The published literature increasingly recognises the need for research beyond the traditional focus on accepting collaborative robots to encompass their impact on system performance. This critical research gap has been articulated by various scholars (Arslan et al., 2022; Hopko et al., 2022; Rinaldi et al., 2023; Ronzoni, Accorsi, Botti, & Manzini, 2021). Moreover, the significance of addressing this gap is further emphasised by Gualtieri et al. (2022), who assert that collaborative robots constitute one of the most transformative technologies within the Industry 4.0 paradigm.

The identified research gap in the literature necessitates a holistic study incorporating human factors, robots, organisational, and environmental factors. The present thesis contributes to this discourse by foregrounding system performance as a critically relevant and underexplored area within the field. As recent studies have shown, optimising system performance not only enhances productivity and quality but also plays a crucial role in ensuring operator satisfaction and organisational sustainability (Fraboni et al., 2023). In addition to engaging substantively with key themes from existing scholarship, the thesis also delineates the methodological parameters underpinning the research design, ensuring alignment between theoretical constructs and empirical inquiry.

Within the scope of existing research designs in the extant literature, the majority of empirical studies are conducted in controlled experimental settings, either in laboratory environments (Fournier et al., 2024; Gualtieri et al., 2022; Probst et al., 2024) or in experimental setups in manufacturing-adjacent contexts (Eimontaite et al., 2022; Zigart et al., 2023). A potential explanation for this methodological preference is that experimental studies offer a controlled environment where researchers can systematically manipulate and isolate key variables. Such settings facilitate rigorous testing and refinement of theoretical models concerning collaborative robot behaviour and human-robot interaction. These models can subsequently be validated and extended to more complex, real-world industrial settings.

Nevertheless, translating these findings from a controlled experimental context into real-world applications remains a significant challenge. The inherent complexity and dynamism of real-world operational environments often limit the transferability of laboratory-based results (Liao et al., 2023). Instead, empirical studies conducted in authentic industrial settings are better positioned to capture the contextual intricacies and operational complexities inherent in real-world settings. In light of this, numerous scholars have called for increased research conducted in real-world environments (Liao et al., 2023; Liu, Caldwell, Rittenbruch, Müge, Burden, & Guertler, 2024; Parvez et al., 2022), particularly within factories that have implemented collaborative robotics in actual production workflows (Liao et al., 2023). One factor contributing to the relative scarcity of such studies is the still-nascent stage of collaborative robot adoption across many industries (Dornelles et al., 2023). Accordingly, the present context emphasises the scholarly relevance and practical urgency of conducting research in a manufacturing facility where a collaborative robot has been fully integrated into routine operations over an extended period.

As asserted by Parvez et al. (2022), research conducted in real-world industrial settings has the potential to shed light on the evolving work experience of different groups of employees while also offering valuable insights into productivity and performance outcomes associated with implementing collaborative robots. To ensure the transferability of such findings, the group of participants must reflect a broad demographic spectrum, including individuals from all age demographics, as Liao et al. (2023) recommended. This consideration is particularly salient given that a significant body of existing research disproportionately focuses on younger participants (Wolf & Stock-Homburg, 2023), constraining the applicability of their findings to the broader workforce.

Based on a critical analysis of selected scholarly publications, a research design grounded in the real-world application of collaborative robots within manufacturing environments emerges as particularly relevant. To ensure an inclusive evaluation, such applications should be analysed through the perspectives of different groups of employees across varying age demographics. These considerations directly inform the research design of the present study to increase both the empirical relevance and practical applicability of its findings. The integration of these aspects is expected to yield a more nuanced and contextually grounded understanding of the impact of collaborative robots on the work environment, as articulated by Parvez et al. (2022).

2.5 Chapter summary

This literature review systematically explores multiple dimensions of utilising collaborative robots, focusing on the factors influencing their acceptance and impact on system performance. Employing a structured review process, including the systematic selection, screening, and analysis of relevant scholarly publications, two primary objectives were accomplished: mapping the available body of literature and the detailed delineation of the previously identified research gap based on the selected publications.

The first objective of the literature review was accomplished using an in-depth analysis of the general, methodological and substantive characteristics of the 63 selected publications. The findings indicate a growing scholarly interest in collaborative robotics, particularly in recent years. Methodologically, the selected publications are predominantly empirical in nature, emphasising the extensive relevance of empirical contributions in advancing understanding within this research domain. Moreover, the selected publications employed a range of theories and frameworks pertinent to technology acceptance and adoption of collaborative robots. Specifically, the TAM, the UTAUT, and the TPB emerged as the most frequently applied theories at the individual-level technology acceptance. Regarding adopting technology at the organisational level, the DOI theory and the TOE framework were commonly utilised to conceptualise technology adoption processes. In addition, the literature explored key dimensions of system performance and examined the barriers and enablers influencing collaborative robot implementation. These factors were categorised across human, robot, organisational, and environmental domains, providing a holistic view of the complex interplay influencing successful integration.

The second objective of the literature review was to identify and synthesise prevailing patterns and emerging themes within the structured body of literature, with particular attention to areas highlighted as priorities for future research. This process facilitated a more nuanced and critical discussion of the previously identified research gap, grounded in the insights derived from the selected publications. Notwithstanding the considerable advances witnessed in recent years, the literature review findings indicate the continued need for empirical investigation, particularly in real-world industrial contexts. This analysis directly informed the substantive focus and methodological design of the present study.

Building upon the insights gained from the literature review, the methodology chapter elaborates on the research philosophy, research design, data collection methods, and analytical techniques employed. This deliberate progression from a critical examination of the extant literature to a detailed discussion of the methodological approach ensures that the current study is firmly grounded in both theoretical foundations and empirical rigour.

Chapter 3: Research methodology

3.1 Introduction

Guided by the research strategy roadmap, this chapter outlines the methodological approach adopted for the study. A qualitative research approach was selected to explore the factors influencing acceptance and system performance when utilising collaborative robots. This approach facilitates an in-depth investigation of participants' subjective experiences and perceptions, which are central to understanding complex socio-technical interactions, as highlighted by Willig (2012). These experiences of working with collaborative robots were examined across different organisational tiers, focusing on the individual and organisational levels to address the research question in an integrative manner.

A well-informed selection of research methodology requires a critical discussion of the underlying philosophical assumptions that guide the research process and shape the researcher's epistemological and ontological positioning. This study adopts a subjectivist philosophical stance, which provides a coherent rationale for the chosen research methodology and design in addressing the stated research objectives. Drawing from this philosophical foundation, this chapter outlines the research methods employed, including the sampling strategy, data collection procedures, and analytical techniques. The chapter also addresses ethical considerations and critically evaluates the strengths and limitations of the chosen approach.

3.2 Research philosophy

The term research philosophy is linked to a system of underlying philosophical commitments, including the beliefs and assumptions of the researcher, that shape the researcher's understanding of reality (Lee & Lings, 2008). These philosophical commitments are inherently embedded in all research endeavours, regardless of whether they are explicitly acknowledged (Burrell & Morgan, 1979/2016). Over the past few decades, the importance of articulating a clear philosophical foundation has gained increasing recognition, as it underpins the coherence, credibility, and rigour of social science research (Coule, 2013; Handema, Lungu, Chabala, & Shikaputo, 2023; Hunt & Hansen, 2010; Sefotho, 2015). In alignment with this view, Alvesson and Sköldberg (2018) argue that the ontological and epistemological assumptions—rather than the methods alone—serve as the primary determinants of rigorous and meaningful research.

A clear understanding of the philosophical commitments of the researcher about the research topic forms the foundation for the research methodology and the research design, which in turn informs the selection of appropriate research methods for a given study (Proctor, 1998). Consequently, research philosophy needs to be addressed in any advanced research project within the social sciences. To classify the underlying research philosophy of this thesis, the philosophical commitments regarding the nature of reality (ontology), the nature of knowledge (epistemology), and the role of values within research (axiology) are used, as recommended by Handema et al. (2023). Consequently, the following sections examine the interrelationship among ontology, epistemology, and axiology concerning the research topic and the rationale for the chosen research philosophy.

3.2.1 Ontology

As Grix (2010, p. 59) asserts, ontology represents the "starting point of all research". It concerns philosophical commitments about social reality and shows how the researcher perceives the world and what can be known about this reality (Ponterotto, 2005). The ontological stance, thus, implicitly informs the researcher's understanding of the research object and how it is studied (Jafari, 2021; Johnson & Clark, 2006). In the context of this thesis, the research objects comprise individuals who directly or indirectly utilise collaborative robots in their work. This encompasses individual experiences and perceptions and their implications on organisational structures and procedures, communication patterns, power relationships, and leadership, all of which have the potential to shape technology acceptance and, in turn, could influence system performance.

Ontological positions in research are often conceptualised on a continuum between two opposing paradigms, realism and nominalism (Easterby-Smith, Jaspersen, Thorpe, & Valizade, 2021). The relativist position, situated closer to the nominalist end of the spectrum, as illustrated in Figure 3-1, asserts that reality is socially constructed and inherently multiple. From this perspective, the comprehension of any research object is contingent upon the observer's interpretive lens (Ponterotto, 2005). This stance aligns with the position of the present study, which aims to explore the diverse lived realities of employees interacting with collaborative robots in their work environments by uncovering their concerns, thoughts, and motivations about working with them. It can be posited that these perceptions significantly shape individual responses and interpersonal dynamics (Saunders, Lewis, & Thornhill, 2023). In light of this, implementing collaborative robots within an organisation is not a static or uniform process but evolves through social interactions across organisational hierarchies (You & Robert, 2017). Consequently, employees may perceive the implementation process differently depending on their role, level of exposure to the technology, and evolving acceptance of collaborative robotics.

Building on the ontological commitments underpinning this research, the focus now shifts to epistemology. The following discourse is informed by the ontological stance that has been previously discussed, ensuring coherence between the assumptions about the nature of reality and the approach to knowledge generation.

3.2.2 Epistemology

The philosophical commitments concerned with epistemology focus on the nature and scope of knowledge, delineating what can be known about social reality and how such knowledge can be assessed (Blaikie, 2007). Consequently, epistemology strives to ensure that the acquired knowledge is adequate and legitimate through a coherent philosophical underpinning (Maynard, 2013). Thus, the epistemological commitments are intrinsically linked to the research question, as they signify the knowledge the researcher seeks to gain about a specific phenomenon (Willig, 2022).

Easterby-Smith et al. (2021) outlined that epistemological positions span a continuum from a positivist to a constructionist perspective. Positivist research is primarily concerned with conducting experiments and observations, which are subsequently subjected to rational deduction to derive scientific evidence (Ryan, 2006). This epistemological stance is thus closely linked to the "correspondence theory of truth", which states that the research object exists independently and directly determines its perception (Willig, 2022). In contrast, constructionist perspectives, despite their internal diversity, fundamentally oppose the positivistic stance and argue that there is no such thing as "objective truth" (Crotty, 1998). Instead, constructionists argue that meaning "is not discovered, but constructed" (Crotty, 1998, p. 9). This perspective aligns with the "coherence theory of truth", which aims to capture subjective realities (Darwin, 2004). From this standpoint, reality is understood as a product of social interactions, particularly manifested and negotiated through language as a form of social action (Willig, 2022).

The research question, namely, how do factors influencing the acceptance of collaborative robots shape system performance, together with the derived research objectives, necessitates an examination of individual realities. This involves studying individual social processes, including recurring patterns of interaction and communication among employees as they work with and without collaborative robots, thereby emphasising the subjective construction of reality at the individual level. In alignment with this focus, the epistemological position of the study can be justified. Specifically, the research adopts a moderate constructionist stance, as conceptualised by Willig (2022), aiming to elucidate the interplay between the discursive construction of participants' perceptions within the implementation process of collaborative robots and the broader socio-organisational context in which these perceptions are embedded. In doing so, it recognises that social realities pre-exist and shape discursive practices, thereby setting constraints on how meanings can be constructed, which distinguishes this stance from more radical or strong forms of constructionism.

Having established the epistemological foundations of this study, it is essential to consider the axiological commitments that underpin the research philosophy within the social sciences. The domain of axiology is thus inherently contingent upon the epistemological discourse.

3.2.3 Axiology

Axiology is a theory of values that aims to define the role of values within the research process (Saunders et al., 2023). Values, as conceptualised by Heron (1996), constitute the guiding reason for human action. Consequently, acknowledging and critically reflecting upon these values is essential to the integrity and rigour of the research endeavour.

Axiological commitments in research can range from claiming to be value-free to value-bound positions. Saunders et al. (2023) defined value-free research as being completely objective, wherein the researcher remained detached and independent from the research process. In contrast, value-bound positions are characterised by the view that the researcher is an integral part of the research context, thereby acknowledging their influence on the construction of knowledge (Winit-Watjana, 2016). This stance requires researchers to explicitly state their motivation, disclose their underlying values, and engage in active reflexivity throughout the research process (Cunliffe, 2003; Jafari, 2021). In alignment with this view, the personal and disciplinary reflexivity of the researcher is presented in Section 1.7, which discusses the role of the researcher. Sefotho (2015) asserts that addressing this topic is necessary for social science research, given that the researcher's values are inseparable from the inquiry and inevitably shape the research process and outcomes.

3.2.4 Choice of research philosophy

The following figure (Figure 3-1) shows the interrelationship between ontology, epistemology, and axiology and the range of positions associated with each philosophical dimension. Furthermore, the blue frame highlights the study's philosophical stance, aligning with the previously discussed philosophical commitments. This position is based on the research objectives and the researcher's stance on these philosophical commitments, consistent with the framework proposed by Thomas (2004). Accordingly, the philosophical orientation of this study is characterised as relativist in terms of ontology, constructionist in terms of epistemology, and value-bound in terms of axiology.

In conclusion, the study's subjectivist orientation is grounded in the nature of the research topic, which focuses on exploring the complex organisational processes associated with implementing collaborative robots. The research objectives reflect this orientation and are threefold. First, the study seeks to explore and identify critical factors influencing the acceptance of collaborative robot work systems. Second, it aims to develop a conceptual framework that illustrates the nuanced relationships among these factors and how they shape system performance. Both objectives are rooted in a core interest in employees' perceptions of collaborative robots, thus necessitating an emphasis on the socially constructed nature of reality. Third, the study proposes recommendations to create conditions for favourable user responses and attitudes towards collaborative robots. Achieving this objective likewise requires a subjective approach that enables a deeper understanding of the intricate and multifaceted manner in which individuals perceive and engage with collaborative robots. This, in turn, may generate more effective and user-centric recommendations.

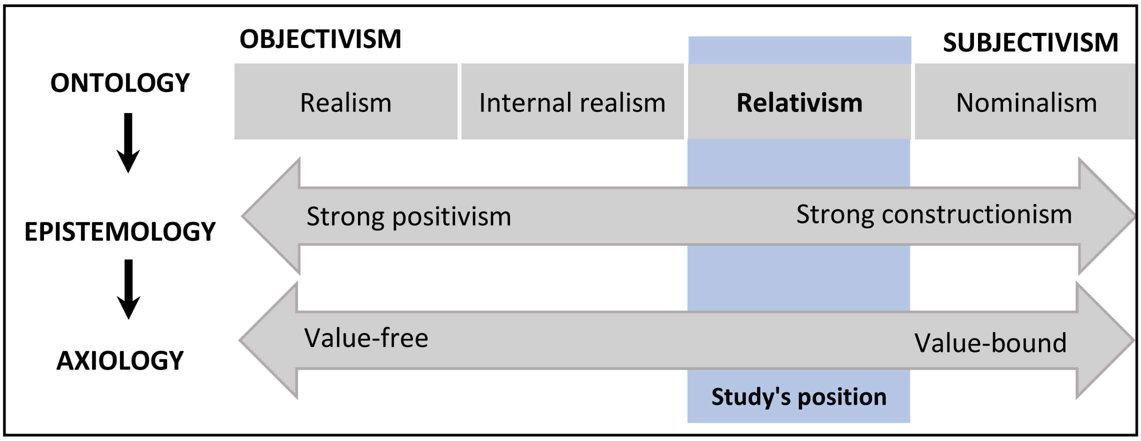


Figure 3-1: Philosophical commitments of the current thesis (Sources: Easterby-Smith et al., 2021, p. 80; Saunders et al., 2023, p. 136)

Furthermore, this study's position also recognises the researcher's philosophical stance, which is based on the understanding that individuals cannot be studied in the same way as natural objects and that researchers cannot be regarded as detached and independent from the research process. A central argument supporting this view is outlined by Orlikowski and Baroudi (1991), who state that objectivist approaches often neglect the fact that individuals actively engage with, interpret, and shape their physical and social realities through their actions. Subjectivist research is thus primarily associated with a qualitative methodology that considers the complexity and contextual nuances inherent in organisational settings (Saunders et al., 2023). In line with this philosophical orientation, the next step involves the selection of a coherent qualitative research methodology that supports the study's ontological, epistemological, and axiological stances.

3.3 Research methodology

One of the methodologies widely employed in organisational studies is grounded theory, which has been developed to generate theories inductively from empirical data (Glaser & Strauss, 1967). Grounded theory is not a single method, but belongs to a research family and is one of the most popular methodologies within qualitative research (Mohajan & Mohajan, 2022). In this research family, three main approaches to grounded theory have emerged, each reflecting different epistemological and ontological orientations. However, not all these approaches align with the research objectives and philosophical commitments underpinning the present study.

The different approaches to grounded theory have evolved since its first publication in the 1960s: (1) The original version, developed by Glaser and Strauss, is grounded in a critical realist ontology and a modified objectivist epistemology (Annells, 1997). Accordingly, this approach is more aligned with the positivist end of the philosophical continuum, as illustrated in Figure 3-1. (2) A subsequent iteration introduced by Strauss and Corbin adopts a relativist ontological stance and a more subjectivist epistemological orientation (Annells, 1997). (3) Finally, the most recent approach advanced by Charmaz, which is called the constructivist grounded theory, is rooted in symbolic interactionism and emphasises the co-construction of meaning between researcher and participants (Charmaz, 2014). This constructivist grounded theory is characterised by a relativist ontology and a constructionist epistemological position (Khanal, 2019).

The approaches advanced by Strauss and Corbin, as well as that of Charmaz, are positioned more towards the right end of the philosophical continuum illustrated in Figure 3-1. Both methodologies align with the subjectivist perspective of the study, as they elucidate the socially constructed nature of reality in complex organisational settings.

Moreover, the nature of the relationship between the research participants and the researcher is crucial for differentiating between the different grounded theory approaches (Mills, Bonner, & Francis, 2006). In contrast to the more conventional grounded theory approaches, Charmaz's constructivist grounded theory emphasises the importance of reflexivity, arguing that researchers are not "scientific observers who can dismiss scrutiny of our values by claiming scientific neutrality and authority" (Charmaz, 2014, p. 27). This assertion resonates strongly with the researcher's axiological stance, which posits that, particularly in the social sciences, research is inherently value-laden and necessitates active engagement with the researcher's positionality.

Accordingly, constructivist grounded theory is philosophically coherent with the present study, offering a sound methodological framework for eliciting and interpreting participants' perspectives and lived experiences. This alignment is critical given the study's aim of understanding the socially constructed realities that shape perceptions of collaborative robots in organisational contexts.

In light of the philosophical underpinning of constructivist grounded theory, it is imperative to discuss the methodology in relation to the relevance of its research findings. A key epistemological distinction within this approach lies in how it differentiates between what is considered "truth" and what is understood to be "reality". Charmaz (2000) defined truth as socially constructed, inherently pluralistic, and subject to variation across contexts and perspectives. Conversely, she accepts the existence of a real-world when she defines reality (Charmaz, 2000). However, Charmaz's definition of truth encompasses not only the phenomenon under investigation but also the interpretive role of the researcher (Charmaz, 2014).

This discussion gives rise to the dilemma of epistemological relativism, which rejects the generalisation of findings due to the definition of truth that neglects cross-framework judgements (Fay, 1996). Under this view, the socially constructed nature of truth precludes the existence of predefined standards for validating research findings (Kikuchi & Simmons, 1999; Stajduhar, Balneaves, & Thorne, 2001). However, without the possibility of validating research findings, the construction of meaning based on the research becomes almost impossible (MacDonald & Schreiber, 2010). To overcome this dilemma, Searle's philosophical underpinning of realism can be applied (Lomborg & Kirkevold, 2003). He based his position on the "correspondence theory of truth" and acknowledges the constructed social reality of individuals while retaining the objective nature of this social reality (Searle, 1997). Most importantly, Searle's reconceptualisation of realism is consistent with Blumer's thoughts on symbolic interactionism, upon which constructivist grounded theory is built (Lomborg & Kirkevold, 2003).

Consequently, Searle's reconceptualisation of realism provides a valuable reference to reassess the philosophical foundation of symbolic interactionism that could thus be described as an implicit realist position (Lomborg & Kirkevold, 2003). Hence, Lomborg and Kirkevold (2003) argue that the limitations of a purely constructionist stance can be mitigated. They suggest that grounded theory, particularly in its constructivist form, need not be restricted to intra-framework judgements but can accommodate broader epistemological claims through a realist-informed perspective. Therefore, the constructivist grounded theory emerges as an appropriate methodology for achieving the stated research objectives.

While constructivist grounded theory is a particularly well-suited methodological choice given the study's philosophical underpinnings, it is not the only possible choice. Alternative approaches, such as symbolic interactionism or phenomenology, are also deemed epistemologically compatible. However, the selection of the most appropriate methodology depends on its alignment with the research question and the study's objectives (Burns, Bally, Burles, Holtslander, & Peacock, 2022). Symbolic interactionism excels when the research focuses on how meaning is constructed and negotiated in specific social contexts (Salvini, 2019), whereas phenomenology is best applied to questions that focus on understanding the essence and nature of individual experiences and subjective perceptions (Urcia, 2021). Accordingly, phenomenology and symbolic interactionism are particularly well-suited for research endeavours that seek to explore individual experiences or to elucidate the meanings generated through social interaction specifically in micro-level contexts. Even if these approaches do not contradict the researcher's philosophical commitments, they are less suitable for answering a research question aimed at developing a theoretical understanding of dynamic social and organisational processes underlying complex phenomena. This need is corroborated by the call for further research into the human-robot collaboration dynamics, particularly within team-based contexts (Di Pasquale et al., 2024; Hopko et al., 2022; Rinaldi et al., 2023).

The appropriateness of this methodology is further reinforced by the study's specific research objectives and overarching purpose. Constructivist grounded theory is particularly well-suited to this aim, as it is explicitly oriented toward generating new theoretical insights, an emphasis less central to symbolic interactionism or phenomenology (Cunliffe, 2010; Nolas, 2011). While contemporary forms of symbolic interactionism and phenomenology may at times extend beyond descriptive analysis, their principal contribution remains the in-depth exploration of subjective meaning (Syamsudin, Haerani, Damayanti, & Fattah, 2022). Consequently, constructivist grounded theory emerges as the most appropriate research methodology regarding the substantive research topic, the research question, and the overarching research objectives. In light of this methodological choice, it is imperative to design a research strategy congruent with the principles and procedures of constructivist grounded theory.

3.4 Research design

According to Payne (2021), the grounded theory research family is particularly well-suited for exploratory research. Adopting an exploratory research design is valuable because it aims to uncover new insights that facilitate a more nuanced understanding of a given phenomenon (Swedberg, 2020). Given the limited empirical research on collaborative robots within real-world settings, as highlighted in the literature review of this thesis, an exploratory approach is deemed appropriate. Consequently, this section provides an overview of the study's exploratory research design and a rationale for selecting the case study approach.

When discussing the research design, it is crucial to ascertain how the study ensures an accurate representation of the phenomenon under investigation. This necessitates a critical assessment of the study's quality, encompassing the validity, reliability and generalisability of its findings (Easterby-Smith et al., 2021). These conventional criteria, rooted in positivist traditions, may not adequately capture the complexities inherent in qualitative inquiry (Easterby-Smith et al., 2021). Instead, these terms are often reconceptualised in qualitative research to align with interpretivist paradigms. For instance, traditional notions of validity and reliability may not adequately capture the nuances of qualitative inquiry.

In qualitative research, the quality of a study can be more effectively evaluated based on trustworthiness, encompassing four key criteria: (1) credibility, (2) transferability, (3) dependability, and (4) confirmability (Guba, 1981; Tierney & Clemens, 2011). These criteria serve as qualitative counterparts to traditional quantitative measures: credibility corresponds to internal validity, transferability aligns with external validity, dependability with reliability, and confirmability with objectivity (Guba, 1981). To ensure trustworthiness, this study has meticulously addressed each criterion (Malterud, 2001; Tierney & Clemens, 2011).

Furthermore, memos emphasising reflexivity were employed throughout the research process to document and justify decisions, as Nowell, Norris, White, and Moules (2017) recommended. Therefore, the research design must be grounded in a well-articulated rationale that informs each stage of the decision-making process. More specifically, this rationale should explicitly address what is being done, how it is being done and why it is being done (Tobin & Begley, 2004). Consequently, the following section presents the theoretical foundations and practical considerations of the research methods, including the sampling strategy, data collection procedures, and data analysis techniques.

3.4.1 Mode of enquiry

To investigate how acceptance-related factors in collaborative robot applications impact system performance, a case study approach focusing on the healthcare manufacturing sector was chosen. Yin (2018) states that a case study approach is particularly suitable for in-depth exploration of complex phenomena within their real-world context, aligning with this thesis's aim. Thus, the case study approach is used as an overarching approach to generate an in-depth and multi-faceted understanding of such a situation within its contextual environment. This aligns with Guercini (2004), who emphasised that case studies are highly suitable for analysing complex organisational processes. Furthermore, the present methodology follows the recommendations of Hancock, Algozzine, and Lim (2021), who advocate for case studies when investigating contemporary phenomena situated within clearly defined spatial and temporal boundaries. Such a research phenomenon is exemplified by analysing the deployment of collaborative robots and their effects on acceptance and system performance based on a real manufacturing setting over a defined period.

To investigate the implications and organisational changes arising from the implementation of collaborative robots, an in-depth analysis of a single case is conducted in the current thesis. As Yin (2018) argues, a single-case design is justifiable when it represents a critical test of existing theory, a unique situation, a typical case or when it constitutes a revelatory or longitudinal study. A single case study approach was chosen for this thesis because it facilitates a detailed and context-specific examination of a unique instance within the organisation where the researcher is employed. This particular case has remained unexplored in previous research due to restricted access, qualifying it as a revelatory case per Yin's (2018) classification.

The case under investigation involves an analysis of the integration of collaborative robots into the manufacturing processes of a packaging department in Germany operated by a leading global healthcare company. The study compares two manufacturing scenarios: integrating a collaborative robot as a new team member versus performing the process without robotic assistance. According to Yin (2018), this represents an embedded case study design as the study involves multiple units of analysis, namely the manufacturing process with and without collaborative robots. The embedded case study design of this revelatory case is visually illustrated in Figure 3-2. In addition, this case involved multiple levels of analysis, including examining the impact of using collaborative robots at both the individual and the organisational level to assess the overall effect of collaborative robots on system performance.

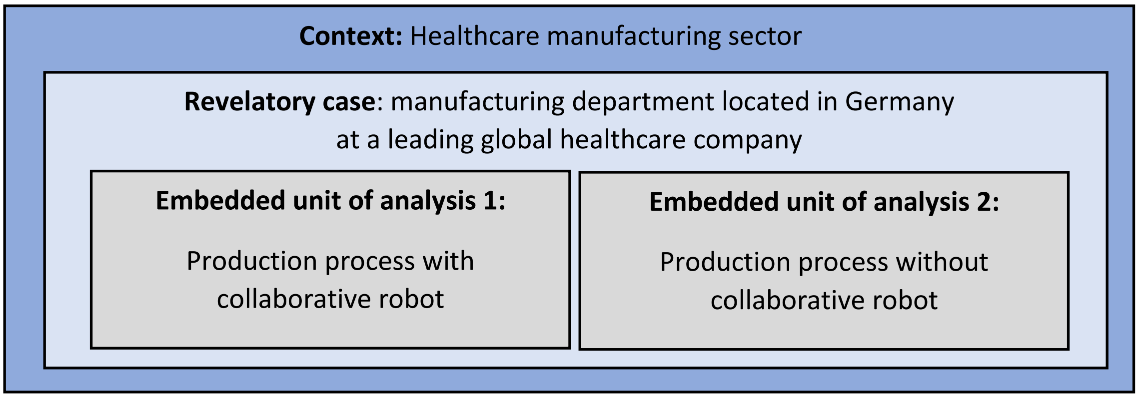


Figure 3-2: Embedded case study design (Source: Yin, 2018, p. 48)

The applied case study approach was used to obtain an in-depth exploration of the phenomenon under investigation. As the case study approach is a research strategy rather than a single method, it incorporates multiple methods of data collection and analysis to generate a rich and holistic understanding (Willig, 2022). One of the key strengths of case study research lies in its methodological flexibility and capacity to integrate various qualitative and quantitative techniques (Yin, 2018). This multimethod approach also responds to existing calls for using diverse methods in qualitative studies of human-robot collaboration, as highlighted by Veling and McGinn (2021) and Bethel and Murphy (2010).

The thesis relies on multiple data collection methods to address its research objectives from multiple angles. Empirical evidence was derived from three sources: (1) document analysis, (2) participant observation, and (3) semi-structured interviews. The first method involved the analysis of secondary data derived from a review of internal documents relevant to the case under investigation. Subsequently, participant observation was used to explore employee interactions and workflows in both scenarios—with and without integrating collaborative robots. During these observations, informal conversations occurred between the participants and the researcher, offering additional contextual insights. Finally, semi-structured interviews were conducted to capture individual perspectives and experiences related to implementing collaborative robots. The data collected through participant observation and semi-structured interviews consists of two primary data types. These data were collected through direct engagement with the phenomenon in its natural setting and by eliciting participants' reflections via interview narratives.

Each data collection method serves different purposes, leveraging its unique strengths while mitigating potential limitations through methodological complementarity (Yin, 2018). Before outlining each data collection method, it is essential to consider the sampling strategy, as it forms a critical foundation for the credibility and relevance of the research findings.

3.4.2 Sampling strategy

One crucial aspect of the sampling process in qualitative research is the determination of an appropriate endpoint for data collection, ensuring the depth necessary to generate a nuanced understanding of the research question. Similar to other qualitative methodologies, there is no universally prescribed optimal sample size within the family of grounded theory (Charmaz, 2014; Glaser & Strauss, 1967).

Within constructivist grounded theory, it is imperative to recognise that the primary objective is not to achieve statistical generalisability but to enable the emergence and refinement of themes grounded in the data (Charmaz, 2014). This sampling strategy allowed the researcher primarily to narrow the focus on the developed themes and their refinement, as suggested by Charmaz (2014). It is, therefore, essential to acknowledge that in such qualitative approaches, the analysis does not culminate in an absolute or complete endpoint (Low, 2019). Instead, the analytical process is inherently interpretative and relies on the researcher's reflexive judgment to assess the sufficiency and depth of thematic development (Braun & Clarke, 2021b). This assertion aligns with a pragmatic conceptualisation of theoretical saturation, wherein saturation is understood not as a fixed standard but as a context-dependent construct shaped by the specific objectives and scope of the analysis (Low, 2019). Consequently, saturation is reached when the addition of new data no longer yields new insights about the coding and theme development process (Islam & Aldaihani, 2022).

Based on the points above, two criteria were used to determine the endpoint of data collection in this study. First, data collection ceased when no new perspectives or themes emerged from additional data. This can only be determined through an iterative process whereby data collection and analysis occur concurrently. Such an approach enables the simultaneous assessment of whether additional data is necessary to enrich or extend the constructed themes. Second, data collection was concluded once the dataset clearly supported answering the research questions and achieving the objectives. Within this framework, saturation is conceptualised not as an absolute state but as a pragmatic threshold defined by the adequacy of the data to address the research objectives sufficiently.

Theoretical sampling constitutes a foundational component of grounded theory, including constructivist grounded theory (Charmaz, 2014; Kearney, 2007). Theoretical sampling is considered a special form of purposive sampling, aimed at theory development rather than representativeness (Morse & Clark, 2019). It starts with an initial dataset, from which preliminary insights are generated. These emergent ideas then guide subsequent rounds of data collection in a manner that is both iterative and responsive to the evolving theoretical understanding (Charmaz, 2014). Thus, theoretical sampling is defined by Charmaz (2014, p. 192) as "seeking and collecting pertinent data to elaborate and refine categories in your emerging theory". In constructivist grounded theory, initial data collection typically starts with purposive sampling to identify participants or cases likely to yield rich, relevant information (Butler, Copnell, & Hall, 2018; Charmaz, 2014). The following subsections delineate how this thesis initially applies purposive sampling, followed by four distinct phases of theoretical sampling.

Purposive sampling

The current study employed a purposive sampling strategy, which commenced with a review of relevant documents and archival materials. This was undertaken to develop a fundamental understanding of the phenomenon under investigation and inform subsequent stages of data collection. The selection of documents was guided by the researcher's judgment regarding their relevance, credibility, and potential to contribute to the study findings meaningfully.

The second phase of data collection involved participant observations guided by purposive sampling criteria. The primary criterion for sample selection was the execution of packaging operations for comparable finished goods under two distinct conditions: one involving collaborative robots and the other without robotic assistance. This approach was designed to facilitate a direct comparison between the two manufacturing processes. The sampling criteria were defined prior to data collection and were already aligned with the embedded case study design. Therefore, this data collection process can also be categorised as purposive sampling. Charmaz (2014, p. 197) characterises purposive sampling as a suitable starting point in grounded theory research, distinguishing it from theoretical sampling, which she defines as a "way to determine where you go".

Theoretical sampling–Step 1

Theoretical sampling facilitates the researcher to develop and refine constructed themes through continuous interaction with the data (Breckenridge & Derek, 2009; Charmaz, 2014). Theoretical sampling often begins with the inclusion of additional data sources to explore preliminary analytical insights (Wuest, 2001). In the current thesis, the first phase of theoretical sampling involved conducting a pilot study with semi-structured interviews as a complementary method. This approach aimed to gain further insight into the phenomenon by addressing open-ended questions about how the participants perceive the implementation of collaborative robots or their perceived benefits and challenges. Typical questions used in the semi-structured interviews are outlined as follows: *"What do you perceive as positive/negative when working with cobots?", "How valuable do you perceive the support from the cobots?", "How has the collaboration within the working group changed because of the implementation of the cobots?",* and *"How has the productivity changed as a result of the cobots?"*

The following criteria were applied when inviting the participants to the study: experience using collaborative robots and their professional role. This approach ensured the inclusion of production workers and production technicians within the sample.

Theoretical sampling–Step 2

Following the analysis of the pilot interviews, several questions were removed, some were refined, and some new questions were added according to the principles of theoretical sampling as outlined by Butler et al. (2018). This represents one of the most frequently used techniques in theoretical sampling, which involves refocusing data collection based on emerging insights to explore specific themes more deeply (Draucker, Martsolf, Ross, & Rusk, 2007). The complete set of semi-structured questions used in pilot testing is presented in Appendix B.1, while Appendix B.2 presents the revised set used in the main study. Modifications made to enhance clarity and additions or omissions prompted by the pilot study findings are explicitly marked in Appendix B.2. The selection criteria for participants remained consistent with those employed in the previous step, ensuring methodological comparability between the pilot and main study groups.

Theoretical sampling–Step 3

The subsequent phase of theoretical sampling introduced a new participant characteristic, similar to the approaches previously adopted by other constructivist grounded theory researchers (Balakumar, Bernar, Crispino, & Winstanley, 2020). Specifically, the focus was placed on the frequency of interaction between the participants and the collaborative robot. This characteristic aimed to capture the diverse perspectives of employees with varying frequencies of interaction with these robots. Snowball sampling was employed to identify potential new participants who varied along this dimension, as suggested by Lune and Berg (2017). In the ninth interview onward, participants were asked to recommend colleagues who met this criterion, and their recommendations were documented in the interview transcripts to ensure transparency.

Theoretical sampling–Step 4

In the final phase of theoretical sampling, the data collection scope was extended by including a new participant group, as suggested by Butler et al. (2018). This entailed integrating the direct managers who regularly interact with the employees operating collaborative robots. Participants were selected based on their position, which provided them with direct interaction with employees working with collaborative robots. This supplementary group yielded novel insights into the research question, enriching a more layered analysis of the phenomenon. Some typical questions for the managers were: "*How has the usage frequency of the cobots changed over time?", "What fears or hopes did your employees have at the beginning of the implementation of cobots, and how has this changed up to now?", "What do you think can be done to increase the acceptance of the cobots?", "To what extent did the product quality change as a result of the cobots?"* The complete set of interview questions used for this group is listed in Appendix B.3.

The four theoretical sampling steps previously outlined culminate in the adoption of a dyadic approach. A dyad is generally defined as a relationship or interaction between two or more individuals (Szulc & King, 2025). In this study, an expanded interpretation of the term dyad is employed to encompass two distinct organisational groups: (1) employees, including both production workers and production technicians and (2) their direct line managers. The dyadic approach typically involves conducting joint interviews with two participants to identify discrepancies and congruences in their perceptions (Szulc & King, 2025). Nevertheless, the current study did not adopt such an interview configuration due to inherent power asymmetry between employees and their line managers, consistent with the methodological guidance by Head, Ellis-Caird, Rhodes, and Mengoni (2021). In circumstances involving a power disparity which may inhibit open dialogue, Head et al. (2021) recommended conducting individual interviews.

The following table presents the dyadic structure used in the study. Furthermore, Table 3-1 illustrates how each group within the dyad was engaged: employees were asked to conduct self-assessments, whereas line managers provided external assessments of their employees. This dual-perspective design aligns with the framework proposed by Gmelch et al. (2008), who recommend such an approach for investigating relational dynamics within dyadic structures.

Dyad		
Group of employees		**Group of managers**
"What did you think (or feel) when you first saw cobots? (fears, hopes)" and "How has it changed since then?"	↔	"What fears or hopes did your employees have at the beginning of the implementation of cobots?" and "How has this changed to date?"
"Have you developed an emotional connection with the cobots (similar to a colleague)?" or "How does it feel to work with the cobots (compared to working with a human colleague)?"	↔	"How are cobots currently perceived by employees (especially in terms of forming an emotional bond comparable to a colleague)?"
"How has collaboration within the group changed because of the implementation of the cobots? "	↔	"How has collaboration within the group changed because of the implementation of the cobots?"

Table 3-1: Dyadic approach of the study

This study captures the nuanced interactions and relational dynamics that shape human-robot collaboration by incorporating both employees who interact directly with collaborative robots and their immediate managers. This dual perspective facilitates a multifaceted understanding of how collaborative robots are perceived, the benefits and challenges encountered, and their broader impact on the manufacturing process and system performance. Integrating both groups ensures the identification and analysis of converging and diverging viewpoints, effectively operationalising a dyadic approach. Such an approach yields deeper insights into the dynamics between employees and managers, facilitating an in-depth analysis of the phenomenon.

Figure 3-3 illustrates the sampling process used in the present study, providing an overview of the procedures outlined in the preceding discussion. This figure presents the integration of the applied sampling methods, incorporating the three distinct data collection methods utilised. In addition, the theoretical sampling approach is demonstrated, highlighting the four sequential steps that guided participant selection and data refinement. In line with Charmaz's (2014) methodological recommendations, key decisions made during the process were recorded using memos, enhancing the transparency and rigour of the research design.

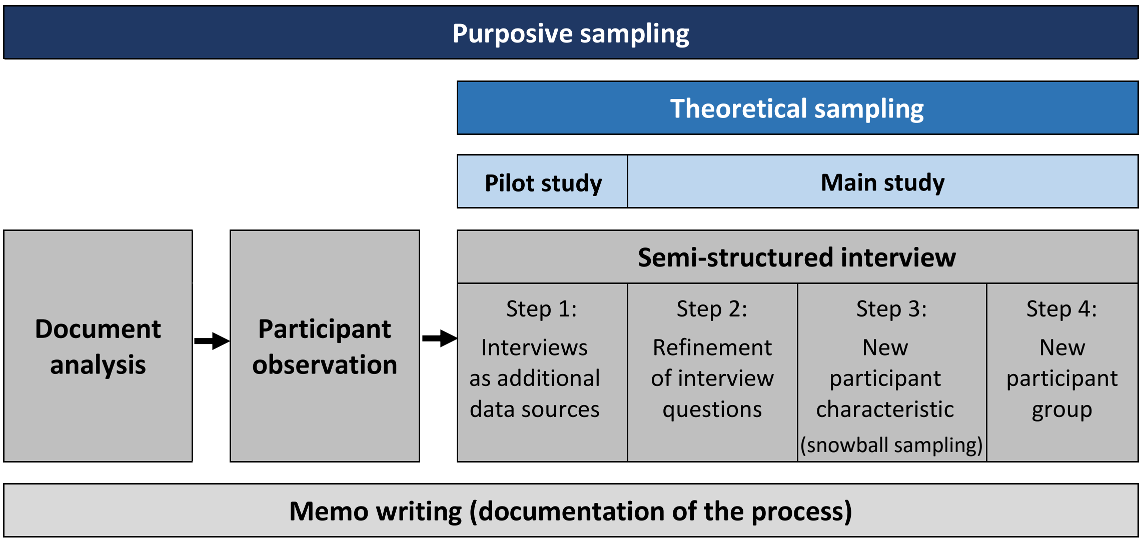


Figure 3-3: Overview of sampling procedure

However, a methodologically sound discussion of the sampling process can only be achieved when the population of interest has been clearly defined (Hossan, Dato' Mansor, & Jaharuddin, 2023). Aligning with the focus of this thesis, the research population is defined as all employees, either directly or indirectly, engaged in utilising collaborative robots within the manufacturing sector of the healthcare industry. However, this population was deemed too expansive and not manageable for empirical investigation. Therefore, following Hossan et al. (2023), a target population needs to be defined. Accordingly, in this study, the target population was refined in collaboration with the organisation under investigation and is detailed in the following section on data collection.

3.4.3 Data collection

The data collection for the current case study was conducted at the German site of a leading global healthcare company. This company specialises in developing and manufacturing innovative diagnostic tests and systems as well as pharmaceutical solutions that significantly contribute to advancing the healthcare sector. The German site, which employs approximately 8,000 personnel, plays a pivotal role in developing and providing diagnostic solutions and pharmaceuticals, making it a particularly suitable setting for examining the integration of collaborative robotics in a high-stakes manufacturing environment.

Within the selected company, the case study was conducted in the packaging department, which specialises in manufacturing finished goods for the diagnostic sector, at one of the company's sites. This department manufactures approximately 1,500 products for in-vitro diagnostics and research purposes and employs more than 50 employees. In 2019, the first collaborative robot was introduced to the department's manufacturing processes. In subsequent years, a workstation comprising two collaborative robots of the same type was established, with an automated supply for filled and labelled components. This workstation, which represents the focus of the present study, was configured in its current form at the end of 2022. Document analysis revealed that the utilised single-arm collaborative pick-and-place robots have seven axes and weigh 18 kg, making them relatively small and lightweight. The maximum payload capacity is 3 kg, with a maximum reach of 850 mm. The collaborative robot under consideration is primarily anthropomorphic regarding movement rather than aesthetics (Scholz, Cao, El Makrini, & Vanderborght, 2023). The seven axes design of this collaborative robot emulates human arm biomechanics, allowing for flexible, joint-like movement and enabling physical guidance.

Implementing these collaborative robots is designed to facilitate pick-and-place tasks performed by employees during the packaging processes of finished goods. This form of interaction between the human operator and the collaborative robot aligns with the concept of cooperation, as defined by Bauer et al. (2016). The human operator and the collaborative robot share the same workspace and act on a common task in such cooperative arrangements. Yet, they do not work on the same workpiece concurrently. In the present thesis, the relevant packaging processes were comparatively analysed under two conditions: with and without utilising a collaborative robot as a new team member. This comparative approach was feasible because only a portion of the products are manufactured with robotic assistance, while the remaining portion is produced manually by human operators.

The following subsections provide a detailed account of the various data collection methods employed in this study—including document analysis, participant observation, and semi-structured interviews. In addition, each method is examined with regard to its theoretical underpinnings and practical implementation within the context of the present case study. The data collection activities were carried out over 14 months, from May 2023 to June 2024.

3.4.3.1 Document analysis

Documents were used as a valuable source of evidence in the current case study. Simons (2009, p. 63) defines documents as "anything written or produced about the research context or site". Archival and documentary sources can take various forms, including individual records, communication records, organisational records and media outputs (Saunders et al., 2023). A common characteristic of these documents is that they were originally created for a purpose unrelated to the current research. Nonetheless, such documentation can function as crucial secondary evidence when triangulated with primary data, such as observations and interviews (Yin, 2018).

In the present study, the document analysis primarily draws on organisational sources, focusing on reviewing existing documents and archival records. These materials provided insight into the chronological sequence of the implementation of collaborative robots and the subsequent development of the respective workstation from its initial deployment to its current configuration. The data sources included calendar entries, organisational images, films, presentations and reports. In addition, materials provided by the collaborative robot manufacturer were used to provide a comprehensive understanding of the collaborative robots used at the case study site. Collectively, these sources provide evidence for the analysis of the implementation process, enabling an analysis of the steps undertaken and the organisational and economic context in which the integration occurred.

However, it is essential to consider the original purpose and the nature of the selected documents when interpreting them and to verify the sources' quality (Hakim, 2012). To ensure methodological rigour, the review of documents was systematically done by developing a protocol. This protocol summarised the key aspects of each reviewed document and provided explicit references to the sources of evidence, following Yin's (2018) recommendations. This approach was critical to ensure methodological credibility, especially given that access to some internal materials was restricted exclusively to the researcher as per company confidentiality policies. The initial data collection began in May 2023 and was concluded once data saturation was reached, meaning that further document analysis did not provide new insights regarding the initial understanding of the collaborative robot implementation process.

A subsequent document and archival review was carried out following the refinement of the research question, with a more focused emphasis on system performance. This phase of analysis involved comparing manufacturing lead times and resource consumption for different finished goods, each produced with and without utilising collaborative robots. The main data sources for this comparison were the bills of materials of the corresponding products. This additional data collection took place in November 2023 and was concluded after comparing the different manufacturing approaches for four products. In total, the document and archival reviews resulted in a secondary data summary of 18 pages.

These secondary data built the baseline for the current case study, establishing the contextual framework for the subsequent collection of primary data. While secondary sources provided the background information and informed the development of research instruments, the primary data constitutes the principal source of evidence on which the thesis is based. Among the primary data collection methods employed, participant observation played a vital role.

3.4.3.2 Participant observation

Participant observation is a well-established method in qualitative research and is frequently used in case study designs (Yin, 2018). Originating from social anthropology, participant observation is particularly suited to exploring the meanings individuals assign to their actions (Saunders et al., 2023). Given that the current research focuses on the interactions between employees and collaborative robots, participant observation was chosen as the initial method for primary data collection. This approach enabled a contextualised understanding of the physical setting and actual practices to obtain a deeper understanding of the similarities and differences in workflows involving collaborative robots compared to those that do not. Participant observation is especially valuable in uncovering nuanced aspects of human-technology interaction, as it provides access to relational dynamics and unspoken tacit behaviours that may be difficult to reveal in interviews or documentary sources (Saunders et al., 2023).

Gold (1958) categorises participant observation into four distinct types based on the researcher's level of involvement and the degree of interaction between the researcher and the participants: (1) complete observer, (2) observer-as-participant, (3) participant-as-observer, or (4) complete participant. These classifications help delineate the researcher's stance during participant observation. In the context of the present study, the researcher's stance can be best described as participant-as-observer. This position is characterised by active involvement in the setting while maintaining complete transparency about the research purpose, with participants explicitly informed of the researcher's role (Easterby-Smith et al., 2021). This stance was particularly appropriate given the professional relationship between the researcher and the participants. The researcher was already embedded within the organisation under investigation and had established longstanding professional ties with the participants. This trust-based relationship facilitated more open interactions, enabling access to deeper insights that would likely remain inaccessible in a single-visit interaction (Takyi, 2015).

A key feature of the participant-as-observer stance is the opportunity for informal conversations between the researcher and participants during observation. Charmaz (2014) posited that informal conversations during the observation process represent an optimal combination of the advantages inherent to both interviews and observations. This is because informal conversations are grounded in the immediate context of observed behaviours, providing concrete reference points for exploring participants' actions, experiences, and emotions (Charmaz, 2014). This contextual anchoring enriches the depth of the data collected. Furthermore, for individuals unfamiliar with formal interview settings, such as shop-floor employees, informal conversations often provide a more comfortable means of expression.

The participant observations aimed to develop a foundational understanding of the manufacturing process—both with and without collaborative robots—and to derive meaningful and context-specific questions for the interviews. Consequently, the observations were intentionally designed to be exploratory and less formalised. Thus, the focus was to gather a broad range of data, including primary observations, secondary observations, experiential data, and contextual data (Saunders et al., 2023). These data types were based on participants' statements, interpretations and perceptions of the observer, or situational insights derived from the context. All these data types were collected during the observations in the current study. The initial step was to take notes during the observation period, including participants' verbatim statements. As Easterby-Smith et al. (2021) suggested, these initial notes were promptly expanded into comprehensive field notes to preserve the richness of the observational data. To prevent misinterpretations, the field notes were subsequently reviewed by the participants.

The participant observations for the current study took place between June and October 2023. Each of the eight observations lasted between 35 and 45 minutes and focused on either manufacturing with or without collaborative robots. On average, each field note comprised about three pages, resulting in 22 pages. The saturation point was reached after the fourth observation in both observation settings. Based on the field notes, this was determined through initial coding and preliminary theme development. At this stage, no new codes or themes emerged to formulate questions for the subsequent semi-structured interviews. This outcome aligns with the definition of data saturation by Islam and Aldaihani (2022). In this context, themes are understood as recurring patterns of meaning or behaviour identified within the data. Research findings derived from participant observations are often highly context-specific and relevant to the observed setting (Allen, 2010). Thus, participant observation was instrumental in ensuring authenticity and producing credible research findings in the present study. However, despite its strengths, Bositis (1988, p. 333) argues that this research method is "more complex and therefore more misunderstood" than any other method. Given these complexities, it is essential to clearly define the researcher's stance and focus on the methodological challenges inherent in this approach. The most commonly cited issues are observer error, observer bias, and the observer effect (Saunders et al., 2023).

According to Saunders et al. (2023), observer error may occur either from a lack of familiarity with the research context or, conversely, over-familiarity with the phenomenon under investigation, resulting in possible unintentional misinterpretation. In the present study, the risk of observer error is reduced due to the researcher's familiarity with the context in which the work is conducted while maintaining a sufficient distance from the work process under observation. The second issue, observer bias, is related to the researcher's subjective interpretation of the setting (Saunders et al., 2023). In the current study, this issue was addressed through informant verification. The participants were asked to read the field notes and correct any misinterpretations to enhance the credibility and accuracy of the recorded data. The third issue is the observer effect, which involves the possibility that the mere presence of the researcher may alter participants' behaviour (Saunders et al., 2023). Based on the participant-as-observer stance, this issue was mitigated using the existing trust-based relationship between the researcher and the participants (Oswald, Sherratt, & Smith, 2014).

Furthermore, in this thesis, several additional measures were implemented to mitigate the impact of the aforementioned issues. These included the systematic documentation of observations, including detailed descriptions of the setting, verbatim quotations, and reflexive notes reflecting the researcher's thoughts and positionality, as suggested by Willig (2022). In addition, several observations were carried out with different participants to provide a broader and trustworthy dataset.

Overall, all identified methodological concerns associated with this method were systematically addressed using appropriate mitigation strategies. Notwithstanding, it is imperative to acknowledge that participant observation was not the sole method of data collection. To enhance the breadth and depth of the empirical evidence, all participants involved in the observations were subsequently included in the interview phase.

3.4.3.3 Semi-structured interview

The study's primary data collection method was semi-structured face-to-face interviews. This method served as a valuable complement to participant observations by capturing human experience that cannot be directly observable, such as thoughts, feelings, and the meaning participants attach to specific situations (Patton, 2015). As Patton (2015, p. 427) notes, interviewing allows the researcher to "enter into the other person's perspective". For the current study, semi-structured face-to-face interviews were chosen due to their methodological flexibility. For instance, this method enables the interviewer to adapt the sequence of questions and to introduce follow-up or probing questions if required to gain further insight into the research objectives (Young et al., 2018).

In the present study, the semi-structured interview approach was deemed the most appropriate compared to highly structured or unstructured formats. This type of interview is particularly well-suited to exploratory research (Saunders et al., 2023). In addition, this interview format is particularly advantageous when engaging participants across varying organisational hierarchies (Soltani, Barnes, Syed, & Liao, 2012). This was critical due to the inclusion of two distinct groups interviewed: shop-floor employees who interact directly with collaborative robots and their immediate supervisors. Including both groups was essential to a multifaceted understanding of the phenomenon under investigation and addressing the research questions from diverse perspectives.

To ensure methodological rigour, the semi-structured interview followed the six-step process outlined by Lucas (2005). These steps include (1) articulating the goals for the interview process, (2) recapping well-known information, (3) developing a set of questions for the interviews, (4) strategising the interview structure, (5) executing the interview process, and (6) conducting a follow-up with the participants (Lucas, 2005). Each of these steps is described in more detail in the following subsections.

Step 1: Articulating the goals for the interview process

The initial step in the interview process is to define the goal for the interview, ensuring alignment with the overarching research objectives of the study (Lucas, 2005). In this case, the primary objective was to explore the critical factors affecting acceptance of collaborative robots within a healthcare manufacturing context and identify how these acceptance-related factors shape system performance. A further objective was to derive actionable recommendations for creating conditions that promote favourable user responses towards the integration and utilisation of collaborative robots on the shop floor, drawing specifically on factors influencing such responses. Given the centrality of qualitative data in this case study, the main goal of the interviews was to serve as a principal means of obtaining in-depth insights.

Step 2: Recapping well-known information

According to Lucas (2005), this step is crucial to formulating meaningful and contextually relevant questions, as existing knowledge is implicitly embedded in the interview questions. In the current study, the outcomes of the document analysis and the field notes generated from the participant observations jointly constitute the foundational understanding of the case under study. This served as a critical starting point for a more focused approach to data collection, aligning with the principles of grounded theory methodology (Willig, 2022).

Step 3: Developing a set of questions for the interviews

In the third step, two distinct interview protocols were developed to address the differing perspectives of the two groups of participants, namely the employees directly interacting with the collaborative robots and the immediate managers of those employees. The development of these protocols was grounded in the thematic patterns identified during the participant observations. This approach ensured the continuity between the different data collection methods.

To enhance the clarity of the interview questions, they were categorised according to the six types of interview questions defined by Patton (2015): (1) experience and behaviour questions, (2) opinion and value questions, (3) feeling questions, (4) knowledge questions, (5) sensory questions, and (6) background and demographic questions. This typology clarified the intent of each question, supporting the development of clear expectations regarding the nature of participants' responses. Moreover, such categorisation facilitates comparability across participants' responses, as Patton (2015) recommended, providing a solid foundation for subsequent data analysis. A mapping of the interview questions to these categories is provided in Appendix B.

The first part of the interview protocol involved background and demographic questions. These questions gathered information on participants' age, gender, educational qualifications, the relevance of these qualifications to their current position, and their professional experience. For employees directly interacting with collaborative robots, additional questions addressed the frequency and nature of their interaction with the technology. Collecting this background and demographic information was used to describe the sample, to compare different groups based on certain characteristics, and to ensure that the findings are appropriately contextualised according to key participant characteristics.

The interview then progressed from general to more specific questions related to the research topic, in line with the funnel approach. Participants were encouraged to use illustrative examples to express their perspectives on the topic, thereby facilitating the recall of personal experiences, as suggested by Jafari, Taheri, and Vom Lehn (2013). The interview questions focused primarily on the participants' structural, individual, and social perspectives on engagement with collaborative robots—addressing respectively organisational processes, personal attitudes and experiences, and collective interactions and changes within the team. They were complemented by questions relating to the perceived impact on productivity and system performance. Each interview concluded with an open-ended prompt inviting participants to share any additional insights not yet covered in the interview process.

Step 4: Strategising the interview structure

The scheduling of interviews followed the stepwise procedure outlined in the theoretical sampling strategy previously described. All interviews took place on the premises of the participating organisation to ensure accessibility and high convenience for the participants. To foster trust and openness, participants were explicitly informed of the confidentiality of their responses. The complete set of questions was not shared with the participants in advance to minimise the risk of peer influence. Nonetheless, the general topic of the interview and its key thematic areas were disclosed in advance to ensure time for reflection.

Step 5: Executing the interview process

Each interview commenced with a formal introduction to the study, during which participants were provided with the participant information sheet, followed by signing an informed consent form. The participant information sheet and consent form are presented in Appendix C.1 and Appendix C.2. In line with the methodological guidance offered by Merriam and Tisdell (2016), a pilot study of three interviews was conducted before the primary data collection phase. This procedure is vital in determining the clarity and comprehensibility of the questions, the relevance of the elicited answers in achieving the overarching research objectives, and the necessity for additional questions based on the participants' responses (Merriam & Tisdell, 2016). Following the analysis of the pilot interviews, several questions were rephrased, while others deemed redundant were removed or replaced. The main study was then conducted using the revised semi-structured interview protocol suggested by Merriam and Tisdell (2016). The revised and finalised interview protocols are provided in Appendix B.

During the interviews, probing techniques such as personal probing and vignettes were employed to elicit more nuanced responses from the participants, as Lim (2024) recommended. The former involves the disclosure of personal experiences and perspectives related to the research context, while the latter pertains to the researcher's presentation of hypothetical yet realistic scenarios involving collaborative robots (Lim, 2024). As per Patton's (2015) classification, the questions most conducive to personal probing include questions related to participants' experiences and behaviours, opinions and values, and feelings. For instance, probing was conducted using vignettes with questions such as: *"What would it be like if additional cobots were to be introduced into your workplace?"* or *"What would it be like if you only worked with cobots?"* Such scenario-based prompts enabled the researchers to ascertain how participants might respond to potential future developments.

Of the 27 semi-structured interviews, participants consented to audio recording in 26 cases. In these audio-recorded interviews, supplementary notes were taken throughout the interview to capture contextual nuances and non-verbal cues. This practice also reinforced the perceived value of participants' contributions, as Lucas (2005) recommended. In the only interview where the participant declined audio recording, detailed notes were taken, including verbatim statements. To ensure comparability across all interviews, audio recordings and interview notes were transcribed immediately following each session, as suggested by Tajeddini and Trueman (2008).

For audio-recorded interviews, the initial transcription was conducted using f4transkript software. In the next step, the researcher reviewed each recording several times to create the final transcript. Following the recommendations of Lofland, Snow, Anderson, and Lofland (2022), the content of each interview was examined shortly after transcription to ensure no meaning distortion of the data. Special attention was paid to critical statements from participants directly addressing the core elements of the research objectives (Tajeddini, Ratten, & Denisa, 2017; Tajeddini & Trueman, 2008). The audio-recorded interviews lasted between 35 and 65 minutes, while the one without recording lasted 1.5 hours. All interviews were conducted between October 2023 and June 2024. On average, each interview transcript comprised approximately 12 pages, resulting in 330 pages.

The first group, comprising employees directly interacting with the collaborative robots, consisted of 17 participants. These participants were further distinguished based on their position and the frequency of interaction with the collaborative robot. After completing 14 interviews, it was determined that theoretical saturation had been achieved. However, three further interviews were conducted to ensure greater accuracy, as Gamage, Tajeddini, and Tajeddini (2022) suggested. This resulted in a total of 17 interviews in the first group. Most of these interviews were completed before engaging with the second group to ensure managers did not influence the interpretation of the employees' responses.

The second group consisted of 10 direct managers. After the eighth interview, the saturation point was reached for this group. Following the same rationale applied in the first group, two further interviews were conducted to increase confidence in the findings (Gamage et al., 2022). The theoretical saturation was achieved more quickly in the second group, which can be attributed to its greater homogeneity than the first group. Determining the saturation point for both groups followed the principles outlined by Islam and Aldaihani (2022). After reaching the stated saturation point in both groups, no new codes or themes emerged during the initial coding process, confirming theoretical saturation.

Step 6: Conducting a follow-up with the participants

The final stage of the formalised interview procedure, as outlined by Lucas (2005), involved a participant review of the interview transcripts. As part of this process, participants were invited to verify the accuracy of their transcripts and to clarify specific aspects where necessary. The responses provided by the participants were incorporated into the respective transcript, enhancing the accuracy and trustworthiness of the data collected.

In the context of semi-structured interviews, several potential sources of bias need to be considered, including interviewer bias, response bias, and participation bias (Saunders et al., 2023). Interviewer bias refers to the unintentional influence exerted by the interviewer on the participant, either through verbal or non-verbal behaviour (Saunders et al., 2023). To mitigate this bias, all participants were explicitly informed before the interviews that their genuine views were essential to the integrity of the study. During the interviews, the questions were posed in a neutral tone, without making any personal judgements. Response bias, while similar in its consequences, originates from the participant's perception of the interviewer, which may influence them to tailor their responses in a socially desirable manner (Furnham, 1986). This was also addressed through the same mitigation strategies mentioned above. Furthermore, the trust-based relationships between the researcher and participants reduced the response bias. In addition, the pilot study, the overall number of interview participants, and the use of clarifying questions during the interviews each contributed to reducing this kind of bias (Saunders et al., 2023). Finally, participation bias or non-response bias refers to the differences between those willing to participate in the study and those not, potentially skewing the findings (Saunders et al., 2023). To address this, efforts were made to ensure maximum accessibility and convenience for all potential participants while maintaining the confidentiality of the data collected. Following the completion of the data collection process and a thorough evaluation of the potential biases inherent in each method, the focus now shifts to the data analysis phase.

3.4.4 Data analysis

Before discussing the data analysis process, it is necessary to consider the language used in data collection and analysis within the current study. All data collection activities were conducted in German, constituting the primary corporate language of the organisation under investigation. This approach ensured the participants could speak freely and express their thoughts without language restraints. As both the participants and the researcher were native German speakers, this did not cause any problems during the data collection phase. However, given that the thesis is written in English, a key methodological consideration arose regarding the appropriate point in the research process at which translation should occur. Suh, Kagan, and Strumpf (2009) identify three possible stages for translation: (1) before analysis, (2) during analysis, and (3) after analysis. They advocate for translation during the analysis phase, as this approach best preserves the semantic integrity of the original data while maintaining the authenticity of participants' perspectives and ensuring the authenticity of the findings (Suh et al., 2009). This recommendation was followed in the current study. Consequently, the secondary data summaries, field notes, and interview transcripts were retained in German, while the analysis commencing from initial coding onward was conducted in English.

Accordingly, the research remained in the original language as long as possible, consistent with van Nes, Abma, Jonsson, and Deeg (2010) recommendations, preserving the contextual and cultural nuances embedded in the data, while still ensuring a fluent transfer of the research findings into English. However, translating critical participant statements for inclusion in the thesis raised concerns about data trustworthiness and interpretive accuracy. As van Nes et al. (2010) advised, the translation process was conducted in collaboration with a translator familiar with the research context to address these challenges. Furthermore, for most statements, translated excerpts were reviewed by the respective participants to minimise the risk of misinterpretation.

Following determining the language used for data analysis, the next step involved selecting the most suitable method of data analysis. The following subsections provide a detailed account of the critical aspects of data analysis, starting with an overview of the data analysis process employed.

3.4.4.1 Process overview

The relationship between the data collection and analysis needs to be considered in qualitative research. At one end of the methodological continuum lies a linear sequential approach, in which data collection is completed before commencing data analysis (Kennedy & Thornberg, 2018). At the other end, an iterative approach is used, where the researcher continuously moves between data collection and data analysis, allowing insights generated through preliminary analysis to inform subsequent data collection

(Kennedy & Thornberg, 2018). This thesis has chosen an approach that is clearly on the iterative side of the continuum. According to Merriam and Tisdell (2016), this recursive and dynamic process is one of the critical elements of a qualitative study. Furthermore, it is also an essential aspect of a constructivist grounded theory study (Charmaz, 2014).

As an applied methodology, constructivist grounded theory provides a rigorous framework for data analysis aimed at constructing theory grounded in empirical evidence. Charmaz (2017) argues that this approach extends beyond a purely inductive logic. Instead, it enables the researcher to engage in a dynamic interplay of inductive, abductive, and deductive reasoning to develop and refine theoretical insights iteratively (Charmaz, 2008). Thus, constructivist grounded theory is a demanding approach, particularly suitable when the goal is to develop a fully-fledged theory. However, developing a full-fledged grounded theory was not in line with the thesis objectives. Instead, the study focuses on identifying the critical factors influencing acceptance of collaborative robots and developing a conceptual framework grounded in the collected data to illustrate how acceptance-related factors are associated with system performance.

Consequently, the aims of this thesis could be more appropriately addressed through thematic analysis than through a grounded theory approach, as Braun and Clarke (2021a) outlined. These scholars provide a set of evaluation criteria that can be used to determine the suitability of thematic analysis for a given study, particularly in comparison to grounded theory.

Thematic analysis is widely regarded as the preferable approach when the objective of the study is to identify and interpret theoretically informed patterns of meaning within the data rather than to generate a full-fledged theory (Braun & Clarke, 2021a). Furthermore, thematic analysis is recognised for its relative accessibility and methodological transparency, making it especially suitable for researchers with limited prior experience in qualitative research (Braun & Clarke, 2021a). This aspect should not be overlooked, given that the researcher has only limited experience in qualitative research.

Based on the above factors, thematic analysis was identified as the most appropriate data analysis technique. However, the researcher argues that the thematic analysis should be embedded in the broader methodological framework of constructivist grounded theory. This positioning is particularly relevant in light of the inherent flexibility of thematic analysis, which can be described as a method rather than a methodology lacking ontological and epistemological stances (Willig, 2022). Besides this extensive flexibility, in this study, thematic analysis is employed within a constructionist paradigm, consistent with Braun and Clarke's (2006) recommendation that thematic analysis can be effectively applied in constructionist research. Accordingly, the methodological framework of the current study draws on key principles of constructivist grounded theory, including theoretical sampling, the constant interaction between data collection and analysis, and theoretical saturation (Charmaz, 2014). This methodological framework informs the adoption of a specific variant of thematic analysis, reflexive thematic analysis, as the analysis technique best aligned with the study objectives.

In this thesis, the term "constructionist" is used in line with Braun and Clarke's (2021) positioning of reflexive thematic analysis within a constructionist paradigm and is further consistent with the continuum of epistemological positions described by Easterby-Smith et al. (2021). By contrast, "constructivist" refers specifically to Charmaz's (2014) use of Constructivist Grounded Theory. These terms are therefore employed in a context-dependent manner.

Using reflexive thematic analysis is also supported by its emphasis on the researcher's active role in the knowledge-creation process, aligning closely with constructivist grounded theory (Braun & Clarke, 2019). Consequently, reflexive thematic analysis was employed to examine the qualitative data collected in the present study. This approach facilitates identifying, analysing, and reporting patterns within the data and developing theoretically informed interpretations, as articulated by Braun and Clarke (2021a).

Thematic analysis has gained prominence as a widely utilised method for qualitative data analysis, particularly following the introduction of the six-phase guide by Braun and Clarke (2006). The current thesis employs reflexive thematic analysis, which is based on Braun and Clarke's step-by-step guide, along with the subsequent methodological refinements articulated by the authors. These phases are as follows: (1) familiarisation with the collected data, (2) generation of initial codes, (3) identification of themes, (4) review of themes, (5) definition of themes, and (6) writing-up (Braun & Clarke, 2006). The six phases of the data analysis process are shown in Figure 3-4, positioned within their broader strategic purpose and iterative analytical trajectory, as outlined by Spencer, Ritchie, Ormston, O'Connor, and Barnard (2014).

The approach of reflexive thematic analysis encompasses three modes of reflexivity: (1) personal reflexivity, which addresses how the researcher's own experiences, values, and identity inform and shape the research process and its findings; (2) disciplinary reflexivity, which involves reflecting on how disciplinary positions and perspectives influence the research's framing and interpretation; and (3) functional reflexivity, which entails critically considering the research design and methodological decisions (Braun & Clarke, 2022). Collectively, these modes of reflexivity encourage a thoughtful and context-sensitive approach to knowledge production.

Before the initial phase of data analysis began, several key methodological decisions had to be made, which are also depicted in Figure 3-4. One such decision involved determining the coding approach for generating patterns or themes. The current thesis adopts an inductive approach to coding, aligned with the constructivist grounded theory methodology underpinning the study. As such, theme development was grounded in the data rather than driven by a pre-existing theoretical framework, reflecting what Terry, Hayfield, Clarke, and Braun (2017) describe as a data-led approach.

Another critical consideration concerned the level at which themes were to be identified, either at a semantic or latent level (Boyatzis, 1998; Braun & Clarke, 2006). In this study, the focus was on the latent level, which permitted an analysis that exceeded the superficial aspects of the phenomenon and incorporated the researcher's interpretive work as described by Braun and Clarke (2021a).

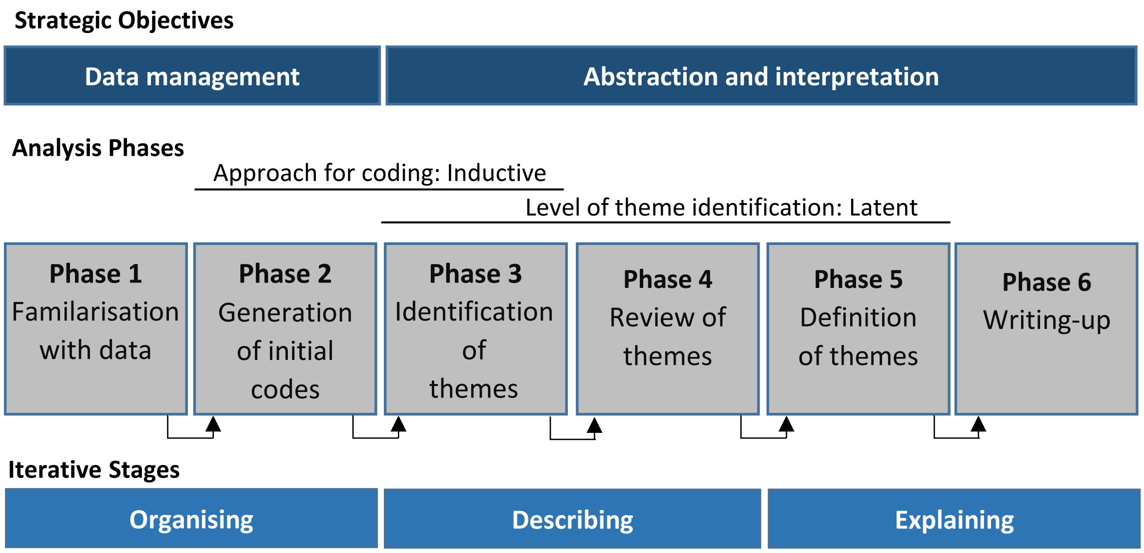


Figure 3-4: Data analysis process (Sources: Braun & Clarke, 2006, p. 83 ff.; Spencer et al., 2014, p. 282)

The data analysis process was facilitated by qualitative data analysis software, the specific details of which are outlined in the following subsection. This software played a vital role in organising, coding, and analysing complex qualitative data, ensuring a systematic and structured data analysis approach, as Braun and Clarke (2006) suggested.

3.4.4.2 Using qualitative data analysis software

Numerous scholars have highlighted the advantages of using computer-assisted qualitative data analysis software in qualitative research (AlYahmady & Al Abri, 2013; Carcary, 2011; Castleberry & Nolen, 2018; Olapane, 2021). These benefits are particularly pertinent to the current study. Given the qualitative nature of this study, which involves large volumes of data, including 330 pages of interview transcripts, 22 pages of field notes, and 18 pages of secondary data summary, managing and analysing these data manually would be time-consuming and potentially detrimental to the accuracy and depth of the findings. Thus, the present study employed NVivo, a computer-assisted qualitative data analysis software, to enhance data organisation, support analytical rigour, and improve time efficiency. The software facilitated the systematic coding and retrieval of data, allowing the researcher to focus more time on the analysis process (AlYahmady & Al Abri, 2013). However, it is imperative to acknowledge that this software is merely a tool designed to assist researchers in the analysis process, and the integrity, depth, and theoretical relevance of the analysis remain the responsibility of the researcher.

In summary, the utilisation of NVivo in this research was not merely due to convenience but rather a methodological necessity to ensure traceability, efficiency, and analytical rigour of the data analysis process. The benefits of using NVivo substantially contributed to the credibility and trustworthiness of the research findings, thus rendering NVivo an indispensable tool in achieving a structured and methodologically sound analysis in this study. Having established the rationale for using NVivo for data management and analysis, the following subsection outlines the reflexive thematic analysis process, as defined by Braun and Clarke (2006).

3.4.4.3 Six phases of reflexive thematic analysis

The entire data analysis process employing reflexive thematic analysis was guided by two strategic objectives: data management and data abstraction and interpretation, as defined by Spencer et al. (2014) and illustrated in Figure 3-4. This process was further framed within the iterative stages outlined by Spencer et al. (2014): organising the data, describing it by developing and refining codes and themes, and explaining it by interpreting key patterns and their interrelationships. Moreover, the reflexive thematic analysis process, detailed phase-by-phase in the following subsections, was augmented by methodological insights from Naeem, Ozuem, Howell, and Ranfagni (2023). It should be noted, however, that these phases were not applied strictly linearly. Instead, they were engaged recursively, as previously described.

Phase 1: Familiarisation with the collected data

In the initial phase of the analysis, a secondary data summary was compiled, field notes were systematically organised, and the transcription was completed and stored in a structured format. Subsequently, the data were sequentially imported into the qualitative data analysis software NVivo. A general familiarisation of the data followed this through re-reading and the development of initial coding ideas, as Braun and Clarke (2006) suggested. Consequently, the data collected through different data collection methods facilitated data triangulation at two distinct levels, as Flick (2018b) conceptualised. The triangulation framework in the current study was grounded in synthesising familiarisation notes from each interview, field notes of the participant observations conducted, and the secondary data summary.

The initial level of triangulation concerns the subset of participants who were observed during the participant observation phase and subsequently participated in semi-structured face-to-face interviews. In the present study, this subset comprised six participants. Following the guidelines by Flick (2018b), this approach enabled a comparison between the behaviours and informal remarks recorded during observation and the formal responses elicited during the interviews at the individual level.

At the second level of triangulation, the findings derived from data collected using one data collection method were compared against those obtained from the other methods (Flick, 2018b; Sandikci, Jafari, & Fischer, 2024). This level of triangulation in the current study encompassed the integration and cross-comparison of data from eight participant observations, 27 semi-structured interviews, alongside a secondary data summary. The synthesis of observational and interview data across distinct participant groups enhances the depth and breadth of the analysis. Observational data provides insights into actual behaviours and interactions within the workplace context, whereas interview data sheds light on the participants' opinions, attitudes, and experiential backgrounds. Significantly, including two interrelated participant groups—employees and their direct line managers—enabled a nuanced understanding of the phenomena under investigation by capturing dyadic relational dynamics.

Phase 2: Generation of initial codes

The analytic procedure in this phase of Braun and Clarke's (2006) reflexive thematic analysis was enriched by identifying keywords directly derived from the data, as Naeem et al. (2023) suggested. These keywords are grounded in participants' lived experiences and deepen the contextual relevance of the analysis (Naeem et al., 2023). This phase involved structuring the relevant data into meaningful groups during coding (Tuckett, 2005). The data were thus subjected to a process of deconstruction, whereby the data were first organised into preliminary non-hierarchical codes. This broke the data down into manageable coded segments, which formed the basis for identifying patterns or themes in the data. Each piece of data that could contribute to the stated research objectives was coded as recommended by Byrne (2022). In this phase, NVivo was used as qualitative analysis software to support this process.

The data were not coded simultaneously but analysed sequentially, reflecting the iterative and recursive nature of the data analysis process (Braun & Clarke, 2006). This iterative approach allows the researcher to review and refine the preliminary codes developed continually. It also permits addressing any ambiguities or questions during the analysis, ensuring that the coding framework remains responsive to the evolving context (Byrne, 2022).

Phase 3: Identification of themes

This phase took place concurrently with the data collection process of this study, reflecting the recursive nature of the qualitative inquiry. In this phase, all generated codes were analysed to derive overarching themes (Braun & Clarke, 2006). Consequently, the codes were structured hierarchically in NVivo, facilitating the emergence of preliminary themes. At this point, the focus of analysis shifted from the individual data item within the dataset to overarching interpretations across the dataset, as Byrne (2022) suggested. In this phase, a theme designated "miscellaneous" was also introduced, as Braun and Clarke (2006) proposed accommodating codes that did not initially align with the developed themes.

The results were visualised in thematic maps, following the approach outlined by Terry et al. (2017). The thematic maps were employed to illustrate the constructed codes and themes, as well as the relationships between them and their respective levels. These maps facilitated a deeper understanding of how the themes were interconnected and how they collectively represented the underlying structure of the data. The iterative nature of the analysis process was evident in the repeated refinement of the map, as the researchers sought to capture the nuanced complexity of the data accurately.

Phase 4: Review of themes

The review process involved a rigorous evaluation of the initially developed themes to assess their coherence between codes and themes and between themes and the overall dataset (Braun & Clarke, 2006). First, this involved analysing the themes generated from the raw data and then refining these themes. This process was undertaken to ensure that each theme is distinctive and captures specific aspects of the data (Braun & Clarke, 2006). Second, this was complemented by re-examining the themes in the context of the complete dataset, enabling the verification and further refinement of the themes identified to ensure that they accurately represent the data collected, as Braun and Clarke (2006) stated. This inherently iterative approach enables the researcher to maintain flexibility and responsiveness to novel insights that emerge from the data (Byrne, 2022). Consequently, several preliminary themes were merged, split or discarded, lacking substantial data support and internal coherence. NVivo software was employed throughout this process to support the systematic organisation, comparison, and modification of themes.

This phase aimed to conceptualise the themes as "patterns of shared meaning" (Braun & Clarke, 2019, p. 592). To support this, the previously constructed thematic maps were systematically revised to incorporate the refinements made during the review phase.

Phase 5: Definition of themes

This phase drew upon the thematic map developed in Phase 4, as suggested by Braun and Clarke (2006). At this stage, the names of the themes were defined and refined according to the scope and focus of each theme (Braun, Clarke, Terry, & Hayfield, 2019). The process involved articulating concise and informative theme names that encapsulated the central organising concept of each theme, thereby providing a clear entry point for interpretation (Braun & Clarke, 2006). Furthermore, this phase aimed to present a detailed analysis of each theme in relation to the research question while also exploring the interrelationships among the themes (Braun & Clarke, 2006). This phase is summarised in the definitions of the themes and their associated codes, which are presented in Appendix E. The analysis yielded twelve themes. Ten themes identify factors influencing the acceptance of collaborative robots in healthcare manufacturing, while two additional themes specifically address acceptance itself and system performance.

In this phase, the researcher also identified critical data excerpts for inclusion in the write-up phase, as suggested by Byrne (2022). This task aimed to select quotations that best illustrate the essence of each theme. The selection of these extracts was driven by their clarity, vividness, and capacity to elucidate the theme's core meaning (Braun & Clarke, 2006). Therefore, the selection process was designed to illustrate the diversity and breadth of participants' opinions while avoiding over-reliance on any single participant or subgroup. This was achieved by ensuring balanced representation across roles, specifically between employees and managers, and the distribution of excerpts among individual participants. An overview of the selected excerpts is provided in Appendix E.

Phase 6: Writing-up

The final phase of the process aimed to provide a multifaceted overview of the data collected, presented as a written report. As Braun and Clarke (2006) emphasised, this report must include carefully selected data excerpts referred to as "critical statements" to substantiate and exemplify the identified themes. Furthermore, it is important to acknowledge that these data excerpts are embedded within an analytic narrative, which illustrates the "story" of the data (Braun et al., 2019). The findings of the thematic analysis of the present study are reported in Section 4.4, addressing the first research objective of this thesis. The writing process was iterative, during which the researcher continually revised and refined the analytical narrative to enhance clarity, coherence, and depth. Feedback from academic supervisors was systematically integrated, contributing to the critical development and articulation of the findings presented in Chapter 4. Finally, it should be noted that reflexive memos were maintained throughout the research process to document the researcher's positionality and evolving interpretations, as suggested by Nowell et al. (2017).

After completing the six phases of reflexive thematic analysis as delineated by Braun and Clarke (2006), the researcher has obtained a deeper and more nuanced understanding of the data. Each phase of this analysis process, namely familiarisation, initial coding, theme searching, theme reviewing, theme defining and naming, and writing-up, has contributed incrementally to extracting rich, meaningful insights from the data. Thus, the foundation is established for translating thematic insights into a structured conceptual framework at this stage of the reflexive thematic analysis process (Naeem et al., 2023).

3.4.4.4 Development of a conceptual framework

The objective of this subsection is to delineate the development of a conceptual framework grounded in the findings of the reflexive thematic analysis. It is, therefore, necessary to discuss the connection between the findings and the construction of the conceptual framework, demonstrating how the identified themes inform and structure it. A visual representation is provided to facilitate a clear explanation of this process in Figure 3-5.

The following figure is mainly inspired by the visual representation developed by Naeem et al. (2023), adapted to reflect the outcomes of the reflexive thematic analysis conducted in this study, as outlined in the preceding subsections. Thereby, Figure 3-5 visualises the results obtained from each phase of the reflexive thematic analysis process, starting with the transcript, the selected keywords, and the developed codes, and culminating in the coding hierarchy, resulting in a coding structure and the generated themes (Braun & Clarke, 2006; Naeem et al., 2023). This figure illustrates the interconnection among the various outputs of each phase, laying the empirical foundation for developing the conceptual framework.

The components depicted in Figure 3-5 illustrate the themes presented in the findings chapter. This visual representation aims to facilitate comprehension of the findings by enhancing readability and clarity, thereby enabling readers to grasp the overall structure and key insights derived from the data. Consequently, each visualisation concisely overviews the relevant keywords and associated codes underpinning the respective themes.

The right-hand section of Figure 3-5 illustrates the subsequent development and conceptualisation of the conceptual framework, derived from the interpretation and synthesis of the identified keywords, codes and themes. This visualisation demonstrates how the emergent themes were integrated into a coherent framework, highlighting their interrelationships and overarching structural configuration. The resulting conceptual framework thus facilitates comprehension of the structure and dynamics of the data (Naeem et al., 2023). Consequently, this part of the data analysis directly addresses the second research objective.

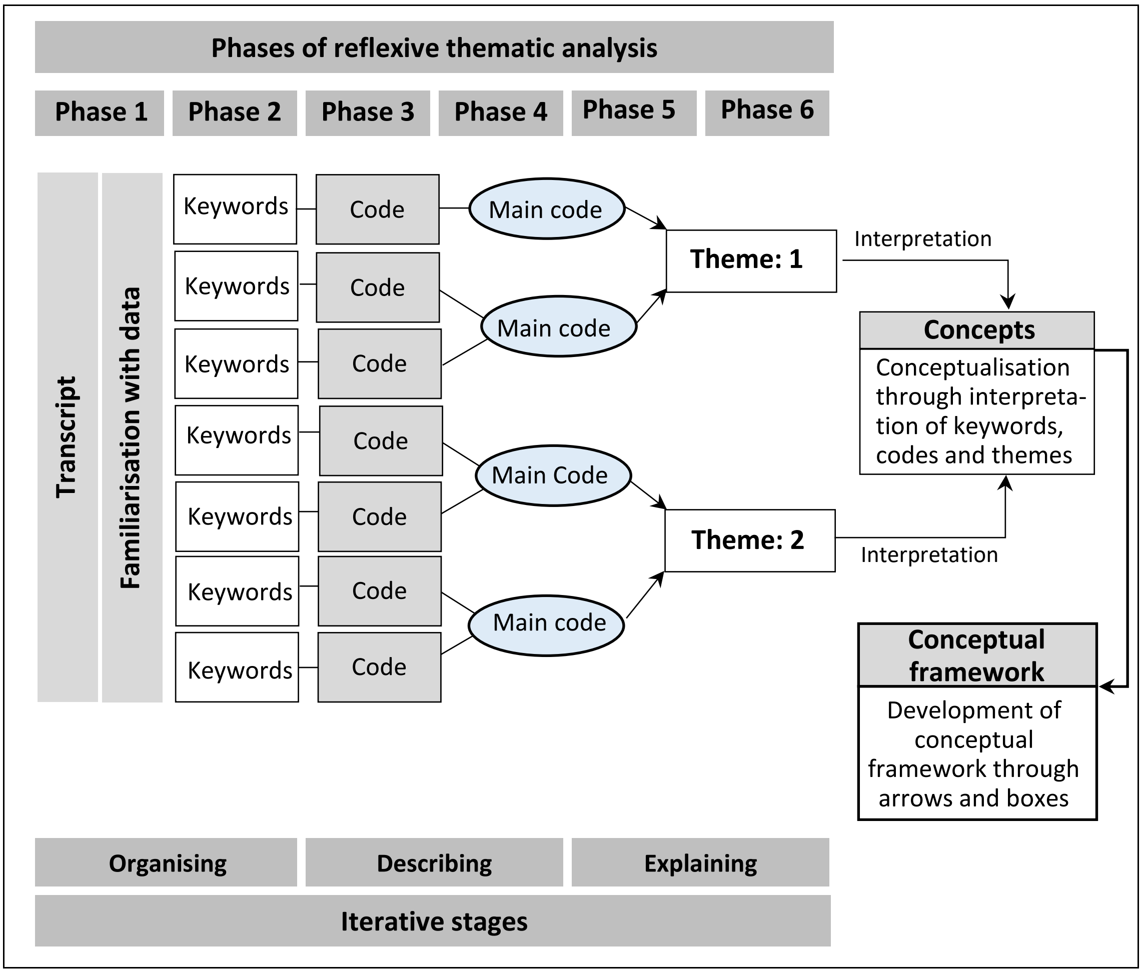


Figure 3-5: Reflexive thematic analysis process: Phases of conceptual framework development (Source: Braun & Clarke, 2006, p. 87; Naeem et al., 2023, p. 4; Spencer et al., 2014, p. 282)

Furthermore, the conceptual framework bridges the detailed findings of the reflexive thematic analysis and their broader theoretical and practical implications, enhancing the overall impact and utility of the research (Naeem et al., 2023). The conceptual framework provides a structured lens through which the empirical insights can be interpreted and applied, forming the foundation for addressing the third research objective. Specifically, this objective focuses on deriving practical implications from the research findings.

Following the comprehensive delineation of the various phases of the data analysis process, it becomes essential to turn attention to the ethical considerations that play a pivotal role throughout the study. Ethical integrity ensures the research is conducted transparently, responsibly, and respectfully, safeguarding all participants' rights and well-being.

3.5 Ethical considerations

According to van den Hoonaard (2002), ethical considerations in research include both the external and the internal contexts of the study. Ethical issues from the external context relate to core ethical principles such as beneficence and non-maleficence, informed consent, confidentiality, and anonymity (van den Hoonaard, 2002). Conversely, ethical issues originating from the internal context are associated with the study design (van den Hoonaard, 2002).

The ethical considerations underpinning this research are primarily informed by Sheffield Hallam University's "Research Ethics Policy and Procedures" (Sheffield Hallam University Research Ethics Committee, 2020). The university's policy itself is anchored in internationally recognised standards, including the Declaration of Helsinki and the Research Ethics Framework of the Economic and Social Research Council (Sheffield Hallam University Research Ethics Committee, 2020). For the purposes of this study, these considerations are discussed in terms of both internal and external ethical contexts, reflecting the multifaceted nature of research ethics. The core ethical principles applied in the present study are outlined in the following table. Furthermore, Table 3-2 demonstrates how these principles were addressed throughout the study.

Context	Guiding principles	Incorporation of ethical guiding principles within this research
External	Beneficence & Non-maleficence	Participants were informed about the researcher's role. Participants were always treated with respect.
	Informed Consent	Participants were thoroughly informed about the study. Consent could be withdrawn at any time.
	Confidentiality/ Anonymity	Participant names were changed to pseudonyms. Interviews were transcribed by the researcher (+ software).
Internal	Integrity	Field notes and transcripts were checked by participants. Translated statements were reviewed by participants.
	Independence/ Impartiality	Interpretations were grounded in verified statements. Potential conflicts were discussed with supervisors.

Table 3-2: Ethical considerations based on Sheffield Hallam University's Ethics Guidelines (Source: Sheffield Hallam University Research Ethics Committee, 2020, p. 2 ff.)

Based on the assessment presented in Table 3-2, together with the guidelines of the research management system for ethics review, this study has been classified as a very low-risk study for human participants. This classification is based on the following factors: (1) participants are not vulnerable, (2) there is no foreseeable risk of physical or emotional harm, (3) the study does not entail any potential pain, (4) the study does not address a sensitive topic, (5) all participants give informed consent, (6) there is no covert observation, and (7) no drugs, food substances or invasive procedures are being administered (Sheffield Hallam University - The Research and Innovation Office, 2023). Ethical approval for this study was obtained from the University Research Ethics Committee at Sheffield Hallam University, with further details of the approval provided in Appendix D.

Another important ethical consideration in this study concerned the secure storage of participants' data. All data were fully anonymised to protect participant identities and stored in a safe, access-restricted environment. Overall, ethical integrity was maintained through a comprehensive review process conducted by Sheffield Hallam University.

Following the thorough examination of the ethical considerations of the research, it is imperative to critically reflect on the strengths and limitations of the applied methodology. While adhering to ethical principles significantly enhances the credibility and integrity of the research, a balanced and reflexive appraisal of the methodological choices is equally important.

3.6 Strengths and limitations of the approach

Several methodological strengths can be attributed to the methodological approach used in this study. First, the framework of constructivist grounded theory is well suited for generating deep, contextualised insights into complex and often hidden organisational practices (Clarke, 2009). This makes it highly compatible with the aim of the study, which was to explore the implications of collaborative robots on acceptance and system performance. This objective was addressed through a single case study that focused on an in-depth investigation of the phenomenon within its real-world context. Furthermore, the social construction of meanings related to technology is widely accepted in technology acceptance research (Leonardi & Barley, 2010), further justifying the methodological choice. The iterative processes of deconstruction and reconstruction inherent in constructivist grounded theory are particularly valuable in unpacking the multifaceted and emergent nature of technology use in organisational settings (Leonardi & Barley, 2010). Moreover, this methodological framework is considered particularly well-suited given the exploratory nature of the study and the limited theoretical understanding of collaborative robot implementation, as Payne (2021) asserted.

Second, the chosen methodological approach is underpinned by the value-bound axiological stance, wherein the researcher's subjectivity and interpretive lens are acknowledged as integral to the analytical process. Such reflexive engagement through ongoing consideration of the researcher's thoughts, experiences, and potential biases enhances analytical depth and contributes to a more nuanced understanding of the research topic (Braun et al., 2019).

Another notable strength lies in using three distinct data collection methods, which facilitated an in-depth investigation of the phenomenon within its social context from multiple perspectives. Furthermore, integrating diverse data sources allowed for data triangulation, strengthening the findings and maximising the theoretical yield from the collected data (Flick, 2018a).

Given the qualitative nature of this study, it is imperative to critically address its limitations, particularly in terms of credibility and transferability. Credibility refers to the extent to which findings apply to the group and context studied (Tobin & Begley, 2004), while transferability concerns the potential generalisation of the findings to other groups and contexts (Malterud, 2001). The current study achieved credibility through measures such as data triangulation, the use of probing techniques during interviews, member checking, theoretical sampling, and trust-based relationships between the researcher and participants. Thus, the conceptual framework developed adequately reflects the complexity and context of the case under study, as is shown in the following chapter. In contrast, transferability is not an intentional objective of qualitative research (Dimmock & Lam, 2016). Consequently, it is not an inherent objective of constructivist grounded theory studies either. This is particularly relevant given the single case study design employed here, which prioritises depth over breadth. The definition of "truth" in constructivist grounded theory is co-constructed by both participants and the researcher, thus incorporating a reflexive epistemological stance (Charmaz, 2014). To navigate the challenges posed by this stance, the present study drew upon Searle's philosophical underpinning of realism and its reconceptualisation, which provides a means of anchoring interpretive findings in observable social practices (Lomborg & Kirkevold, 2003). Moreover, reflexive memo writing was employed throughout the research process to enhance transparency and maintain integrity. On this basis, the context-specific and interpretive conceptual framework developed in this study offers findings that, while not universally generalisable, may be meaningfully transferred to similar organisational settings or contexts.

3.7 Chapter summary

This research aimed to investigate how acceptance-related factors shape system performance in collaborative robot applications. Central to this inquiry were the social processes and interactions of the people who interact directly and indirectly with these collaborative robots. It was, therefore, essential to focus on the participants' subjective perspectives and the socially constructed nature of their realities. This chapter outlined the methodological choices informed by the substantive focus of the study and the researcher's subjectivist philosophical underpinnings.

In this context, constructivist grounded theory was identified as the most appropriate research methodology, given its capacity to generate a conceptual understanding grounded in participants' experiences. Subsequently, the research design was justified by adopting a single case study approach, explicitly chosen due to the revelatory nature of the case under investigation. Furthermore, the two different units of analysis were differentiated in terms of the manufacturing process with and without collaborative robots, hereby constituting an embedded case study design, as Yin (2018) emphasised.

Figure 3-6 presents the methodological framework of the research project, illustrating the interrelationships between the philosophical foundation of the study and the different levels of the study's research design, as Proctor (1998) conceptualised. These considerations provide a structured basis for moving to Chapter 4, where the research findings are presented in detail.

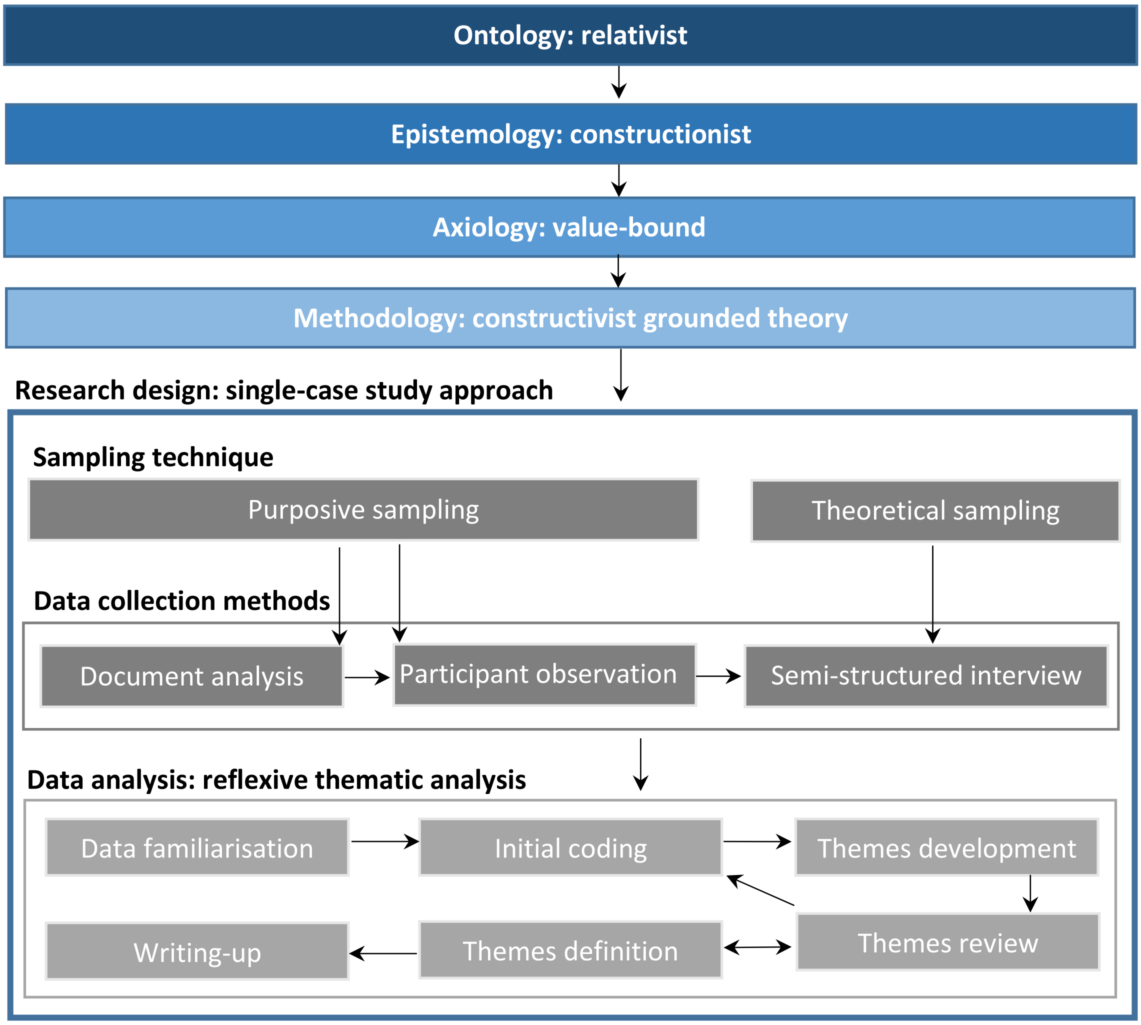


Figure 3-6: Research methodology framework

Chapter 4: Presentation of research findings

4.1 Introduction

This chapter presents the research findings with a focused reference to the three research objectives outlined in the thesis. The first research objective was accomplished through a detailed analysis of the collected data, resulting in the development of main codes, codes, and subcodes. These analytical steps led to the synthesis of themes, each of which encapsulates a key factor relevant to the research question. Reflexive thematic analysis was employed to facilitate this, as Braun and Clarke (2006) proposed.

In the subsequent phase of the research, the identified themes were compared and contextualised within a broader analytical framework, culminating in the development of a conceptual framework. This approach was informed by the work of Naeem et al. (2023) and is aligned with the second objective of the research. Finally, the third research objective was addressed by providing recommendations for different groups of employees based on their level of acceptance of collaborative robots. These recommendations were grounded in the insights derived from the conceptual framework developed. To provide a contextual foundation for interpreting the research findings, this chapter begins with a detailed overview of the study participants, followed by an analysis of the temporality of the research, offering further contextualisation.

4.2 Participants

Exploring critical factors influencing acceptance and system performance when integrating collaborative robots is grounded in a purposive sampling strategy to yield rich and insightful data on the phenomenon under investigation. This process commenced with document analysis and archival review to understand the organisational context and the integration of collaborative robots. This was followed by participant observation, facilitating an understanding of the physical setting and providing the foundation for formulating the interview protocols.

The interview questions were derived from insights gained through participant observations, ensuring their contextual relevance and addressing challenges encountered by the participants. The findings from this initial purposive sampling phase provided the basis for the subsequent theoretical sampling phase, which was predicated upon semi-structured interviews involving participants with varying frequencies of interaction with collaborative robots and occupying different positions. The detailed demographics and background information presented in the following section serve as the basis for the reflexive thematic analysis, allowing for a nuanced interpretation of how participants in different positions within the organisation perceive the integration and interaction with collaborative robots.

A summary of participant information for both primary data collection methods is presented in the following tables. These tables include background and demographic information to contextualise the findings discussed in the subsequent sections. To maintain confidentiality, participants' names have been anonymised. Instead, each participant was assigned a numerical identifier ranging from 1 to 27. Gender is indicated using F (female) or M (male). The nationality of the participants is not specified in the tables, as all participants were German nationals.

Gender/ Person	Age	Position	Qual.	Qual. relevance	Tenure (years)	Prior exp. with robots	Interaction frequency
M1	32	Production technician	VET	yes	12	yes	high
M2	42	Production worker	VET	no	19	no	low
F3	57	Production worker	VET	no	25	no	medium
F4	44	Production worker	VET	no	7	no	medium
M5	54	Production worker	VET	no	3	no	high
F6	38	Production worker	VET	no	13	yes	high
F7	58	Production worker	VET	no	28	no	low
F8	61	Production worker	VET	no	18	no	low
M9	29	Production technician	VET	yes	10	yes	high
M10	25	Production technician	VET	yes	4	yes	low
M11	56	Production technician	VET	no	10	yes	medium
F12	42	Production worker	VET	no	17	no	low
F13	41	Production worker	VET	no	6	no	low
M17	31	Production technician	VET	yes	7	yes	high
F22	58	Production worker	VET	no	31	no	medium
M23	50	Production technician	VET	yes	3	yes	low
M25	33	Production worker	VET	no	9	yes	medium

Definition of interaction frequency:	Notes:
High: regular interaction (min. 1x per week) Medium: regular interaction (min. 1x per month) Low: occasional interaction (min. 1x per year)	Qual.: Qualification VET: Vocational education training (apprenticeship)

Table 4-1: First group–profiles of participants

As illustrated in Table 4-1, the first group under consideration comprised 17 employees who interacted directly with collaborative robots. This group is further subdivided based on the participants' job positions and the frequency of interaction with the collaborative robot. In addition, further details were provided regarding participants' qualifications and their relevance to their job positions. As shown in the table, most production technicians have completed vocational education training that is aligned with the technical demands of their positions. However, this alignment is less consistent among production workers. Moreover, the experience gained in the current position and prior experience with industrial robots is also presented. The age range of this group spans from 25 to 61 years, exhibiting a relatively balanced gender distribution between male (n=9) and female (n=8) participants.

Table 4-2 presents the second participating group, comprised of 10 managers directly interacting with the employees in the first group. This managerial group is distinguished from the first group by a comparatively higher level of educational qualifications. Furthermore, the duration of participants' tenure in their current managerial roles is also presented. Certain data elements reported for the first group were deemed not applicable to this group and were therefore excluded. The age range of this group spans from 31 to 55 years, with a gender distribution of male (n=8) and female (n=2) participants, which is less balanced compared to the previous group.

Gender/ Person	Age	Position	Qualification	Qualification relevance	Tenure (years)
F14	33	Operational assistant	Graduate deg	yes	3
M15	42	Group lead	Undergrad deg	yes	3
M16	46	Operational assistant	VET	no	2
M18	37	Operational assistant	VET	yes	8
M19	46	Group lead	Undergrad deg	yes	11
M20	37	Group lead	Graduate deg	yes	4
M21	31	Expert	Graduate deg	yes	2
M24	44	Order specialist	VET	yes	9
F26	32	Operational assistant	Undergrad deg	yes	8
M27	55	Expert	Graduate deg	yes	16

Notes:
VET: Vocational education training (apprenticeship)
Undergrad deg: Undergraduate degree
Graduate deg: Graduate degree

Table 4-2: Second group—profiles of participants

The primary data, obtained through participant observation and semi-structured interviews with the participants described above, form the foundation for the analysis undertaken in the current study. To ensure a nuanced understanding of these qualitative data, it is essential to consider their temporal context before delving into the detailed analysis process and the subsequent presentation of research findings.

4.3 Temporality of the research

The temporality of this research must be discussed from two distinct but interrelated perspectives. First, it is essential to consider the current implementation stage of collaborative robots in the organisation under investigation. Second is the temporality of data collection, including the period during which data were collected and the time frame to which participants' reflections pertain.

The organisation under investigation may be positioned within the acceptance stage of the Kübler-Ross Change Curve model, which distinguishes five phases through which organisations typically progress during transformation processes. This assessment is primarily grounded in the analysis of participants' responses provided to the following interview questions: "*If you have the choice of running a production with or without cobots, how would you decide and why?" and "How valuable do you think the cobots are to the department?*" Approximately 85% of the participants (n=23) expressed positive sentiments regarding collaborative robots. The following excerpts exemplify these sentiments, demonstrating that many individuals have come to terms with the new reality of integrating collaborative robots in work settings.

> *M25 (employee): Well, I would do anything related to counting with the cobot straight away. Simply because I have experienced that it works well.*
>
> *F6 (employee): With the cobots. As I said, I fully support it. I think it is good.*
>
> *F13 (employee): Well, I could imagine it (using a cobot). It is not that I would say, yeah, I really want to do it, but I could definitely imagine it.*

The introduction of the workstation comprising two collaborative robots, which is the focal point of the present analysis, occurred approximately one year before the commencement of the primary data collection phase of the study. This temporal distance further supports the contention that the participants were situated at a relatively advanced stage in the organisational change process. As posited by Davis-Adesegha (2025), acceptance is defined not by unanimous approval but by recognising the inevitability of the technological transition by employees. Acceptance, in this context, does not imply that all individuals express positive sentiments towards the new technology. Nonetheless, the following excerpts from M2 and F13 indicate that not all participants had entirely accepted the change at the stage of data collection.

> *M2 (employee): The only thing I see is that you do not have to fill the modules yourself. Otherwise, I do not see any improvement through the cobot.*
>
> *M2 (employee): I get really annoyed just having to walk past it.*
>
> *F13 (employee): Well, I would definitely choose to do it (production) by myself, but just because I have a lot of respect for these machines, these robots.*

While the organisation appears to be broadly situated within the acceptance stage of the change curve, it is imperative to recognise that the collected data does not exclusively reflect this stage. This can be attributed to the temporal variation across the multiple data collection methods employed in the study. In particular, the document analysis encompasses the entire period from the initial implementation of the first collaborative robot in the organisation until the point of data collection. This method was primarily employed to provide contextual grounding for the primary data collection, focusing on the technical and organisational aspects of the implementation process.

In contrast to the document analysis, the two primary data collection methods focus predominantly on participants' experiences, perceptions, and reflections following the implementation of the workstation with two collaborative robots. Thus, the data obtained from participant observations can primarily be positioned at the acceptance stage of the change process, as previously outlined. Nevertheless, it is crucial to recognise that semi-structured interviews encompass a broader temporal scope by allowing respondents to elicit responses related to the current state of the implementation and its earlier phases. For instance, when participants were asked about prior experiences, their responses revealed insights into earlier stages of the change process. These questions contributed to a deeper understanding of the organisation's evolving response to technological change. As such, interviews capture the organisation's developmental trajectory related to collaborative robot implementation over time. However, it is critical to consider this temporal variability when interpreting and presenting the research findings. To clarify the temporal dimensions of the data collection methods, these distinctions are visually illustrated in Figure 4-1.

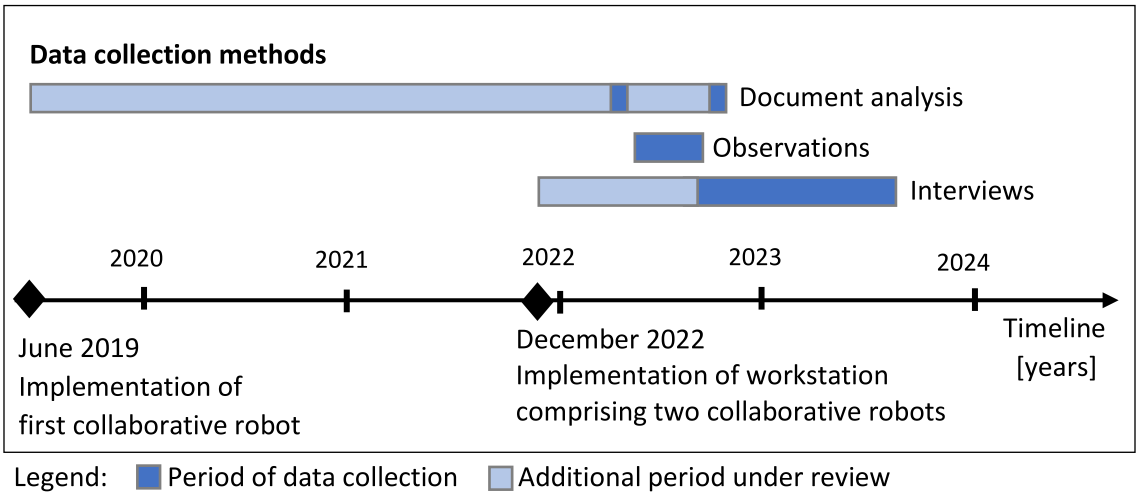


Figure 4-1: Temporality of data collection methods

Overall, this section established the organisation's positioning within the broader change process, with most of its employees and managers situated within the acceptance stage. This positioning provides the foundation for understanding the organisation's current state of technology transformation. In addition, this section gave an overview of the data collection methods employed and the corresponding temporal scope of each approach. Taken together, these elements form the basis of the present study by acknowledging the temporality inherent in the research design. This temporal framing enables a more focused exploration of the critical factors influencing the acceptance of collaborative robot integration and their relation to system performance within the organisational context.

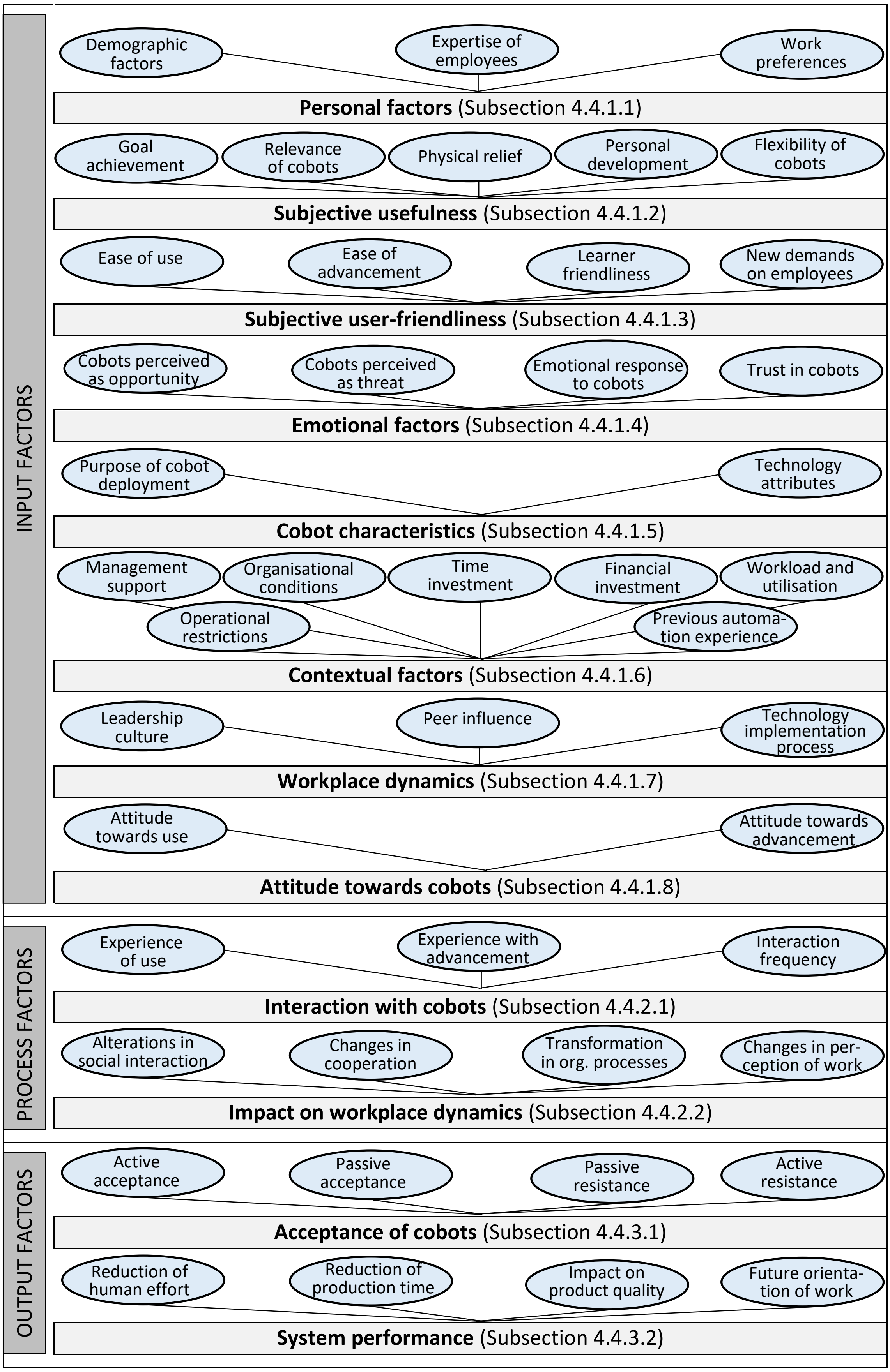
4.4 Factors influencing acceptance of collaborative robots

The following subsections examine the critical factors influencing acceptance of collaborative robots within the organisation under study, taking into account its position on the adapted Kübler-Ross change curve. These critical factors are presented as themes in the following analysis. Reflexive thematic analysis of the qualitative data collected from the previously listed participants generated a total of ten themes influencing the acceptance of collaborative robots. Two further themes were defined on the output level: employee acceptance of collaborative robots within the organisation, based on the first research objective, and system performance, which was conceptualised as a complementary output factor to facilitate exploration of the relationship between acceptance and system performance in developing the conceptual framework. The thematic structure was developed through a rigorous coding process that involved the generation of 84 initial codes, which were subsequently organised into main codes, codes, and subcodes.

During the study's data analysis, a thematic map was iteratively developed and refined, aligning with the stages of reflexive thematic analysis. The initial version of the thematic map was constructed in Phase 3 of the analysis, during the search for themes, wherein the generated codes were organised into preliminary themes. At this stage, a provisional theme was also created to accommodate miscellaneous codes that did not directly align with other themes.

Subsequently, in Phase 4, these emergent themes were reviewed and refined to create a clear hierarchical structure, which served as the conceptual foundation for each theme. Afterwards, each theme was again reviewed using two criteria: assessing the internal coherence of each theme and its consistency with the complete data set, as Braun and Clarke (2006) recommended. During this phase, the miscellaneous theme was deconstructed, with its codes either discarded due to irrelevance or integrated into more appropriate themes. In the subsequent phase, further refinement was undertaken, and each theme was clearly defined, as illustrated in Appendix E. Thus, each theme was considered a distinct construct, ensuring conceptual clarity and interpretative depth, as Braun and Clarke (2006) suggested. The thematic map resulting from the analysis process described above is presented in Figure 4-2. This map provides a visual synthesis of the key findings and serves as a conceptual foundation for the structure and narrative of the subsequent analysis in Section 4.4 and its subsections.

The visualisation presented below is intended to support the reader's navigation of this section by offering a high-level overview of each theme, organised according to its main codes. Additionally, the map references the specific subsections in which each theme is discussed in greater depth. The themes were classified into three domains: input, process and output factors. This classification is also visually depicted in Figure 4-2.



Notes: org. = organisation

Figure 4-2: Thematic map

The input factors encompass a set of individual and organisational conditions that establish the foundation for implementing collaborative robots and shape attitudes towards their adoption. Process factors refer to the activities, interactions, and experiences that transform the input factors into the desired output. These factors are largely driven by the internal dynamics within the organisation. Finally, output factors focus on the outcomes resulting from these organisational processes. Key output factors in this analysis include the degree of acceptance of collaborative robots and the overall impact on system performance.

Given the high-level overview presented in the thematic map in Figure 4-2, further detail is necessary to develop a multifaceted understanding of the thematic structure. This is because the codes and sub-codes were intentionally excluded from the figure for clarity and visual simplicity. To address this, Table 4-3 provides a detailed breakdown of each theme, including its corresponding main codes, codes, and sub-codes, illustrating the complete coding hierarchy. It should be noted that the number of referenced statements originating from participant observation is considerably lower than those from the semi-structured interviews. This is because participant observation was primarily used to develop interview protocols and establish a foundation for data triangulation, rather than to yield a large volume of critical statements.

As shown in Table 4-3, the level of indentation within the coding hierarchy indicates the relative level of subordinance of each code. Increased indentation corresponds to a more subordinate position within the coding structure. Furthermore, the table reports the average number of participant observations and interviews in which each code appeared, as well as the total number of critical statements (referred to as excerpts in the table) related to each code.

By systematically presenting the themes and codes identified through analysis, Table 4-3 provides a holistic overview of the collected dataset. It also highlights data that are frequently referenced in the subsequent sections of the thesis, thereby serving as a key resource for understanding the results. Further details about the definition of each theme and code, along with representative examples of critical statements, from observations as well as interviews, are provided in Appendix E. This appendix contains a selection of verbatim excerpts in the original German language and their English translations. To enhance readability, all quotations in the main text are presented exclusively in English.

Themes / Codes	Observation		Interview	
	Ø Number	Σ Excerpts	Ø Number	Σ Excerpts
INPUT FACTORS	*	**58**	**13**	**1613**
Personal factors	**1**	**4**	**12**	**87**
Demographic factors	1	1	8	11
Expertise of employees	1	3	13	76
Familiarity with technology	-	-	14	27
Self-help capability	1	2	12	26
Work preferences	1	1	13	23
Subjective usefulness	**2**	**14**	**17**	**225**
Goal achievement with cobots	3	3	21	51
Relevance of cobots	2	3	20	56
Physical relief	3	8	18	53
Personal development	-	-	15	44
Flexibility of cobots	-	-	9	21
Subjective user-friendliness	**2**	**9**	**13**	**145**
Ease of use	2	2	12	21
Ease of advancement	2	3	7	15
Learner friendliness	2	4	21	100
Support and assistance	2	2	17	40
Training setup	2	2	24	60
New demands on employees	-	-	7	9
Emotional factors	*	**5**	**12**	**304**
Cobots perceived as opportunity	1	2	13	93
Curiosity about cobots	-	-	17	37
Positive expectations	-	-	8	13
Reduction of fear	-	-	14	20
Satisfaction	2	2	14	23
Cobots perceived as threat	*	2	11	130
Fears around cobots	*	-	10	80
Damage concerns	-	-	4	8
Doubts about value	-	-	10	17
General anxiety	-	-	11	18
Job loss fears	-	-	16	37
Frustration	2	2	10	23
Scepticism	-	-	13	27
Emotional response to cobots	1	1	12	49
Humanisation	1	1	17	37
Objectification	-	-	6	12
Trust in cobots	-	-	15	32
Cobot characteristics	**1**	**10**	**12**	**216**
Purpose of cobot deployment	2	8	11	97

Themes / Codes	Observation		Interview	
	Ø Number	Σ Excerpts	Ø Number	Σ Excerpts
Collaborative use	5	8	21	57
Economic efficiency	-	-	6	22
Work quality	-	-	6	18
Technology attributes	*	2	12	119
Appearance	-	-	12	27
Collaboration needs	-	-	12	18
Production speed	1	2	20	58
Noise level	-	-	4	16
Contextual factors	**1**	**8**	**13**	**251**
Management support	-	-	10	19
Organisational conditions	-	-	12	25
Time investment	-	-	16	47
Financial investment	-	-	16	32
Workload and employee utilisation	1	1	17	40
Operational restrictions	5	5	12	45
Previous automation experience	1	2	9	43
Failed implementation	1	2	11	33
Successful implementation	-	-	6	10
Workplace dynamics	**-**	**-**	**10**	**182**
Leadership culture	-	-	9	76
Peer influence	-	-	10	22
Technology implementation process	-	-	10	84
High involvement	-	-	10	21
Low involvement	-	-	12	29
Communication	-	-	9	34
Attitude towards cobots	**1**	**8**	**14**	**203**
Attitude towards use	*	3	14	86
Positive attitude	-	-	21	48
Neutral attitude	-	-	8	11
Negative attitude	1	3	13	27
Attitude towards advancement	1	5	14	117
Improvement ideas	1	2	12	37
Negative attitude	2	2	11	23
Positive attitude	1	1	19	57
PROCESS FACTORS	**1**	**19**	**17**	**386**
Interaction with cobots	**2**	**18**	**19**	**259**
Experience of use	5	16	22	102
Negative experiences	6	12	22	52
Positive experience	4	4	21	50
Experience with advancement	*	1	16	88
Negative experience	-	-	13	18
Positive experience	1	1	18	70
Interaction frequency	1	1	21	69
Impact on workplace dynamics	*****	**1**	**16**	**127**

Themes / Codes	Observation		Interview	
	Ø Number	Σ Excerpts	Ø Number	Σ Excerpts
Alterations in social interaction	-	-	14	46
Changes in comm. and cooperation	-	-	19	29
Changes in perception of work	-	-	20	36
Transformation in org. processes	1	1	9	16
OUTPUT FACTORS	*****	**5**	**14**	**261**
Acceptance of cobots	*****	**1**	**11**	**96**
Active acceptance	-	-	18	34
Passive acceptance	-	-	13	29
Passive resistance	-	-	10	23
Active resistance	1	1	4	10
System performance	*****	**4**	**17**	**165**
Reduction of production time	-	-	18	40
Reduction of human effort	-	-	21	50
Impact on product quality	2	4	18	53
Future orientation of work	-	-	11	22

Notes: * average number of observations < 1
Org. = organisational; comm. = communication

Table 4-3: Thematic table with themes, codes and sum of excerpts

Each subsection is dedicated to one of the identified themes within the domains of input, process, and output factors. These subsections present each identified theme in detail, including the corresponding codes and illustrative critical statements. The latter refers to salient excerpts from the qualitative data that serve as empirical evidence supporting the interpretation of each theme. Accordingly, an in-depth overview of each theme is presented, providing a nuanced understanding of the factors influencing the implementation of collaborative robots.

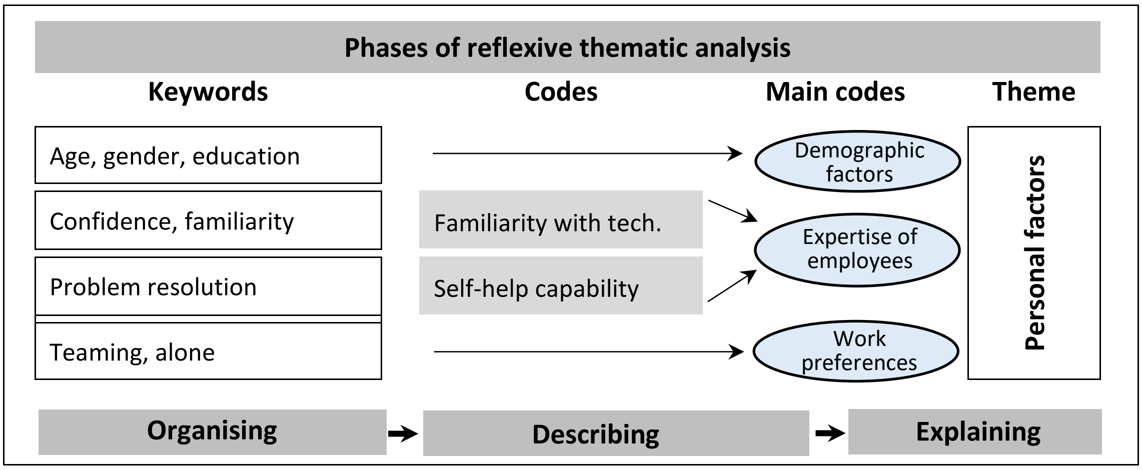
Moreover, a visual representation of the reflexive thematic analysis process is provided in each subsection, thus demonstrating the development of each theme. It provides a schematic overview of the keywords associated with specific codes. In addition, this visualisation serves as a basis for exploring the relationship among keywords, different levels of codes, and themes, as suggested by Braun and Clarke (2006) and Naeem et al. (2023). Through this approach, the visual representation played a critical role in establishing the foundation for developing the study's conceptual framework.

4.4.1 Input factors

The present analysis identified eight themes classified as input factors. These themes were derived from 65 main codes, codes, and sub-codes, supported by over 1,600 critical statements from participants, as shown in Table 4-3. The themes *"personal factors"*, *"subjective usefulness"*, *"subjective user-friendliness",* and *"workplace dynamics"* were each composed of five to six distinct codes. In contrast, the theme *"emotional factors"* encompassed the highest number of codes, demonstrating the importance of these factors in shaping participants' perceptions. The themes of *"cobot characteristics"*, *"contextual factors",* and *"attitude towards cobots"* were each composed of eight to nine codes. The following describes each input-related theme, highlighting the key findings and insights derived from the reflexive thematic analysis.

4.4.1.1 Personal factors

This theme addresses the individual attributes and characteristics that influence employees' perceptions of collaborative robots. These include demographic factors, personal experiences, related familiarity with the technology and self-help capabilities, and individual work preferences. The visual depiction of this theme is shown in the following figure, reflecting the analytical process employed in the reflexive thematic analysis outlined in Subsection 3.4.4.4.



Notes: tech. = technology

Figure 4-3: Reflexive thematic analysis process–personal factors

A total of 91 critical statements were associated with this theme, most of which were primarily based on the interviews conducted, as shown in Table 4-3. The development of this theme was informed by participants' responses to interview questions designed to elicit their reflections on experiences and perceptions of collaborative robots. Example questions included: *"How good or confident do you feel when using the cobots?"*, *"What would it be like if additional cobots were to be introduced into your workplace?"*, and *"What would it be like if you only worked with cobots?"* On this basis, the following main codes were inductively constructed.

Demographic Factors

The participants highlighted the impact of demographic factors on the perception of collaborative robots, with particular reference to the influence of age and educational background, which were identified as keywords. The excerpts from Participants F6 and M21 evidenced this relationship. In addition to age and education, participants were also asked to provide information regarding their gender, current position, and tenure.

> *F6 (employee): I belong to a generation that is more familiar with new technologies.*
>
> *M21 (manager): Of course, it also depends on personal factors such as educational background and age. If someone belongs to a younger generation, they may also be more tech-savvy and more interested in technology than an employee who has only known traditional manual work for years or decades.*

These statements indicate that younger employees and those with higher educational qualifications tend to exhibit greater comfort and confidence in engaging with collaborative robots.

Expertise of employees

This main code is derived from two underlying codes: *"familiarity with technology"* and *"self-help capability".* These codes are characterised by keywords such as confidence, familiarity, and problem resolution, which emerged inductively from the collected data. Participants referenced these aspects in various contexts when discussing their confidence in using collaborative robots, as illustrated by the following statements. This main code is further enriched with information about the participants' prior experience with robots collected from all employees interacting directly with this technology.

Familiarity with technology:

> *M5 (employee): I arrive in the morning and switch it (cobot) on if there is a work order and it is running.*
>
> *M2 (employee): I do not feel confident; when I am alone with the cobot, I do not know how to operate it.*

Self-help capability:

M5 (employee): From time to time, we have been able to fix the little things ourselves so that it keeps running.

M23 (employee): What I have noticed now, but that could also be changed, as I said, if people are trained intensively. That would be better for us and also good for the company, I would say. Then everyone would be autonomous.

Employees' familiarity with the technology and ability to independently resolve minor technical issues were found to positively influence their confidence and autonomy in using collaborative robots. In addition, participants emphasised the importance of adequate training as a critical enabler for developing these competencies, thereby leading to increased acceptance and better integration of the technology.

Work preferences

The third main code within this theme, *"work preferences"*, was identified as an influential factor in shaping employees' perception of collaborative robots. In particular, the qualitative data suggest that individual differences in preferred working styles, whether to work collaboratively or independently, influence how employees engage with this technology. For instance, M11 preferred team-based work, while F6 opted for working independently.

M11 (employee): I do not want to sit around machines all day. I like dealing with people, but that is just me.

F6 (employee): Preferably alone. Of course, it is nice to do something together sometimes, but I do not think it would be good for me to always work in a team.

The critical statements of this main code indicate that a preference for working with colleagues may negatively influence employees' attitudes towards working with collaborative robots.

Overall, the *"personal factors"* theme offers a nuanced perspective on the impact of individual characteristics on employees' attitudes towards collaborative robots. The supporting evidence, drawn from critical statements from participants, highlights the diversity of viewpoints within the sample. These findings underscore the complex and multifaceted relationship between personal attributes and the perception of collaborative robot integration.

4.4.1.2 Subjective usefulness

This theme explores participants' perceptions of the value and effectiveness of collaborative robot technology. These perceptions are reflected in users' personal impressions and opinions regarding the practicality and benefits of integrating collaborative robots in their work environment. This theme is structured around the following main codes: *"goal achievement with cobots"*, *"relevance of cobots"*, *"physical relief"*, *"personal development",* and *"flexibility of cobots"*. Figure 4-4 illustrates this theme as constructed through the reflexive thematic analysis process outlined in Subsection 3.4.4.4.

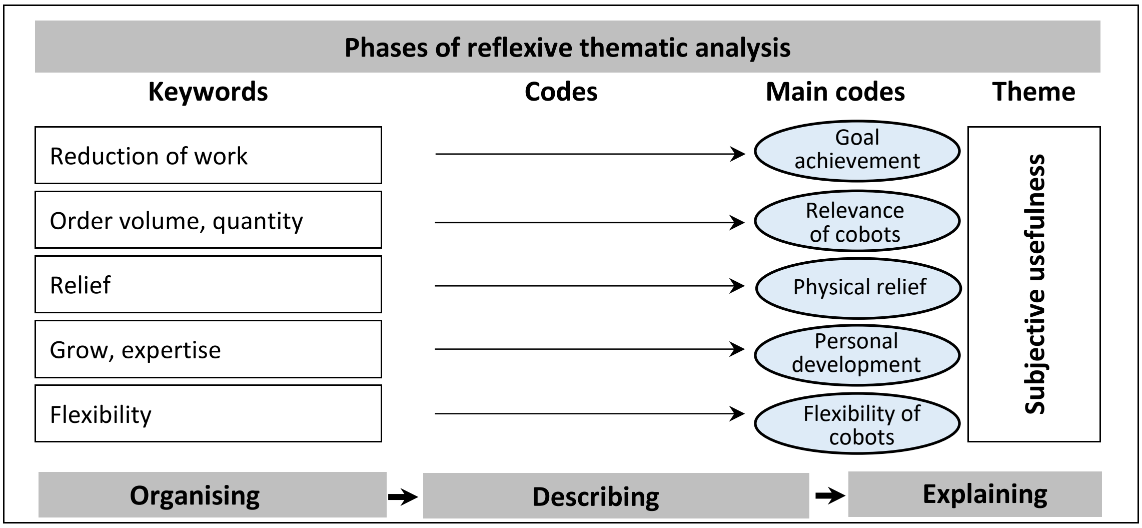


Figure 4-4: Reflexive thematic analysis process–subjective usefulness

As shown in Table 4-3, a total of 239 critical statements from participants were identified concerning this theme. These statements primarily derive from responses to questions such as: *"How valuable do you consider the support provided by the cobots? "* and *"Have the cobots met your expectations?"* It should be noted, however, that the statements are not solely based on semi-structured interview data. Instead, the first three main codes were determined based on observation data, integrating multiple data sources to enrich the analysis.

Goal achievement with cobots

This main code captures critical statements regarding how collaborative robots assisted the participants in achieving their goals. The following statements from Participants F4 and F8 illustrate how the collaborative robots facilitated task completion, enhancing their effectiveness and efficiency. Notably, reduction of work emerges as a keyword for this main code.

> *F4 (employee): It does the same work that we do. It cannot do everything, but it can do parts of it, and for that reason, I really see it as a good co-worker.*
>
> *F8 (employee): If you look at it, you do about half now. Before, you had to do everything yourself, but now you only have to do 50%.*

The identified critical statements indicate that collaborative robots are perceived positively when their contribution to task completion is evident. This can include the reduction of workload, thereby rendering tasks easier and more efficient for employees.

Relevance of cobots

This main code encompasses participants' critical reflections on the relevance of using collaborative robots for a given task. The study's findings indicated that utilising collaborative robots was perceived as advantageous in certain circumstances, as exemplified by the responses of F13. Conversely, in some cases, the utilisation of collaborative robots was deemed ineffective primarily due to the complexity and scale of the task, as illustrated by the example provided by M5. Within the context of this code, it is essential to highlight the emergence of keywords, namely order volume and quantity.

> *F13 (employee): I think it is a huge relief, especially when it comes to large quantities. Otherwise, one of us would be working on it for several days, just sitting there and inserting vials.*
>
> *M5 (employee): Small jobs are not worth doing with the cobot. Each time, we spend more time selecting and setting up the programme and making sure it is running.*

The critical statements associated with this main code indicate the importance of task selection when deploying collaborative robots. This is because the perceived effectiveness of collaborative robots is contingent upon the nature of the tasks they are employed to perform. Findings from this study suggest that collaborative robots are beneficial for highly repetitive and simple tasks.

Physical relief

This code captures the physical relief of integrating collaborative robots in the workplace. A notable proportion of the participants (18 out of 27) indicated during the interviews that using collaborative robots reduced physical strain and discomfort, allowing employees to perform tasks with less fatigue. This is illustrated by the following statements and further supported by the recurring use of the keyword relief.

F8 (employee): If you stand there like that all day, you get neck pain, headaches, or something like that, and you just do not have that (with the cobot).

M25 (employee): But every tray we do not have to do ourselves is also a physical relief in some way.

Collaborative robots are considered particularly beneficial when they facilitate work processes, enabling employees to perform tasks with greater physical comfort.

Personal development

This main code addresses the personal development opportunities of working with collaborative robots. Through the coding and analysis process, keywords such as growth and expertise emerged. For instance, Participants M10 and M27 emphasised the value of engaging in more challenging tasks and acquiring new skills as key benefits of working with collaborative robots.

M10 (employee): So working with the cobot is fun because it also challenges you a bit.

M27 (manager): Well, I say, maybe it takes away the job of a less skilled worker, but on the other hand, it creates a job for a highly qualified worker. Because the thing (cobot) also needs to be looked after, sometimes something breaks, and sometimes it needs to be programmed.

These statements suggest that utilising collaborative robots can potentially foster opportunities for personal development. However, based on the data, the perceived benefits of such opportunities are contingent upon employees' motivation to pursue developmental activities.

Flexibility of cobots

This main code addresses the flexibility inherent in collaborative robot technology. Participants, including M17 and M27, emphasised the versatility of these robots as a key benefit, highlighting their capacity to perform a wide range of tasks and adapt to varying operational requirements.

M17 (employee): I think that the cobot's greatest strength is that it is incredibly flexible. It can insert modules today and close bottles tomorrow or whatever.

M27 (manager): You can react very flexibly and quickly to minor requirements. That is the advantage—the major advantage—of the cobot.

The capacity of collaborative robots to operate flexibly was identified as a critical factor contributing to their value in dynamic work environments. Their adaptability allows them to perform diverse tasks in response to evolving demands.

Overall, the theme of *"subjective usefulness"* provides nuanced insights into how employees perceive the utility and benefits of integrating collaborative robots in their work environment. This theme encompasses that collaborative robots were perceived as valuable primarily for their ability to enhance efficiency and job satisfaction, which was largely attributed to the high flexibility of the technology.

4.4.1.3 Subjective user-friendliness

This theme captures participants' perceptions of the user-friendliness and accessibility of collaborative robot technology. It includes assessments of the ease of use, technological advancement, learner friendliness, and the impact of new demands on employees as main codes. Figure 4-5 illustrates this theme, as outlined in Subsection 3.4.4.4.

Table 4-3 shows that this theme comprises 154 critical statements derived from the associated codes. Most of these codes were initially identified during the analysis of participant observations and were later corroborated through semi-structured interviews. Typical questions that elicited responses relevant to this theme include: *"How were you trained to use the cobots? ", "How long did the training take? ",* and *"If you needed help working with the cobots, how were you supported?"* As a result of the analysis, the following main codes were established.

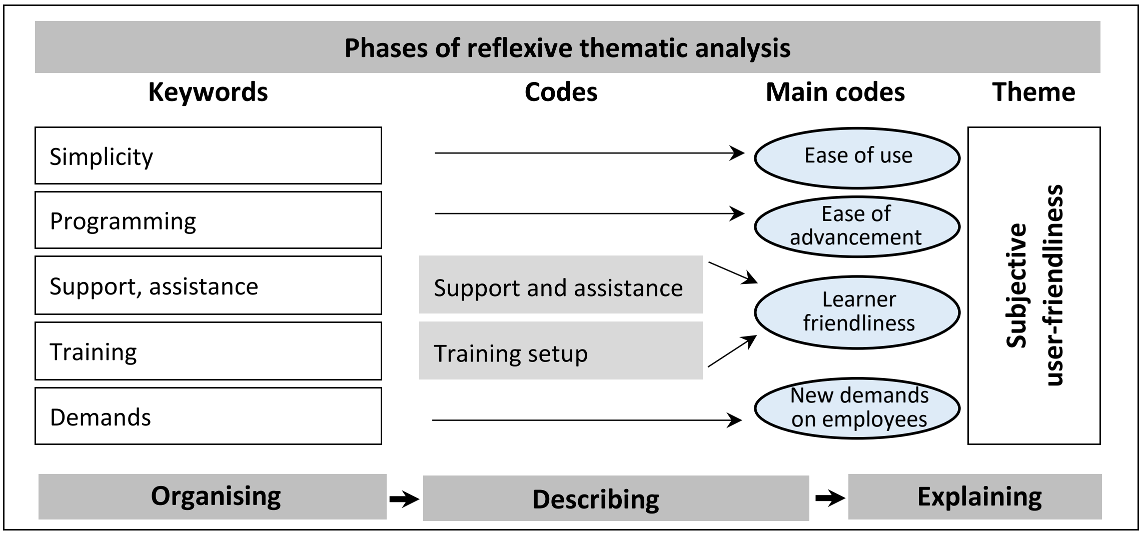


Figure 4-5: Reflexive thematic analysis process–subjective user-friendliness

Ease of use

This main code encompasses critical statements from participants regarding their perceptions of the ease of use of collaborative robots. Participants highlighted specific features of collaborative robots that make them user-friendly and straightforward. This assertion is supported by interview excerpts presented below, in which both participants underscored that the deployed collaborative robots are characterised by a high degree of operational simplicity. Accordingly, simplicity was identified as a recurrent aspect throughout the data.

> *F3 (employee): You do not have to do anything complicated. I think it is relatively easy to understand.*
>
> *M16 (manager): The operation itself is very, very simple.*

As demonstrated by the preceding statements, the ease of use of collaborative robots is a critical determinant of their accessibility and plays a vital role in achieving workforce acceptance.

Ease of advancement

This main code addresses how participants perceive the ease of developing and adapting collaborative robots within practical applications. Participants, including M1 and M19, noted that the adaptability of collaborative robots facilitates modifications of manufacturing processes without requiring advanced specialist expertise in robotic technology. Most identified critical statements under this theme are assigned to the keyword programming.

> *M1 (employee): It was more difficult at the beginning. It got easier and easier as you learned the first few things. Once I started to understand how the program works, or the programming itself, it became easier relatively quickly.*
>
> *M19 (manager): Well, I do not need a certified robotics expert to set it up. I think that is very positive. It is like a smartphone. That makes it very easy, or at least much easier, to integrate into work processes.*

The participants stated that a key advantage of collaborative robots over traditional industrial robots is their greater adaptability and reduced programming complexity.

Learner friendliness

This main code captures participants' perceptions of leaner-friendliness, as reflected in the codes: *"training setup"* and *"support and assistance"* provided to the workforce. This encompasses both the initial training programme and the ongoing support mechanisms. The following excerpt, drawn from interviews with M25 and M11, elucidates these aspects by detailing the initial training phase. Concurrently, F8 highlights the availability of support, particularly in cases of collaborative robot malfunction.

Support and assistance:

F8 (employee): If there is an error […] you are not on your own. There is always someone there if you do not know what to do.

M1 (employee): I have two colleagues who have also been trained. They can also programme the cobot, and we can exchange ideas with each other.

Training setup:

M25 (employee): I remember very clearly when the cobot arrived. I think we simply had a group training session about how it works in general.

M11 (employee): Yes, we actually visited the company where the cobots are produced, had the cobots explained to us, and received basic training there.

These statements highlight the importance of initial training and continuous support in promoting learner friendliness and ensuring employees develop confidence and proficiency in operating collaborative robots.

New demands on employees

This main code covers participants' critical reflections on the new demands and challenges of integrating collaborative robots. It includes statements highlighting the need for employees to acquire additional skills and competencies to effectively navigate these technological requirements, as evidenced by the interview excerpt from M17. Moreover, the statement from M26 emphasises the workforce's capacity to adapt to these evolving demands, particularly those associated with deploying collaborative robots. As demonstrated in the following examples, demand emerged as a particularly salient keyword.

M17 (employee): Of course, robotics has been added, which we hardly had before. And especially with this teaching and programming, that is something completely different compared with the other machines.

F26 (manager): That is why I was not sure whether they (the employees) would really be able to operate a robot. I was a bit sceptical at first, but I was proven wrong.

The preceding statements indicate that implementing collaborative robots has generated new occupational demands, necessitating the development of additional skills and competencies among employees.

In summary, the codes underpinning this theme highlight multiple facets that shape participants' perceptions of the overall user experience with collaborative robots. This theme demonstrates a predominantly positive perception among the study participants, particularly regarding the robots' ease of use and their flexibility.

However, several participants acknowledged the new demands and potential challenges, particularly regarding acquiring the skills necessary to engage effectively with this technology. These observations suggest that not all employees are necessarily equipped with the requisite skills and competencies to meet the evolving demands posed by this new technology. Consequently, these findings offer useful insights that can inform the design and implementation of future training programmes and support mechanisms to maximise the potential benefits of collaborative robot technology in the workplace. From a broader perspective, this also points to the need for strategic workforce development initiatives, including developing appropriate leadership capabilities to support the sustainable integration of such a technology.

4.4.1.4 Emotional factors

This theme captures the full spectrum of emotional responses, perceptions, and attitudes individuals express towards collaborative robot integration. It encompasses positive and negative emotional responses, including framing collaborative robots as opportunities or threats within the workplace. Furthermore, this theme incorporates critical factors such as trust in technology and the humanisation and objectification of collaborative robots. The visual representation of this theme is shown in the following figure, developed through the reflexive thematic analysis process outlined in Subsection 3.4.4.4.

In terms of the number of critical statements identified, the aspects of this theme were mentioned more frequently than those of any other single theme, with a total of 309 statements, as shown in Table 4-3. The majority of these statements were identified through the data collected from semi-structured interviews. Typical questions in this context, in which statements on this theme were identified, include: *"What did you think or feel when you first saw cobots?"*, *"How does it feel to work with the cobots compared to working with a human colleague?"*, *"To what extent do you think a cobot can replace* *a human?"*, and *"How are cobots currently perceived by employees especially in terms of forming an emotional bond comparable to a colleague?"* The formulated main codes that contain this theme are outlined in the following.

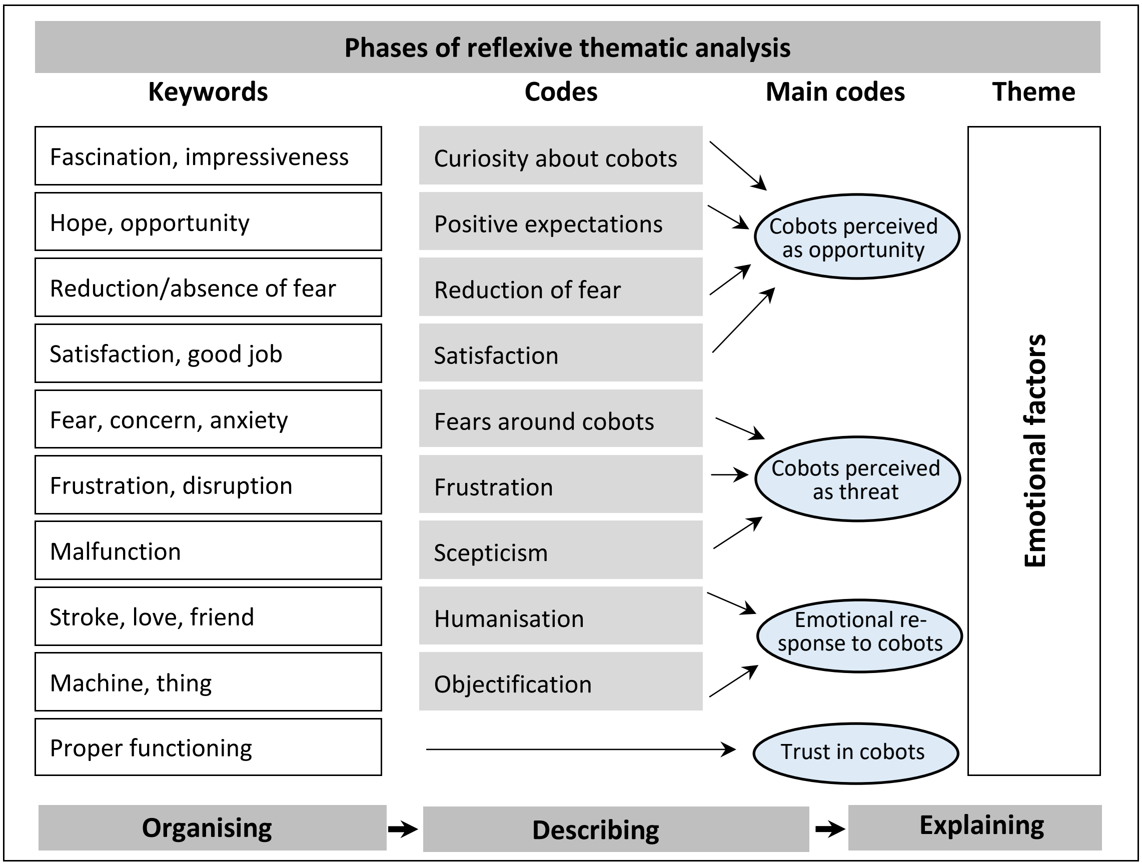


Figure 4-6: Reflexive thematic analysis process–emotional factors

Cobots perceived as opportunity

This main code encompasses participants' critical reflections that frame collaborative robots as opportunities. The data set includes expressions of curiosity, positive expectations, a reduction in fear, and reported satisfaction associated with using collaborative robots. The following interview excerpts provide evidence for this code and illustrate the emergence of previously stated keywords.

Curiosity about cobots:

> *F4 (employee): Because it is actually quite fascinating how the cobot works.*
>
> *M11 (employee): Just this future-oriented work–that we finally have a robot that automates something you can see in real life, and that also works collaboratively.*

Positive expectations:

> *M19 (manager): On the one hand, there is definitely the hope that it will take over some of the work that is just monotonous.*

M10 (employee): So now my hopes are actually quite high, because I think maybe we can do many, many things with this device (cobot) that, keep us from working.

Reduction of fear:

F8 (employee): Well, it is good that you just lose your fear and that you can simply get into working with it.

F4 (employee): But it does not take long before you realise that it does not run without people. So I did not have any fears.

Satisfaction:

F12 (employee): Otherwise, I feel that once it is up and running, everyone will be quite satisfied and things will just work out.

M17 (employee): Well, I think it works pretty well.

The statements above suggest that curiosity about and satisfaction with collaborative robots are critical in shaping employees' perceptions of opportunities. Consequently, this may contribute to greater openness towards collaborative robots and may enhance employees' willingness to interact with them, which could, in turn, lead to a reduction of fears.

Cobots perceived as threat

This main code covers critical statements from participants who perceive collaborative robots as a potential threat. Within this theme, the analysis identified four sub-codes related to *"fears around cobots"*: *"damage concerns"*, *"doubts about value"*, *"general anxiety"*, and *"job loss fears"*. The following interview excerpts exemplify the various forms of fear that the participants expressed.

Fears around cobots:

F3 (employee): The worry is that you just touch it and then something breaks, because you have no experience with a machine like that.

M15 (manager): They often showed errors. Therefore, the added value was not there at first or could not be seen immediately.

M5 (employee): In the beginning, not being computer literate and having to start the programme and then make it work made me feel a bit insecure and reluctant.

F13 (employee): On the one hand, of course, you worry about it because you are obviously afraid that you might be replaced by all these robots and cobots at some point.

In addition to the previously identified fears associated with collaborative robots, this main code also encompasses: *"frustration"* related to their use and *"scepticism"* regarding their overall implementation. Participants M2, F3, and F8 offer nuanced perspectives on these issues, as illustrated in the following interview excerpts. Notably, keywords like frustration, disruption, and malfunction emerged, highlighting how these negative experiences shape employees' perceptions toward collaborative robots.

Frustration:

M2 (employee): The cobot is not a machine colleague, as I was promised, but a hindrance.

F3 (employee): If it does not work, then it is really frustrating because, in that case, you lose time.

Scepticism:

M2 (employee): I feel like I have to watch it (cobot) all the time, otherwise it does nothing or does not do it properly.

F8 (employee): Sometimes, it (cobot) simply does not work properly. It is just a machine. It is also not infallible.

In light of the above-mentioned critical statements, collaborative robots are perceived as potential threats, particularly in scenarios involving system malfunctions, the need for additional skills that employees may lack, or concerns about their potential to replace human workers.

Emotional response to cobots

This main code deals with participants' emotional responses to collaborative robots, particularly focusing on the humanisation and objectification of the technology. One group described the collaborative robot in relational terms, likening it to a colleague or friend, as exemplified by the statements of M23 and F4. In contrast, the other group perceived the collaborative robot as a functional, impersonal instrument, as reflected in the excerpts from F8 and M25. These divergent viewpoints are further evidenced by the identified keywords, such as stroke, love, and friend, indicating humanisation, while terms like thing and machine signal objectification.

Humanisation:

M23 (employee): It is a typical machine, but over time it becomes your friend somehow. That was the case for me; you develop a bond with it.

F4 (employee): Well, I have already stroked it and things like that.

Objectification:

M25 (employee): It is more of a tool or a machine that you operate.

F8 (employee): Well, I think it is a machine, and the other one is a person, and you cannot have a relationship with it. At least, I cannot build a relationship with a machine. No, that is not possible.

The critical statements identified within these codes demonstrate that collaborative robots are perceived in a highly polarised manner across different groups of participants. This divergence is particularly relevant in understanding employees' perceptions regarding implementing such a technology.

Trust in cobots

This main code captures participants' critical reflections on trust in collaborative robots, including expressions of confidence and the conditions under which such trust is established. Statements from Participants M5 and M10 exemplify this theme. Notably, the keyword of proper functioning emerged in this regard.

M5 (employee): It was important to me that it runs and does not constantly stop because of minor issues.

M10 (employee): Yes, because for me, the cobot is more of a burden than a help. That is why I say personally. Yes. The cobot has to run reliably.

As the statements above demonstrate, trust in collaborative robots is closely linked to their consistent functioning and reliability within the manufacturing process. Reliable and error-free functioning, in turn, enhances employee trust in the technology.

Overall, the *"emotional factors"* theme offers a holistic overview of the diverse emotional responses, perceptions, and attitudes employees exhibit towards collaborative robots. These range from perceiving collaborative robots as opportunities marked by curiosity, optimism, and satisfaction to expressions of fear, frustration, and scepticism. This divergent emotional landscape emphasises the complexity of employee perceptions in human-robot interactions. Crucially, these findings highlight the importance of incorporating emotional dimensions in both the implementation and training processes, as addressing employees' emotional responses substantially contributes to fostering trust, creating conditions for favourable user responses, and cultivating a supportive work environment.

By recognising and addressing both the perceived opportunities and threats associated with collaborative robots, organisations can more effectively manage their integration into the workplace. It is, therefore, crucial to assess and analyse employee perceptions at individual and collective levels, particularly regarding whether these reflect a humanised or objectified view of the technology.

4.4.1.5 Cobot characteristics

The theme *"cobot characteristics"* encompasses a broad range of features associated with collaborative robots as well as an analysis of the underlying rationale behind their implementation. Two main codes define this theme: *"purpose of cobot deployment "* and *"technology attributes".* The first refers to the objectives and reasoning for implementing collaborative robots, which is essential for effective integration into work processes and understanding employees' perceptions and attitudes. The second, technology attributes, covers technical characteristics such as appearance, production speed, and noise level, all relevant to the collaborative robot's performance and workplace integration. Figure 4-7 illustrates this theme as it emerges from the reflexive thematic analysis process outlined in Subsection 3.4.4.4.

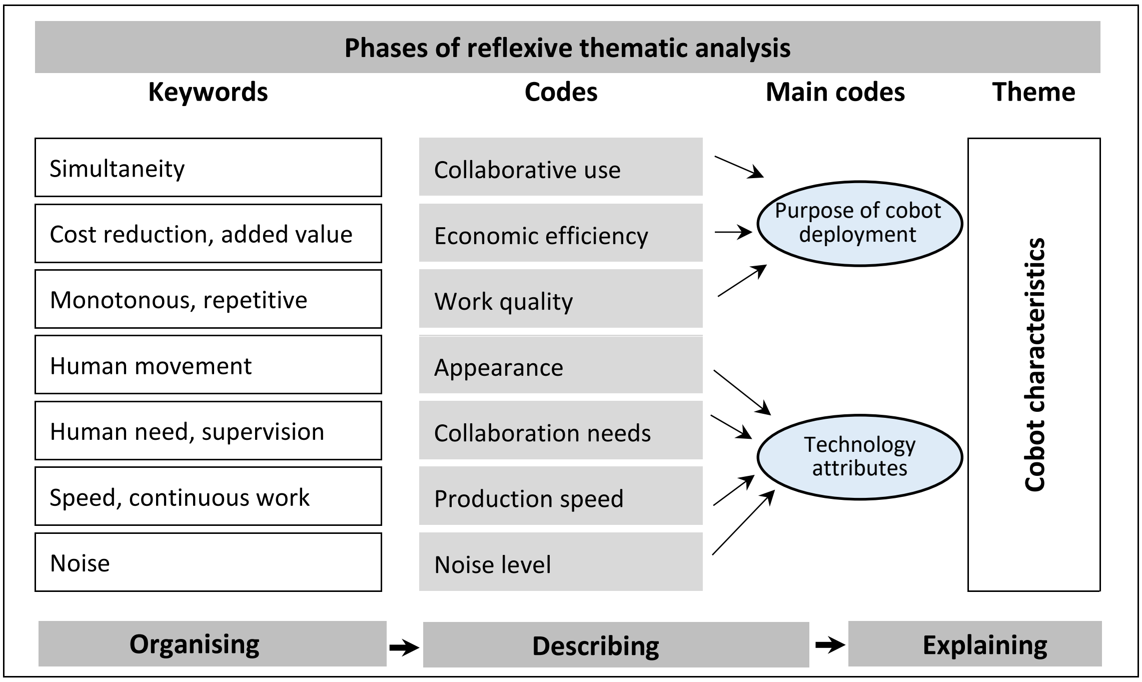


Figure 4-7: Reflexive thematic analysis process—cobot characteristics

A total of 226 critical statements related to this theme were identified, primarily based on the semi-structured interviews, as shown in Table 4-3. These statements were elicited mainly through follow-up questions, which probed deeply into the characteristics of collaborative robots mentioned during the interviews. By requesting further elaboration on these aspects, additional relevant insights were uncovered. In addition, document analysis revealed further insights, particularly regarding the technology's characteristics and safety aspects. The reflexive thematic analysis yielded the following main codes.

Purpose of cobot deployment

The main code includes critical statements from participants about the intended purpose and rationale for implementing collaborative robots. The implementation of collaborative robots is primarily driven by the desire to enhance collaborative work, improve economic efficiency, and improve the quality of work for employees. The following interview excerpts and the identified keywords substantiate these motivations.

Collaborative use:

> *M21 (manager): The employee can do other tasks while the robot is working.*
>
> *F26 (manager): The employees can do something else at the same time and thus be more productive in that respect. You might say, well, they could be assembling other components that the machine cannot process. Or perhaps they are already filling out production paperwork.*

Economic efficiency:

> *M20 (manager): But of course, our annual cost reduction targets, which we had to and still have to achieve, were essentially the original trigger for automation.*
>
> *M16 (manager): Of course, this also means that you can either reduce staff or assign them to more meaningful activities. Let us put it this way: not reduce staff.*

Work quality:

> *M16 (manager): It is an adequate means of easily completing monotonous work.*
>
> *M20 (manager): And these are assembly tasks, always repetitive. These are actually great patterns that you could teach directly to the cobot.*

The aforementioned insights regarding the purpose of deploying collaborative robots were primarily identified through the dyadic approach, which incorporated both employee and manager perspectives during data collection. Notably, these aspects were mentioned mainly by managers and might not have been identified had the data collection focused solely on employees.

Technology attributes

This main code covers the technological attributes of collaborative robots, including features such as their appearance, collaborative needs, production speed, and noise level.

These characteristics are not solely technical descriptors. Instead, they can evoke either a positive or a negative response from employees. The following excerpts from participants and the associated keywords evidence this. The identified attributes directly influence user perception and, consequently, play a critical role in shaping the effectiveness of collaborative robots within the workplace.

Appearance:

> *M17 (employee): Well, you cannot really equate the two, but I would say it is much more human-like than any other production line.*
>
> *M2 (employee): The cobot imitates human movement, and that cannot work.*

Collaboration needs:

> *M9 (employee): Well, the cobot can only do the simplest tasks, and you always need a human as well. And a human to operate it.*
>
> *M21 (manager): And so there will always be a need for supervision and certain areas of focus, which may shift but remain within the same general field.*

Production speed:

> *M5 (employee): During coffee breaks or lunch, for example, it keeps working. That way, I do not experience any downtime during packaging.*
>
> *M25 (employee): It does not have the same speed that we have as human workers. It is somewhat slower, but as support, it is a great thing.*

Noise level:

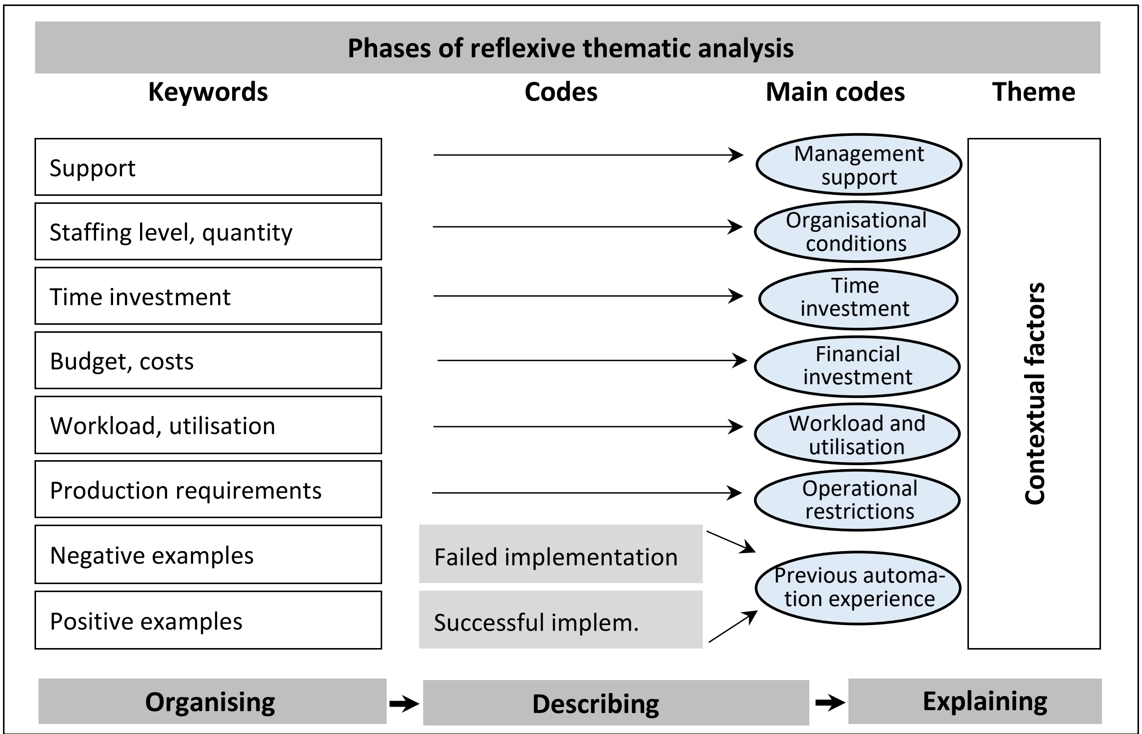
> *F22 (employee): And then there are days when it is annoying because of the noise—as we actually noticed today—the noise is different when it is malfunctioning.*
>
> *M5 (employee): The noise level, sometimes it is annoying. Not the air, because everything is powered by air, but the distributor at the front. That iron sound. Click, click, click. And that is damn loud.*

Participants' responses indicated a preference for the appearance of collaborative robots over conventional industrial robots, particularly among employees with limited experience in machine operation. Employees viewed the collaborative robot's supportive role as beneficial, rather than preferring fully autonomous operation. Moreover, reducing disruptions in the manufacturing process was cited as a key benefit by those working with collaborative robots. However, if the collaborative robot's production speed was perceived as inadequate, its overall value and utility were questioned. Perceptions of noise levels varied across participants and appeared to fluctuate depending on the day of observation.

In total, the theme of *"cobot characteristics"* offers a nuanced understanding of the attributes and strategic intentions behind the implementation of collaborative robots. The main codes elucidate the practical considerations driving the collaborative robot adoption, particularly related to enhancing collaborative processes, improving economic efficiency, and elevating work quality. The technological attributes of collaborative robots emerged as significant factors influencing employees' perceptions. A nuanced understanding of these characteristics and proactive efforts to address employee concerns, particularly related to noise and production speed, can facilitate more effective collaborative robot integration and utilisation across diverse work environments.

4.4.1.6 Contextual factors

This theme explores diverse external and internal conditions influencing the implementation and utilisation of collaborative robots within organisational settings. It encompasses managerial, financial, and operational considerations related to collaborative robots and prior experience with automation. The thematic structure derived through the reflexive thematic analysis outlined in Subsection 3.4.4.4 is visualised in Figure 4-8.



Notes: implem. = implementation

Figure 4-8: Reflexive thematic analysis process–contextual factors

A total of 259 critical statements related to the theme *"contextual factors"* were identified, as shown in Table 4-3. These statements were derived from observations and responses to key questions, such as: *"Are there any current constraints/limitations in the organisation that you are aware of? If so, what are they?"* and *"How is the implementation of cobots supported by senior management?"* Based on the analysis of these responses, the following main codes were developed.

Management support

This main code captures participants' critical reflections on the role of managerial support in implementing and utilising collaborative robots. The findings are substantiated by the excerpts from Participants M15 and M19, who emphasised that such support was a primary enabler for advancing to subsequent stages of the implementation process. The prominence of the keyword support underscores its centrality to this aspect.

> *M15 (manager): We always present the technology, and I have consistently received positive feedback. I also feel this provides support to push this forward.*
>
> *M19 (manager): Our former senior manager was really enthusiastic about automation, and we used this enthusiasm to come up with a few ideas.*

The critical statements associated with this main code indicate the need for management support beyond mere formal endorsement of technology. Instead, effective implementation requires proactive managerial support, including encouragement and strategic guidance to facilitate the seamless integration and advancement of collaborative robots.

Organisational conditions

The following main code addresses the participants' references to the pre-existing organisational conditions that influence the implementation and utilisation of collaborative robots. Key factors identified include staffing levels, production quantities, and setup times, as Participants F4 and M1 illustrated.

> *F4 (employee): Well, we have also had phases where we simply did not have enough people in labelling.*
>
> *M1 (employee): On the one hand, the quantity plays a very important role. I think that for 50 pieces, I do not need any automation, and I would probably be faster if I just did it quickly by hand.*

The study findings suggest that organisational factors, such as few employees with prior experience in operating collaborative robots, can considerably hinder the adoption of this technology. A comparable constraint was also observed concerning suboptimal production volumes for effectively utilising collaborative robots.

Time investment

This main code captures participants' critical reflections regarding the time required for implementing and programming collaborative robots. The time needed to become acquainted with such new technologies was identified as a key determinant in the adoption process. This is substantiated by the statements of Participants M18 and M21, and further reflected in the selected keyword associated with this code.

> *M18 (manager): Yes, at times the resentment was quite considerable when someone had to spend a lot of time with the cobot or worked with it without achieving much.*
>
> *M21 (manager): The time required for programming is initially an investment. During this period, the employee cannot perform any other production tasks but is 100% focused on the cobot, thinking about programming and so on. However, you have to calculate this over the medium and long term; it will definitely pay off in the end.*

It can be posited that the initial time required for programming and familiarising with collaborative robots constitutes a critical phase in the implementation process, as it may temporarily impact the organisation's productivity during the transition period. The findings indicate that lower time investment in implementation and programming leads to higher acceptance, making the minimisation of this time crucial for the successful adoption of collaborative robots.

Financial investment

This main code comprises critical statements from participants regarding the financial investment associated with implementing collaborative robots, acknowledging the pivotal role of financial implications in organisational decision-making. Consequently, managers, including M27 and M15, emphasise the comparatively modest financial investment required for collaborative robots relative to conventional industrial robots. In this context, the keywords budget and cost emerged as particularly salient.

> *M15 (manager): Well, of course, we do not have an unlimited budget that would allow us, for example, to buy additional feeding stations so that we could insert two components at the same time.*

M27 (manager): As I said before, the acquisition costs are low.

The critical statements in this study identify financial investment as a pivotal factor influencing the adoption of collaborative robots, with their comparatively low cost perceived as a significant advantage over traditional industrial robots.

Workload and employee utilisation

This main code captures participants' critical reflections on workload and employee utilisation regarding implementing collaborative robots. For example, Participant F4 highlighted situations where the existing workload was considered insufficient to justify the use of collaborative robots. Conversely, Participant M19 emphasised that the number of employees expressing interest in specific tasks also plays a vital role in determining effective collaborative robot integration.

F4 (employee): Nowadays, in the current situation, you are often just glad if you have enough work to do yourself.

M19 (manager): Because not enough people want to do such work. That is what makes it different from the past. In packaging in the 80s, you could find many more people for such work, and there are fewer and fewer of them.

Participants' responses indicate that workload is a crucial factor influencing the acceptance of collaborative robots, with high workload levels —where demands exceed the capacity of the available workforce—being associated with increased acceptance. In contrast, the motivation to integrate collaborative robots decreases when the existing workload is perceived as insufficient.

Operational restrictions

This main code captures critical statements related to operational constraints influencing the use of collaborative robots, including physical restrictions and environmental conditions. These constraints encompass factors relating to product specifications and manufacturing parameters. For example, Participant M15 highlighted temperature exposure requirements during production, which impose restrictions on allowable production durations. Additionally, Participant M9 emphasised the necessity of appropriate mounting and stability conditions for the collaborative robot.

M15 (manager): There are limitations regarding the products themselves, for example, when it comes to temperature exposure. The cobots are located in normal rooms, but our products are temperature-sensitive, or at least mostly temperature-sensitive.

M9 (employee): It only became apparent later that it has to be 100% stable and that it needs to be screwed on. It is not enough for the cobot to just stand on a stable table.

The operational constraints associated with using collaborative robots indicate the necessity of meticulously selecting manufacturing processes suitable for their integration. This can enhance their acceptance, effectiveness and provide a foundation for reliable system performance.

Previous automation experience

The main code, *"previous automation experience"*, encompasses critical statements relating to participants' prior involvement in automation projects. This main code is further delineated into two codes addressing both successful and unsuccessful implementations, thereby providing insights into the challenges and achievements experienced by participants in the past. For instance, as evidenced by Participant F12, introducing a specific industrial robot has failed to meet production objectives. Conversely, Participant F3 reflects a perception of work simplification attributable to previous automation efforts.

F12 (employee): I think this is more of a negative example (existing industrial robot). It definitely was not worth it at all. I believe it was a bad investment.

F3 (employee): In retrospect, I have to say that all the machines we received have actually made our work easier.

It is imperative to recognise that prior experiences with automation, irrespective of their outcomes, directly influence employees' attitudes towards adopting new technologies, such as collaborative robots. Positive experiences in particular contribute to a favourable perception, whereas negative experiences have the opposite effect.

In conclusion, *"contextual factors"* highlight the importance of considering external and internal organisational influences when implementing collaborative robots. Key determinants of successful adoption include robust management support, conducive organisational conditions, and sufficient allocation of time and resources. Past experiences with automation also offer valuable insights for planning and executing future initiatives. Consequently, it would be advisable to assess how individuals and groups view previous automation projects, as these perceptions underpin the effective implementation and acceptance of collaborative robots.

4.4.1.7 Workplace dynamics

This theme explores the influence of workplace dynamics on employees' perceptions and attitudes towards collaborative robots. It considers the role of leadership culture, peer influence, and the technology implementation process, with particular attention to social interactions such as employee involvement and quality of communication throughout the process. A visual representation of this theme is shown in the following figure, derived from the reflexive thematic analysis process outlined in Subsection 3.4.4.4.

The 182 critical statements analysed within this theme were derived from data collected through semi-structured interviews, as delineated in Table 4-3. These statements emerged in response to key questions designed to explore social and organisational dynamics, such as: *"Do you think there are opinion leaders in the group?, How do they behave?"*, *"How have cobots changed your human resources management?"*, and *"Is there a (conflicting) positioning within the group (pro/con cobot)? If so, why and how do you deal with it?"* Based on these responses, the following main codes were developed.

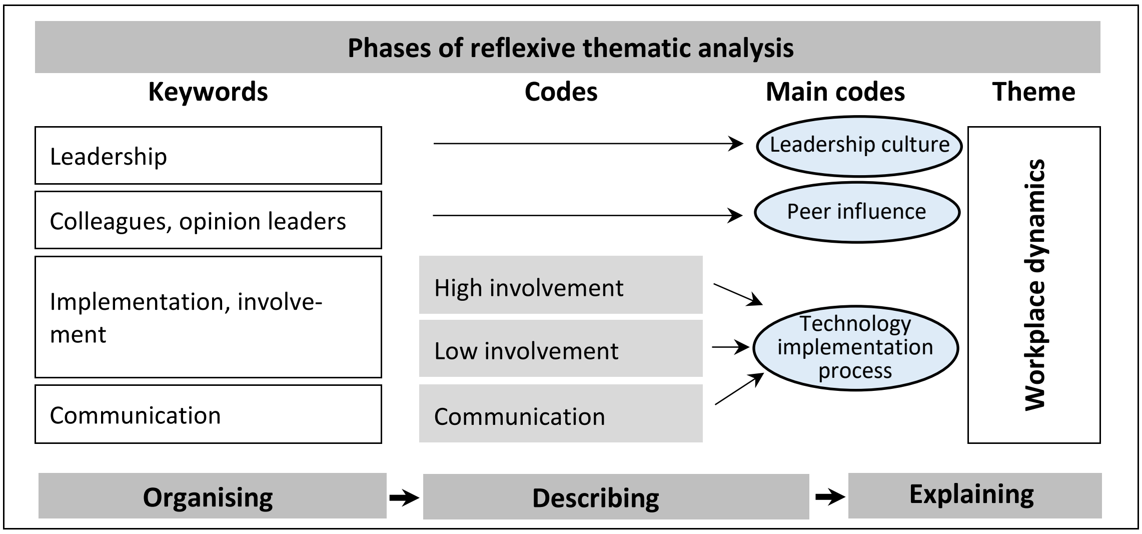


Figure 4-9: Reflexive thematic analysis process–workplace dynamics

Leadership culture

This main code, anchored by the keyword leadership, addresses the role of leaders in introducing and integrating collaborative robots within the workplace. The approach taken by leaders in managing technological change is vital in shaping employees' attitudes, levels of receptivity, and overall acceptance of the new technology, as evidenced by the following excerpts from managers.

> *M15 (manager): I think some of the employees can be convinced very well with theoretical explanations, but others need to be convinced in practice.*
>
> *M20 (manager): And that is a classic management task: simply bringing the whole team back together, getting everyone back on track, and formulating a clear vision. We need to increase efficiency, but we are also trying to relieve employees by reducing their workload and repetitive tasks.*

The critical statements associated with this main code indicate the importance of effective leadership in shaping positive employee attitudes towards collaborative robots. The data further suggest that a dual approach, involving both practical demonstration and clear explanation of the underlying principles and benefits, can be particularly beneficial in communicating the full potential of this technology.

Peer influence

This main code captures the impact of peer influence on employees' perceptions of collaborative robots. The opinions, behaviours, and prior experiences of colleagues can substantially shape individual perceptions and attitudes, as stated by Participants F12 and M15.

> *F12 (employee): At the beginning, you often heard that it did not work […], especially from people who had worked with it a lot, who were familiar with the technology, and who had to learn it.*
>
> *M15 (manager): I hope that he (the employee) not only experiences the benefits firsthand when things work well, but is also encouraged by seeing his colleagues use it successfully, motivating him to move in that direction as well.*

The findings of this study indicate that peer influence may contribute to shaping attitudes towards collaborative robots. Positive experiences shared by colleagues appear to encourage openness to the technology, while negative accounts may, at times, challenge its integration within the workplace.

Technology implementation process

This main code examines the role of employees in the implementation process of collaborative robots, particularly emphasising the level of involvement and the mode of communication. Both factors are critical in shaping employees' willingness to adopt this technology. Accordingly, the main code *"technology implementation process"* is structured into three codes: *"high involvement"*, *"low involvement"*, and *"communication"*. The interview data revealed notable discrepancies in participants' perceived levels of involvement in the implementation process, as evidenced by the differing excerpts of M1 and M13. Additionally, the significance of transparent communication during the implementation phase was repeatedly emphasised, as exemplified by the insights provided by Participant F8.

> *M1 (employee): I was involved from the initial idea through to implementation and wrote most of the programs for it together with a few other colleagues.*
>
> *F13 (employee): Well, as I said, we were not really involved in the set-up of the whole thing.*
>
> *F8 (employee): Yes, when it was introduced to us, we received a presentation, and I thought to myself: "Wow".*

In light of these critical statements, it is imperative that managers carefully determine the appropriate level of employee involvement in the implementation process of collaborative robots. Equally important is establishing clear, consistent, and transparent communication strategies.

Overall, *"workplace dynamics"* highlights the importance of leadership style, peer influence, and communication in shaping employees' perceptions and attitudes towards collaborative robots. A participatory leadership approach, positive experiences shared by peers, and high levels of employee involvement and transparent communication during implementation are crucial for the successful integration of collaborative robots. Addressing these factors can foster a supportive organisational climate for adopting collaborative robot technology, improving operational efficiency and employee satisfaction.

4.4.1.8 Attitude towards cobots

This theme captures individuals' overarching perceptions of collaborative robots concerning their use and advancement. These perceptions are shaped by the cumulative influence of the previously identified input factors, reflecting how collaborative robots are understood and valued at both the individual and organisational levels. This theme includes a spectrum of attitudes, encompassing positive, negative, and neutral or ambivalent sentiments towards collaborative robots. Figure 4-10 visually represents this theme derived from the reflexive thematic analysis process outlined in Subsection 3.4.4.4.

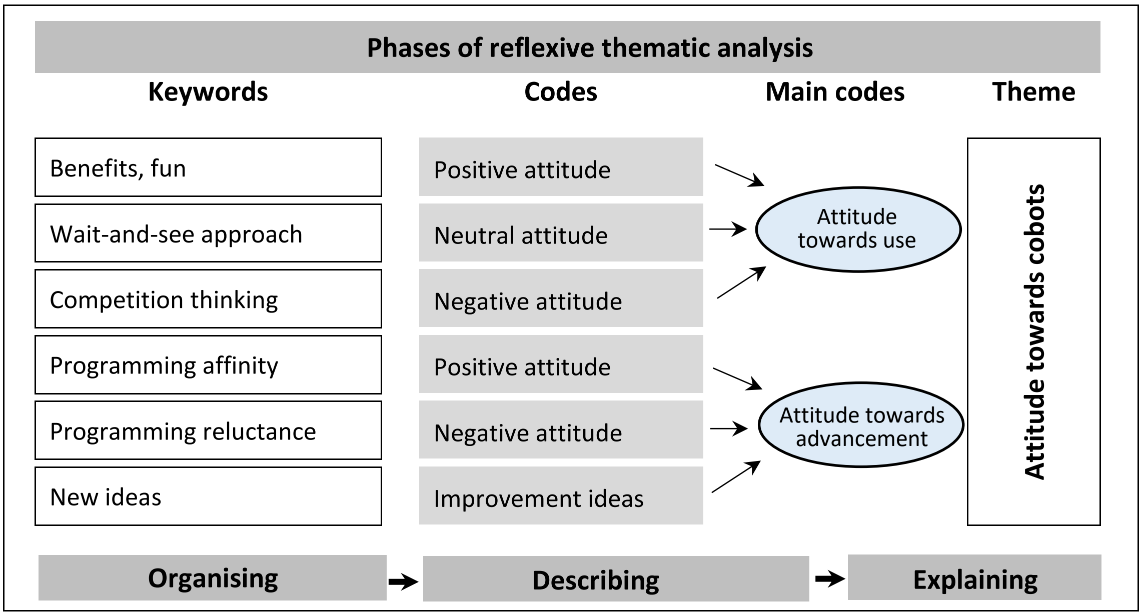


Figure 4-10: Reflexive thematic analysis process–attitude towards cobots

A total of 211 critical statements were identified regarding this theme, as shown in Table 4-3. These statements were elicited through observations and key questions in the semi-structured interviews, including: *"What is your perception of the cobots?"* and *"How valuable do you think the cobots are to the department?"* The analysis of the qualitative data collected resulted in a set of main codes outlined in the following section.

Attitude towards use

This main code covers critical statements from participants on individual attitudes and opinions towards the practical application and everyday use of collaborative robots. These attitudes span a spectrum from positive to neutral and negative, reflecting the diversity of employee perspectives. The variability in these perceptions is illustrated through selected interview excerpts. In this context, key words such as benefits, fun, wait-and-see approach, and competition thinking serve as the conceptual anchors for these codes.

Positive attitude:

> *M10 (employee): We should work together, and I think [...] we will have a lot of fun with the cobots.*

M11 (employee): If you look at costs and benefits, I would always say it is beneficial. Because if we discover even one small thing that no person has to deal with anymore, but the robot can handle, then we have already gained something.

Neutral attitude:

F22 (employee): Let us wait until the thing is here, and then we will see. And then we have to wait and see how it develops.

F12 (employee): I need to see it for myself or work with it myself in order to really be able to judge it.

Negative attitude:

F13 (employee): Yes, in the end, I have to say it is a strange feeling to work with the machines.

M15 (manager): And there are also employees, but in my view, there are only a few who still say: I am even faster than the cobot. I can do it more reliably and faster.

The critical statements above reflect a broad spectrum of attitudes towards collaborative robots. Importantly, these attitudes are a foundation for successfully integrating collaborative robots into pre-defined work processes. Understanding and addressing these varying perspectives is essential for effectively integrating collaborative robots.

Attitude towards advancement

In contrast to the previous main code, this main code encompasses participants' critical statements concerning their attitudes and expectations regarding developing and adapting collaborative robots in practical applications. The focus here is on ongoing technological development within the work process, setting it apart from the broader organisational openness to technological change in general. The associated codes illustrate the coexistence of both positive and negative sentiments. For instance, Participants M1 and M19 express favourable views, whereas M2 and M24 articulate negative perspectives. Furthermore, another identified code captures constructive recommendations for potential improvements to the collaborative robots or the manufacturing process involving their use, as exemplified by statements from F14 and M5.

Positive attitude:

M1 (employee): It is easy to work with these cobots, to create a new program and see if it works. It is always the same: if it works, then it is fun.

M19 (manager): And it was precisely the people with an affinity for technology who wanted to use it straight away, and there were a few who then familiarised themselves with the programming.

Negative attitude:

M2 (employee): Theoretically, it is possible to learn how to program the cobots. But everything in me resists even thinking about it.

M24 (manager): New products are usually somewhat more complex in structure, and sometimes I do not see the potential for them to be processed by the cobot.

Improvement ideas:

F14 (manager): Yes, it would be cool if it (the cobot) could insert two components, one after the other, for example.

M5 (employee): That it could possibly make slightly faster movements.

With respect to the improvement process, the critical statements suggest that not all employees prioritise the various aspects of improvement equally in the early stages of implementation. However, continuously advancing collaborative robots and adapting their applications to operational settings may be beneficial in order to unlock their full potential in efficiency, flexibility, and quality.

Collectively, the theme of *"attitude towards cobots"* offers a nuanced and in-depth overview of individuals' perceptions, encompassing both the practical utilisation and prospective development of this technology. While some employees express enthusiasm and recognise substantial benefits and future potential, others adopt a more cautious or sceptical perspective. Given that the number of critical statements regarding the main codes' *"attitude towards use"* and *"attitude towards advancement"* is comparable, it can be argued that both dimensions hold equal significance in understanding employees' overall perception toward collaborative robots.

In light of the identified themes categorised as input factors, it is recommended that these themes be considered when assessing employees' perceptions of collaborative robots. This assertion is supported by the diverse attitudes toward collaborative robots observed among employees throughout the study, with findings indicating that the identified input factors have a direct influence on these attitudes. Thus, these input factors can offer strategic leverage points that organisations can utilise to support positive employee attitudes and foster the effective adoption of collaborative robots, which might have the potential to influence system performance.

4.4.1.9 Summary of input factors

This subsection summarises the critical input factors identified through reflexive thematic analysis as the following themes: *"personal factors"*, *"subjective usefulness"*, *"subjective user-friendliness"*, *"emotional factors"*, *"cobot characteristics"*, *"contextual factors",* and *"workplace dynamics"*. This study posits that these input factors collectively contribute to shaping the overarching construct of *"attitude towards cobots"*, reflecting the cognitive and affective stance individuals or groups adopt towards collaborative robots. This construct comprises the underlying beliefs and emotional responses influencing the acceptance and integration of collaborative robots within organisational settings.

Overall, the significance of the identified input factors lies in their role as fundamental determinants for the successful implementation of collaborative robots in manufacturing settings. A thorough understanding and systematic consideration of these factors enables organisations to design targeted interventions and support mechanisms that facilitate employee acceptance and promote the effective utilisation of collaborative robots.

Nonetheless, the identified input factors reflect employees' pre-existing perceptions rather than their experiential insights gained through interacting with collaborative robots. Therefore, incorporating the experiential dimensions into the analysis is imperative. To this end, the following subsection introduces the process factors, specifically capturing the lived experiences of using collaborative robots in practice.

4.4.2 Process factors

In addition to the aforementioned input factors, the current study identified two overarching themes categorised as process factors. The process-related themes were constructed from the analysis of 11 codes derived from over 400 critical statements from participants, as shown in Table 4-3.

Specifically, these themes were *"interaction with cobots"* and *"impact on workplace dynamics"*. The first theme concerns employees' direct experiences with collaborative robots. These experiences include utilising collaborative robots within existing work processes, advancing such processes, or configuring new processes facilitated by integrating such robots. A key determinant shaping these experiences was the frequency of interaction. The second theme explores the broader implications of collaborative robot interaction on workplace dynamics. This includes shifts in organisational processes, social interaction and communication, and changes in employees' perceptions of their work. Both themes were informed by four to seven underlying codes each. The following subsections provide an in-depth examination of each theme, outlining the key aspects and insights derived from the reflexive thematic analysis.

4.4.2.1 Interaction with cobots

The theme *"interaction with cobots"* captures participants' first-hand experiences with the practical application and routine use of collaborative robots, particularly focusing on the frequency of interactions. This theme encompasses positive and negative experiences and reflects a range of engagement types when utilising collaborative robots. The visual presentation of this theme, as elucidated by the reflexive thematic analysis process outlined in Subsection 3.4.4.4, is shown in the following figure.

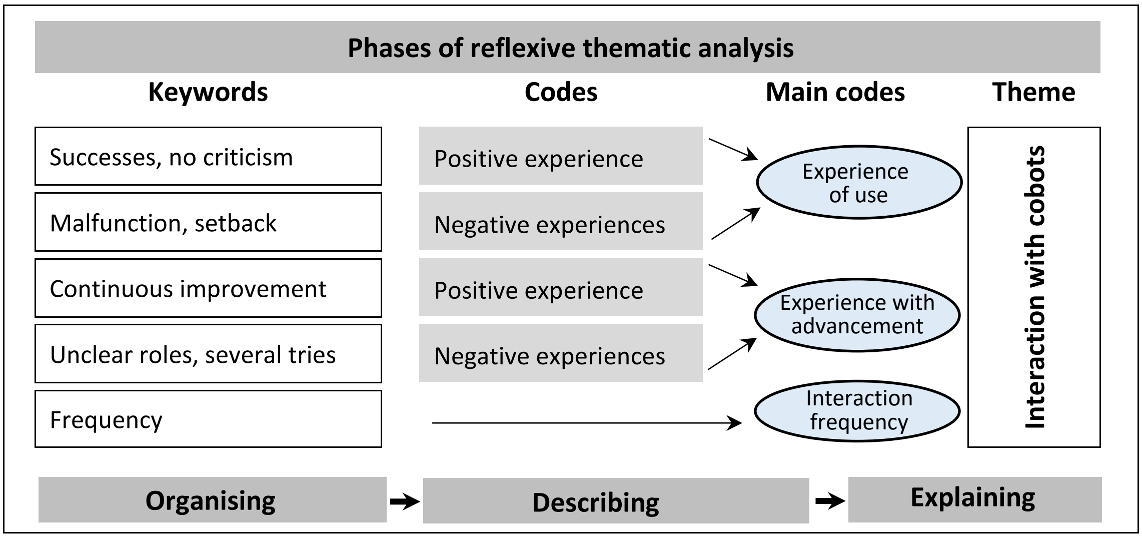


Figure 4-11: Reflexive thematic analysis process–interaction with cobots

This theme and associated codes are grounded in 277 critical statements, as depicted in Table 4-3. Except for one code, the initial identification of critical statements was primarily informed by data collected through participant observation. These codes were subsequently refined based on the interview data, which included responses to experience- and behaviour-oriented questions such as: *"What do you see as positive or negative about working with cobots?"*, *"Have there been any improvements in the collaboration/working process with the cobots, or do you have any additional ideas for improve-*

ments?", and *"How has the use of cobots changed over time?"* The analysis of this qualitative data led to the development of the main codes outlined below.

Experience of use

This main code includes participants' critical statements about their experiences with the practical application and utilisation of collaborative robots. The experiences are classified into two codes based on recurring keywords, distinguishing between positive and negative experiences. For example, Participants M18 and M1 reported favourable experiences, highlighting the collaborative robot's effective support in facilitating manufacturing processes. Conversely, several participants described negative experiences primarily associated with malfunctions and operational disruptions. These experiences are further elaborated below, drawing on illustrative excerpts from participants.

Positive experience:

> *M18 (manager): Yes, it has become more positive, thanks to successes and results.*
>
> *M1 (employee): Well, the last few orders really went through smoothly from start to finish. So, there are simply no points of criticism: it works.*

Negative experiences:

> *F6 (employee): As I said, at the moment we have been set back significantly by the offset.*
>
> *M10 (employee): If it does not work or only works halfway, at half power, then it takes away more work time than it is worth.*

In light of the aforementioned critical statements, positive user experiences are strongly related to the reliable and uninterrupted operations of collaborative robots, free from malfunctions.

Experience with advancement

This main code captures critical statements from participants concerning their experiences with developing and adapting collaborative robots in practical applications. The experiences encompass both positive developments and negative setbacks and are organised into two distinct codes based on the selected keywords. Positive experiences are exemplified by statements from Participants M17 and M25, who emphasised that collaborative robots have significantly improved since their initial implementation. In contrast, negative experiences were also reported, as illustrated by excerpts from Participants F4 and M1.

Positive experience:

M17 (employee): So yes, it is a continuous process that never stops, I would say. We then simply rewrote a programme, for example, used less speed, and then checked whether it was better or worse. So yes, there are continuous improvements going on.

M25 (employee): But especially since the upgrade, when it became capable of handling five at once, there has been a remarkable improvement.

Negative experience:

F4 (employee): Did anyone really feel responsible for it at the beginning? I do not think anyone said at first: You have to take care of it now.

M1 (employee): Sure, of course there were things that did not work right from the start. With the grippers, for example, we went through several rounds, tried different approaches, and had to print new parts.

As indicated by the critical statements associated with this main code, positive experiences are closely linked to continuous improvement processes related to the utilisation of collaborative robots. Conversely, negative experiences were primarily attributed to ambiguous role responsibilities and extended development timelines. These experiences reflect the advancement and adaptation of collaborative robots as technological systems, distinct from broader organisational attitudes or readiness for change.

Interaction frequency

The following main code includes critical statements from participants regarding the frequency of their interactions with collaborative robots. The frequency of utilisation appears to influence employees' degree of familiarity and proficiency with the technology, as evidenced by excerpts from Participant F12. Furthermore, several statements addressed an acceptable frequency of interaction for employees, as illustrated by the excerpt from participant M17.

F12 (employee): I just think that someone who has worked entirely or extensively with the cobot naturally has a completely different level of knowledge and a completely different attitude towards it.

M17 (employee): I would not have a problem if I did that more often or mainly that.

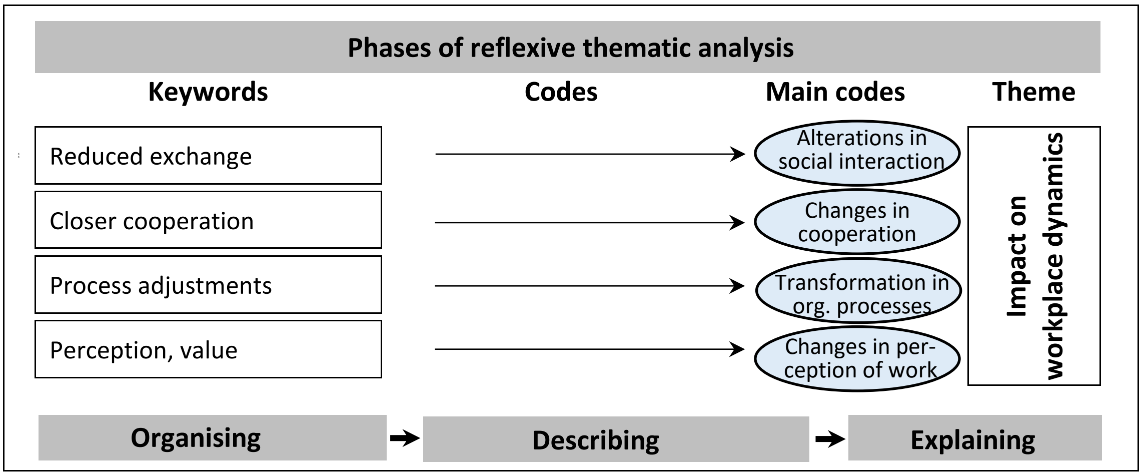
Participants repeatedly emphasised that frequent interaction is vital to enhancing proficiency when working with collaborative robots.

In conclusion, the theme of *"interaction with cobots"* emphasises the significance of understanding both the positive and negative experiences of employees in utilising and advancing collaborative robot technology. While some employees reported productive engagements fostering a more optimistic perspective, others encountered challenges and setbacks hindering effective integration. Notably, a comparative analysis of critical statements relative to positive and negative experiences highlights the added value and progress achieved in human-robot collaboration.

Moreover, the frequency of interaction was found to substantially influence employees' attitudes and knowledge levels regarding collaborative robots. Employees who engaged more regularly with the collaborative robots tend to report more positive experiences and greater familiarity. However, it is crucial to acknowledge that not all employees are willing to interact with collaborative robots daily. As such, individual preferences must be considered to foster positive user experiences.

4.4.2.2 Impact on workplace dynamics

The theme, *"impact on workplace dynamics"*, captures the multifaceted transformations associated with integrating collaborative robots into the workplace. This theme underscores how collaborative robots reshape the workplace by influencing interpersonal dynamics, modifying work processes, and contributing to changes in the broader organisational culture, thus altering the social structure and team relationships. As Figure 4-12 illustrates, these dynamics emerged from the reflexive thematic analysis process outlined in Subsection 3.4.4.4.



Notes: org. = organisational

Figure 4-12: Reflexive thematic analysis process–impact on workplace dynamics

This theme is grounded in 128 critical statements, almost exclusively derived from data collected through semi-structured interviews, as shown in Table 4-3. Central to the development of this theme were key questions, including: *"How has collaboration within the group changed because of the implementation of the cobots?"*, *"Has the implementation of the cobot changed employees' perceptions of the value of their work? If so, how or why?"*, and *"How has working with cobots changed the working atmosphere?"* These questions formed the foundation upon which the subsequent main codes were developed.

Alterations in social interaction

This main code includes critical statements from participants regarding changes in social interaction due to direct engagement with collaborative robots within work processes. In this context, social refers to the interpersonal contact, collegial feedback, and conversational aspects that shape relationships and team atmosphere. Changes in this context reflect how collaborative robots influence social aspects of work, as stated by Participants F22 and M10.

> *F22 (employee): Yes, of course, there is no feedback if something is not working. Or you do not have that collegial interaction that is completely gone.*
>
> *M10 (employee): Well, if I were in a room with the cobot, it would get boring at some point. So, I would prefer to sit with someone, because then you can talk to each other.*

As indicated above, participants reported reduced social interaction when working with collaborative robots, a development that may affect the overall workplace atmosphere.

Changes in communication and cooperation

This main code includes critical statements from participants regarding the impact of collaborative robot implementation on intra-team communication and cooperation. These insights demonstrate how the integration of collaborative robots can influence team dynamics. Notably, the statements from Participants F26 and M10 indicated that adopting collaborative robots strengthened closer cooperation between teams within a working group.

> *F26 (manager): In terms of how it feels, I would say that there used to be the group of production technicians and the group of production workers, which were two small, distinct groups. I do not think that has completely gone, but it has definitely softened.*

M10 (employee): Well, you work a bit more closely with the production workers because there needs to be an alignment.

Participants' critical statements indicate that closer cooperation between the teams is facilitated by a shared objective, specifically, the implementation and use of collaborative robots.

Transformation in organisational processes

This main code includes critical statements from participants concerning the transformation of organisational processes due to implementing collaborative robots. These statements demonstrate the necessity for modifying established workflows and procedures, as Participants F6 and F15 asserted. In light of this data, the keyword process adjustments were identified.

F6 (employee): But I also see it as a process we have to get used to—for example, that one or two people cannot go to the production belt because there is now a cobot working (that needs to be supervised). You simply have to establish a procedure so that everyone can deal with it. There are simple rules, and that is all.

F15 (manager): And if I am not doing the work at my own workstation, but at another general workstation at the cobot, I simply have to change the processes.

The critical statements highlighted the necessity of adapting organisational processes to accommodate the new manufacturing configuration introduced by integrating collaborative robots. Such targeted adjustments are likely to play an important role in ensuring that workflows remain efficient and employees can effectively use the new technology.

Changes in perception of work

This main code encompasses critical statements from participants regarding alterations in their perception of work and their value after implementing collaborative robots. This is exemplified by interview excerpts from Participants M19 and M1, who emphasised the importance of using collaborative robots for meaningful tasks and more satisfying work processes.

M19 (manager): Because we did not say that you are doing a job that a machine could just do without a second thought. Instead, we argued that it is really a shame for someone like you to sit at a table for eight hours just putting vials in. A machine can do that, too. You can do something more valuable in this time.

M1 (employee): But, as I said, I really enjoy working with them. It is just incredibly satisfying for me, and yes, it is fun.

Overall, the interviews revealed a positive shift in employees' perceptions of their roles, based on their experiences working with collaborative robots. Employees reported that their redefined tasks were perceived as more valuable and intrinsically satisfying.
In conclusion, the theme of *"impact on workplace dynamics"* elucidates the multifaceted effects of collaborative robot technology within workplace settings. Although integrating collaborative robots can lead to enhanced efficiency and the implementation of new work processes, it simultaneously has the potential to alter social interactions, communication patterns and employees' perceptions of their work.

Evidence suggests that the integration of collaborative robots has reduced social interaction and, consequently, cooperation among colleagues—an outcome regretted by most employees who mentioned this aspect. In contrast, the case study revealed that collaboration between teams within a work group was strengthened through a shared goal associated with implementing collaborative robots. In addition, employees who engaged directly with collaborative robots reported a positive shift in their perception of work. However, it is vital to acknowledge that improvements in system performance are contingent upon the adaptation of organisational processes to meet the evolving demands posed by collaborative robot integration.

4.4.2.3 Summary of process factors

The themes identified as process factors encompass dynamic elements integral to human-robot collaboration, characterised explicitly as *"interaction with cobots"* and *"impact on workplace dynamics"*. These process factors exert a direct influence on collaborative robot acceptance, manufacturing productivity and overall efficiency. Improved acceptance and work outcomes can be achieved by creating an environment that fosters positive experiences in human-robot collaboration and proactively managing shifts in workplace dynamics. The changes observed in this study are multifaceted, stemming from alterations at both the individual and group interaction levels and broader organisational process adaptations. Collectively or independently, these transformations can reshape employees' perceptions of their work. Consequently, continuous improvements in these process factors hold potential to increase acceptance, productivity and efficiency in the long term.

Overall, the identified process factors serve as a bridge between input and output factors. Thoughtful consideration of these input and process factors facilitates the effective development of human-robot interactions, which drive favourable outcomes. Accordingly, the output factors elucidated in the current study are discussed in the following subsection.

4.4.3 Output factors

The analysis defined two overarching themes conceptualised as output factors. Within this context, eight main codes were derived from nearly 300 critical statements made by participants. These statements were subjected to a systematic derivation process, culminating in the two themes shown in Table 4-3. The developed themes are *"acceptance of collaborative robots"* and *"system performance"*. Each theme is underpinned by a distinct set of four main codes.

Acceptance of collaborative robots predominantly relates to individual-level factors, whereas system performance is primarily related to organisational-level processes. Notably, system performance aligns closely with the study's objective to explore and identify the critical factors influencing system performance when integrating collaborative robots in the healthcare manufacturing sector.

The study findings reveal a strong interrelationship between *"acceptance of collaborative robots"* and *"system performance"* themes. The latter theme extends beyond the conventional production efficiency measures, such as time savings and reductions in human effort, to accommodate broader considerations, such as product quality and the long-term orientation of work practices. Consequently, this conceptualisation of system performance extends beyond the conventional manufacturing productivity framework, which typically focuses on output and resource utilisation. While Coronado et al. (2022) provide valuable insights, their perspective differs from the framework applied here.

The following subsection provides a visualisation and detailed discussion of each theme, following the analysis approach previously undertaken for the input and process factors.

4.4.3.1 Acceptance of cobots

The theme *"acceptance of cobots"* is grounded in the premise that accepting collaborative robots is contingent upon individuals' attitudes and prior experiences with the technology. Acceptance and resistance are conceptualised in active and passive forms, offering a nuanced understanding of the individual perspectives and behaviours observed in this context. Figure 4-13 illustrates this theme following the analysis process described in Subsection 3.4.4.4.

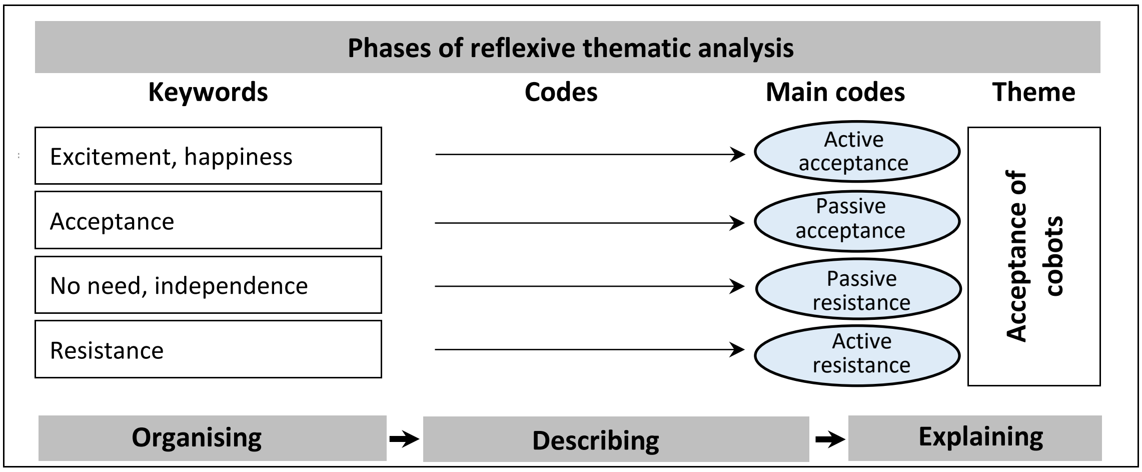


Figure 4-13: Reflexive thematic analysis process–acceptance of cobots

This theme is derived from 97 critical statements, most of which originate from data collected through semi-structured interviews, as shown in Table 4-3. The key questions guiding participants' reflections on this theme included: *"If you have the choice of running a production with or without cobots, how would you decide and why?"* and *"Should the cobots be removed from the production process? (and why/why not)"* The responses to these questions informed the conceptualisation of the main codes underpinning this theme.

Active acceptance

The main code comprises critical statements from participants demonstrating a clear and active acceptance of collaborative robots. In this context, the keywords excitement and happiness emerged as salient indicators of participants' positive mindset when engaging with the technology. Illustrative evidence of this main code is presented in the following interview excerpts.

> *M9 (employee): I am happy every time I go to the cobot and think, yes, I can set up something new again or fix an error.*

F4 (employee): So, nothing has changed. I am still genuinely excited—about what it does, what it can do, and especially about what it might be able to do in the future.

Participants who demonstrated active acceptance of collaborative robots frequently expressed a strong commitment and enthusiasm toward the technology.

Passive acceptance

The main code includes critical statements from participants who passively support integrating collaborative robots. While generally receptive, these individuals do not exhibit strong enthusiasm or a high level of commitment, as illustrated by the following statements from participants.

M19 (manager): I believe that the more you deal with it or the more you have to do with it yourself, the more you accept it.

M18 (manager): Then acceptance is simply higher if I do not have to go there every time only to find that the thing is whistling and not working.

The data suggest that passive acceptance of collaborative robots reflects a relatively positive, albeit restrained, attitude toward the technology.

Passive resistance

The main code of *"passive resistance"* comprises critical statements from participants who adopt a passive stance towards using collaborative robots, often expressing a preference for alternative methods. These individuals, such as Participants F12 and F13, do not display overly negative or hostile attitudes towards collaborative robots. Instead, they prefer to avoid their use when possible.

F12 (employee): So, for me personally, for my work, for my everyday work, I honestly do not need it right now.

F13 (employee): And that is why, at the moment, I would prefer to do it manually, simply because I feel better or safer doing it that way.

Participants within this group frequently cited a lack of personal interest as a primary reason for preferring manual manufacturing processes over collaborative robots.

Active resistance

This main code includes critical statements from participants who actively resist using collaborative robots, express strong negative sentiments, and reject the technology. Such attitudes are exemplified in the statements provided by Participant M11 and are similarly reflected in the remarks of Participant F14.

M11 (employee): Well, it just had the effect that there was total rejection. Really, absolutely total.

F7 (employee): I do not need to stand next to it (cobot) because of the noise. The noise level is just too much for me.

In the present study, instances of active resistance were relatively limited. However, when such resistance occurred, it was characterised by strong objections and, at times, a complete rejection of the technology.

In conclusion, the *"acceptance of cobots"* theme demonstrates employee attitudes towards collaborative robots, ranging from active acceptance to varying degrees of resistance. While some employees demonstrate enthusiasm and proactive support for integrating collaborative robots—often associated with higher levels of direct interaction—others exhibit passive or active resistance, which is generally associated with lower or moderate interaction frequencies and adverse experiences. Notably, in an extreme instance, the rejection of an entire manufacturing process involving a collaborative robot was observed, influenced by the interplay between the robot's specific attributes and individual employee factors.

By elucidating these divergent acceptance levels, organisations can tailor their strategies to foster greater acceptance, for instance, by optimising user experiences and promoting transparent communication about the benefits and challenges of the technology.

4.4.3.2 System performance

The theme of *"system performance"* encompasses the impact of the implementation of collaborative robots on the overall productivity of the organisational system. It incorporates multiple dimensions, including human effort, production time, product quality, and future work orientation, all collectively influencing overall productivity and efficiency. This theme is visually represented in Figure 4-14, developed through the reflexive thematic analysis process detailed in Subsection 3.4.4.4.

The theme is grounded in data from document analysis—especially the comparison of bills of materials from production with and without collaborative robots—and 169 critical statements provided by study participants, as depicted in Table 4-3. These statements were elicited through key questions such as: *"How has the productivity of the relevant production lines changed as a result of the cobots?"* and *"To what extent did* *the product quality change as a result of cobots?"* The reflexive thematic analysis of these data resulted in the following main codes.

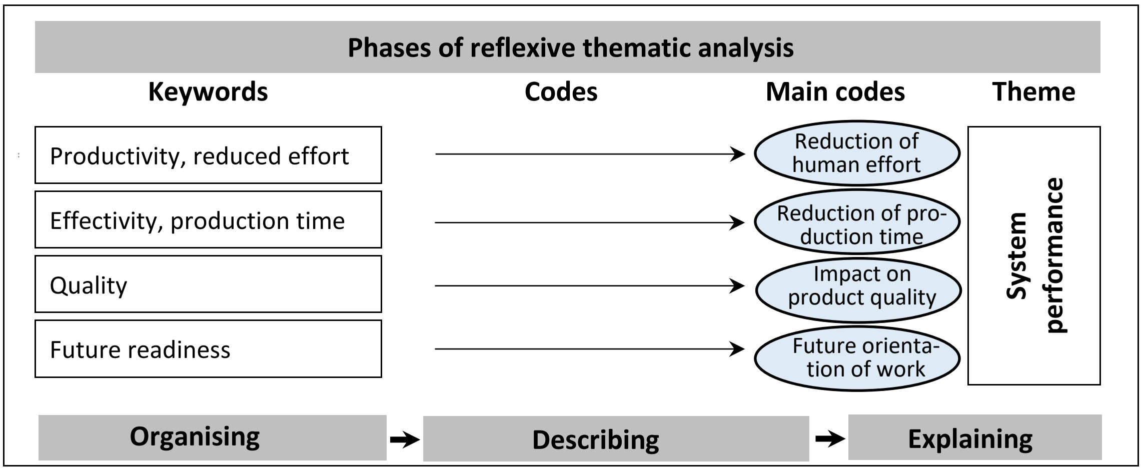


Figure 4-14: Reflexive thematic analysis process–system performance

Reduction of human effort

This main code includes critical statements from participants indicating reduced human effort required in manufacturing processes attributable to utilising collaborative robots, a finding also apparent in the data analysis of the bills of materials. Illustrative excerpts from interviews with Participants M11 and M23 are provided below.

> *M11 (employee): So you save yourself one person who would otherwise spend the whole day on the insertion process. Of course, that person can then work on something else and therefore also contributes to output. So, from that perspective, productivity has definitely increased.*
>
> *M23 (employee): The employee is only there to fix errors and either bring pallets over, take the full ones away, and put the empty ones back in. That just means less work and fewer employees are needed.*

The critical statements mentioned above demonstrate the potential of collaborative robots to undertake repetitive and labour-intensive tasks, thereby reducing the amount of human effort required for certain production processes. This reduction in human involvement may allow organisations to reallocate workforce resources in accordance with operational needs.

Reduction of production time

The following main code comprises critical statements from participants concerning reducing production time facilitated by utilising collaborative robots. Notably, reflections from Participants F6 and M1 emphasise the potential of collaborative robots to improve the efficiency of manufacturing processes, a finding further substantiated by document analysis.

F6 (employee): Then I only need half the time for the order.

M1 (employee): Well, the cobots became more efficient because they simply got faster. As I said before, first we went from just one pick to handling four Sarstedt vials at the same time, and then, with the second cobot, we were able to increase throughput simply by increasing the number of pieces.

Within the context of the study, participants asserted that collaborative robots possess the capacity to facilitate enhanced throughput and faster order fulfilment.

Impact on product quality

This main code explores the impact of collaborative robots on product quality within manufacturing settings. It includes critical statements highlighting the capacity of collaborative robots to enhance consistency and reliability in manufacturing processes, as exemplified by Participant M1. Concurrently, this main code also reflects the limitations of collaborative robots in replicating the meticulous attention to detail inherent in human labour, as illustrated by Participant M19.

M1 (employee): And the cobot does not have any concentration problems either, because it just puts its stuff in. It always fills up this module, and it does not forget a Sarstedt vial. It simply cannot do that. That is a big advantage.

M19 (manager): But the cobot cannot see what it is doing. Just to give one example: our employees are used to paying a lot of attention to the appearance of the product.

Product quality enhancement emerged as a recurring topic among participants, with many attributing reductions in error rates to the utilisation of collaborative robots. However, most participants who discussed this aspect also observed that product aesthetics may be superior when certain tasks are executed manually, reflecting nuanced perceptions of quality.

Future orientation of work

Finally, this main code incorporates critical statements from participants concerning the impact of collaborative robots on the future orientation of work, anchored conceptually by the keyword future readiness. The following excerpts from Participants F13 and M25 illustrate perspectives related to this topic.

F13 (employee): Because I believe that it is extremely important for the future to simply be open. Regardless of the cobots, something always changes.

M25 (employee): For me, that has always been a step into the future, and basically, I think it is a good thing.

Participants perceived the utilisation of collaborative robots as indicative of a transition towards a future-oriented approach to work, characterised by organisational openness to adopting new technologies and a commitment to keeping work practices current and innovative. This reflects an organisational mindset defined by openness toward change. In conclusion, the *"system performance"* theme demonstrates the substantial positive impact of collaborative robots on an organisation's overall performance. Central to this enhancement is the minimisation of human effort, highlighted by 21 out of the 27 participants, underscoring its critical role in driving system performance improvements. Additionally, 18 participants each emphasised the importance of reducing production time and maintaining product quality, indicating that considerations extend beyond mere output volume to encompass process efficiency and final product quality. It is reasonable to infer that product quality benefits from error reduction associated with the automation of manual tasks. Finally, the future orientation of work was identified as a salient factor influencing system performance, reflecting participants' view that an organisation's attitude toward embracing new technologies and keeping work practices up to date signals its readiness for change and innovation. This future-readiness is considered increasingly important in today's dynamic manufacturing landscape.

4.4.3.3 Summary of output factors

The defined output factors, namely *"acceptance of cobots"* and *"system performance"*, focus on the measurable outcomes of implementing collaborative robots within the manufacturing process. A key finding of this study is the significant role that individual acceptance of collaborative robots plays in fostering a productive organisational system. Moreover, the analysis underscores the importance of the previously identified input and process factors in facilitating overall productivity enhancements. Evaluating these outcomes illustrates that implementing collaborative robots has improved workflow efficiency and product quality. In particular, reducing human errors and automating repetitive tasks emerged as critical contributors to increased organisational productivity.

System performance, as an output factor pertaining to the organisational context, highlights the tangible benefits of collaborative robots within real-world manufacturing settings. Thus, organisations must engage in meticulous planning and implementation that systematically integrates input and process factors to fully realise these advantages.

The insights presented in this subsection regarding the critical factors influencing system performance in the healthcare manufacturing sector provide a solid empirical foundation for developing a multifaceted conceptual framework.

4.5 Development of the conceptual framework

The analysis process undertaken thus far has focused on organising, describing, and explaining the qualitative data, following the three steps described by Spencer et al. (2014). The ensuing discussion advances to the interpretative phase and the formulation of abstract concepts, ultimately leading to the development of a conceptual framework, as Naeem et al. (2023) advocated.

The generated themes were initially categorised as input, process, and output factors, representing a preliminary structuring to guide conceptual framework development. This categorisation was subsequently refined to reflect the influence exerted by each theme, distinguishing between individual-level and organisational-level factors influencing acceptance. Furthermore, these acceptance-related factors were explicitly associated with system performance. The researcher posits that a holistic analysis of attitudes and experiences regarding collaborative robots necessitates a nuanced understanding of the interaction between individual-level and organisational-level factors. Such an understanding is essential for examining how acceptance of collaborative robots shapes system performance within healthcare manufacturing.

Individual-level factors influence employees' acceptance and effective utilisation of collaborative robots, shaping their engagement with the technology. Conversely, organisational-level factors encompass broader social dynamics and contextual characteristics that govern collective interactions with collaborative robots. These factors are vital in shaping organisational culture and influencing workforce-wide acceptance. The delineation between individual and organisational levels of analysis thus offers an essential structural dimension for developing the conceptual framework.

The resulting conceptual framework is presented in Figure 4-15. As previously outlined, the identified themes are differentiated along two key dimensions: first, in terms of their classification as input, process, or output factors, and second, concerning their relevance at the individual or organisational level.

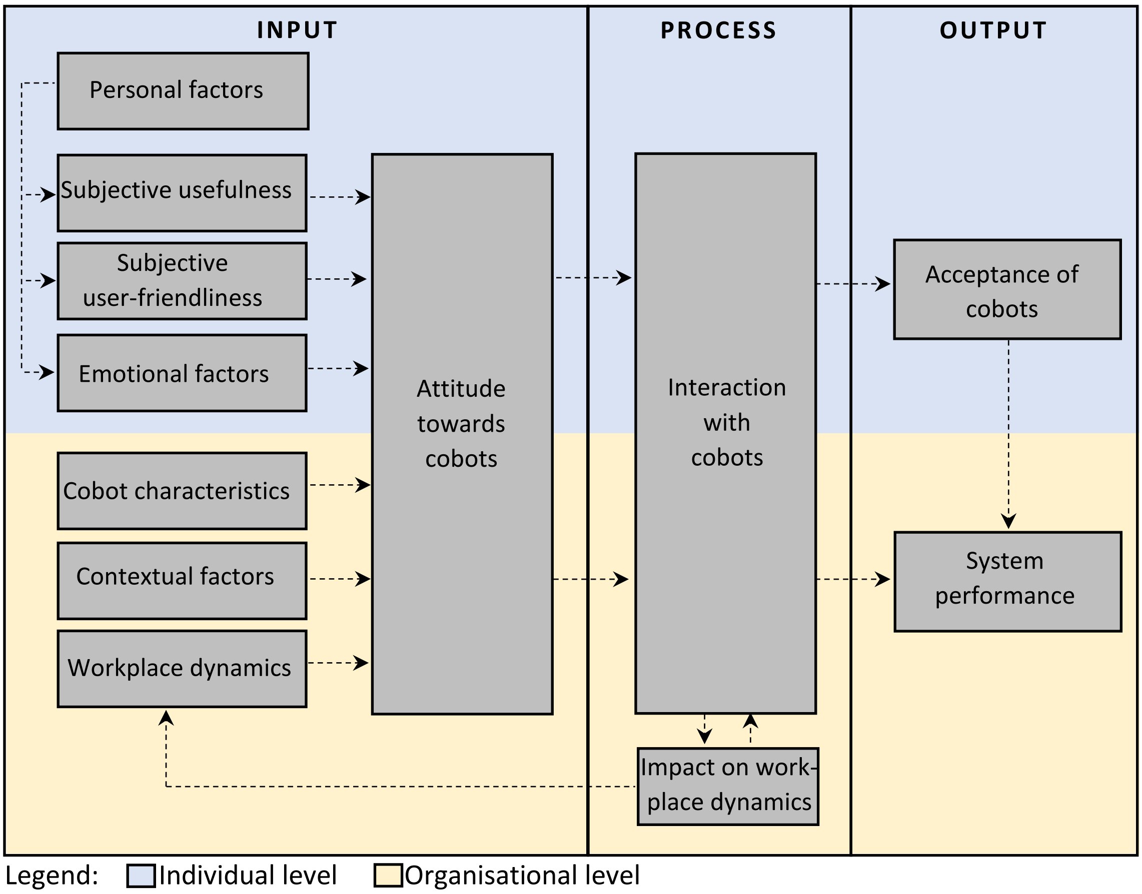


Figure 4-15: Conceptual framework of cobot acceptance and system performance

The following subsection presents the development of the conceptual framework by contextualising the developed themes in relation to one another, with particular emphasis on their interrelationships. It addresses each process dimension within the framework, commencing with the input dimension.

4.5.1 Input dimension

Input factors at the individual level

At the individual level of the input dimension, four themes were identified, as they each reflect personal characteristics, perceptions, and preferences that directly influence individual perceptions and responses. The first theme, *"personal factors"*, encompasses employees' personal attributes, expertise about collaborative robots, and inherent predispositions towards engaging with this technology. This theme appears to exert a formative influence on three other individual-level themes: *"subjective usefulness"*, *"subjective user-friendliness"* and *"emotional factors"*. It can be argued that personal factors function as a fundamental layer shaping an individual's cognitive evaluations and affective responses. Thus, these personal factors act as background conditions that influence how individuals perceive the usefulness, usability, and emotional acceptability of collaborative robot integration.

To illustrate this relationship, the role of previous experience with robots serves as a pertinent example. This experiential value was particularly relevant for employees who engaged directly with the collaborative robots. A distinction was drawn between employees with prior experience with industrial robots and those without, to assess whether this personal factor influences other individual-level input factors.

Of the participants, nine employees reported no previous experience with robots, while eight had previous experience with robots. Despite this nearly equal distribution, a striking disparity emerged in their perceptions: over 80% of the 95 critical statements related to the main code *"cobots perceived as threat"* were made by employees without previous experience with robots. This pattern suggests that a lack of direct experience with robots substantially shapes negative perceptions of collaborative robots.

In contrast, the 72 critical statements assigned to the code *"cobots perceived as opportunity"* were more evenly distributed between the two groups, with approximately 45% originating from employees without experience with robots and 55% from those with previous experience. This relatively balanced distribution suggests that both groups may share a comparable level of curiosity and hold similarly positive expectations regarding collaborative robots. Nevertheless, prior experience with robots might mitigate anxiety regarding integrating collaborative robots, diminishing the tendency to perceive them as a threat.

Another example of how personal factors influence individual-level input factors can be observed through the demographic variable job position. This factor categorises the employees interacting directly with collaborative robots into two groups: production technicians (n=6) and production workers (n=11). Regarding the code *"physical relief"*, it is noteworthy that over 80% of the 57 critical statements identified were made by production workers. These workers reported experiencing greater physical relief in their routine work activities due to utilising collaborative robots. However, when accounting for differences in group size, a more balanced distribution of critical statements emerged for codes *"relevance of the cobot*" and *"goal achievement"*. This suggests that, despite role-based differences in task execution, these themes are equally salient across both occupational groups.

To further elucidate the interrelationship between the theme of *"personal factors"* and other individual-level input factors, *"subjective user-friendliness"* can be examined through the lens of *"learner friendliness"*. Analysis of relevant critical statements revealed that both production technicians (33 statements) and production workers (57 statements) addressed this topic. Adjusted for group size, learner friendliness emerges as a salient concern across both occupational categories, with production technicians mentioning it more frequently. In contrast, managers (n=10) referenced this aspect considerably less often (15 statements).

At the theme level, a notable divergence emerged between production workers and technicians regarding the frequency and focus of critical statements on subjective user-friendliness. Specifically, production workers placed greater importance on *"ease of use"*, whereas production technicians more frequently highlighted *"ease of advancement"*. These findings suggest a divergence in priorities between the two groups, with production workers emphasising operational usability and production technicians placing greater emphasis on the advancement and adaptation of the technology.

In addition to these findings, *"personal development"*, understood as opportunities for individual growth, also revealed notable differences, as managers referenced this theme considerably more often (26 statements) than production technicians (10 statements) or production workers (8 statements). These disparities highlight role-specific differences in the emphasis placed on development opportunities.

The frequencies of the previously mentioned critical statements are presented in the matrix coding queries in Appendix F.1 and Appendix F.2, further illustrating these findings. It is imperative to emphasise that these numerical values are not intended to be interpreted quantitatively. Instead, their purpose is to describe the patterns and relational trends evident within the data.

Moreover, additional demographic factors categorised under the broader theme of *"personal factors"* were identified as influencing the three remaining input factors at the individual level. Specifically, age and gender emerged as salient variables in this context. The influence of these demographic factors is presented in Appendix F.3 and Appendix F.4, which present matrix coding queries stratified by participants' age and gender.

Finally, within the theme of *"personal factors"*, another aspect represents working preferences, such as the tendency to prefer working in a team or individually. These preferences are considered a background condition, as indicated by critical statements from participants regarding their preferred working style. However, this relationship could not be systematically analysed through a matrix coding query, since not all employees explicitly stated their preferences during the interviews. This is because the potential influence of working preferences in shaping participants' experiences only became apparent at a later stage during data analysis, by which point not all participants were available for further inquiry. Nevertheless, the available evidence suggests that working preferences may play a noteworthy role in shaping individual attitudes towards collaborative robots.

In conclusion, the examples discussed above illustrate the impact of personal factors on the remaining three individual input factors. This relationship is visually represented by the corresponding arrows in the conceptual framework, signifying the interconnectedness of these variables.

Input factors at the organisational level

At the organisational level of the input dimension, three overarching themes were identified through the analysis. These themes were assigned to the organisational level because they reflect factors that originate from, or are shaped by, the broader organisational environment rather than by individual characteristics.

The first theme, *"cobot characteristics"*, pertains to the intrinsic attributes and functional capabilities of collaborative robots, including their technical specifications and the rationale underlying their implementation. The second theme, *"contextual factors"*, captures the broader environmental and situational context in which collaborative robots are deployed. This includes external aspects such as workload intensity, employee utilisation, and operational constraints, together with internal elements such as organisational conditions and management support. The third theme, *"workplace dynamics"*, addresses the interpersonal and social dimensions within the work environment that influence the perception and integration of collaborative robots. This theme includes team dynamics, communication patterns, and the overall social atmosphere.

Resulting input factor: Attitude towards cobots

The previously identified themes at the individual and organisational levels function as critical input factors that collectively influence attitudes towards collaborative robots. This overarching theme encompasses holistic perceptions of the technology, including initial impressions of its role, utility, and value within the workplace. These attitudes encompass a spectrum of positive to negative responses and neutral or ambivalent stances. The diversity of these perspectives is exemplified by the contrasting statements of Participants M17 and M2, who illustrate fundamentally divergent attitudes toward integrating collaborative robots.

> *M17 (employee): So, I enjoy working with machines. But whether it is a robot arm or another machine does not really matter to me.*
>
> *M2 (employee): Until everything is running smoothly, I am glad if I do not have anything to do with the cobot.*

In conclusion, this theme encompasses the cognitive and affective components of individuals' responses to collaborative robots, including their perceptions and intended use patterns. The theme *"attitude towards cobots"* thus constituted the foundation for the process dimension of the conceptual framework.

4.5.2 Process dimension

Process factor: Interaction with cobots

The process factor *"interaction with cobots"* operates across both the individual and the organisational levels, as it encompasses both personal engagement and experiences, as well as collaborative dynamics that emerged during the use of the technology. Here, collaborative dynamics refer to the ways in which employees work together, share experiences, and adapt collectively to the integration of collaborative robots. In this context, the frequency of interaction with collaborative robots was identified as a vital variable.

Employees directly interacting with the collaborative robot can be distinguished according to their interaction frequency, which is classified as low, medium, or high. As defined in Section 4.2, the frequency of interaction is considered low when an employee interacts with collaborative robots at least once per year, medium when interaction occurs at least once a month, and high when interaction occurs at least once a week. The participant sample comprised seven employees with low interaction frequency and five in the medium and high interaction categories.

The frequency of critical statements coded under *"experience with advancement"* exhibits a clear positive association with interaction frequency. This is evidenced by 3 critical statements from employees with low interaction frequency, 17 from those with medium interaction frequency, and 42 from those with high interaction frequency. Notably, the data indicate that as interaction levels increased, so did the proportion of positive experiences in relation to negative ones. Therefore, these findings suggest that variations in interaction frequency lead to changes in the nature and intensity of user experience with the technology, as evidenced by the varying prevalence of this aspect across different groups. The frequencies of critical statements referenced above are documented in Appendix F.5. These data are utilised solely for qualitative interpretation to substantiate the identified relationships within the main code.

Overall, the conceptual framework employs directional arrows to illustrate the direct impact of the critical input factor *"attitude towards cobots"* on the subsequent process factor *"interaction with cobots".*

Additional process factor at the organisational level

In the process dimension, the second developed theme, *"impact on workplace dynamics"* pertains to the organisational level, as it addresses changes in social interactions, communication patterns, collaborative work processes, and the perceived value of work. For example, Participant F13 indicated reduced social interactions when working with collaborative robots compared to manual manufacturing settings. Moreover, Participant M20 suggested that the perceived value of work improved with the introduction of collaborative robots, particularly because tasks previously performed without the assistance of collaborative robots were characterised by a high degree of repetition.

F13 (employee): I do think it is getting a bit lonelier. Maybe you work a bit more for yourself, alone.

M20 (manager): There were also other areas of application (for the cobots), because the job was very repetitive and anything but rewarding.

These changes are attributed to the introduction of collaborative robots, ongoing interaction with them, and the optimisation of work processes involving these robots. They include modifications to organisational practices, operational procedures, and workplace conditions, collectively resulting in a reconfigured work environment.

This reconfiguration has implications for two critical factors: *"workplace dynamics"* as an input factor and *"interaction with cobots"* as a process factor. The former concerns the evolving nature of organisational dynamics, whereas the latter refers to employees' experiential engagement with collaborative robots under the new conditions. This interrelationship is visually illustrated in the conceptual framework depicted in Figure 4-15, which features bidirectional arrows between *"interaction with cobots"* and *"impact on workplace dynamics",* as well as a feedback arrow from *"impact on workplace dynamics"* to *"workplace dynamics"*. These connections underscore the recursive nature of the conceptual framework, whereby changes to critical factors can initiate a renewed cycle of adaptation and interaction. Against these interdependencies, the discussion now turns to the output dimension of the conceptual framework.

4.5.3 Output dimension

Output factor at the individual level

The output dimension at the individual level of the conceptual framework relates to the degree of acceptance of collaborative robots. This dimension enables the categorisation of employees into four distinct groups based on their acceptance or resistance towards integrating collaborative robots. The critical factor, *"acceptance of cobots"*, is shaped by two crucial factors, as viewed from the process dimension. First, a direct influence is exerted by the theme *"interaction with cobots"*, which reflects the employees' lived experiences with the technology. Second, an indirect influence arises from the *"impact of workplace dynamics"* theme. The corresponding directional arrows visually represent these interdependencies in the conceptual framework.

Output factor at the organisational level

At the organisational level, the output factor is represented by the theme *"system performance"*, capturing the impact of collaborative robot integration on the overall performance of the organisational system. To illustrate the interdependencies within the conceptual framework, directional arrows were included to link the individual-level output factor *"acceptance of cobots"* with the organisational-level output factor *"system performance"*. This linkage reflects that system-level outcomes are largely contingent upon individuals' acceptance of the technology.

From a process dimension perspective, an additional arrow was drawn from the theme *"interaction with cobots"* to the theme *"system performance"*, representing a direct influence of individual experiences with collaborative robots on organisational performance and an indirect influence mediated through the theme *"impact of workplace dynamics"*. Including this pathway emphasises the significance of lived experiences within the social context in shaping *"system performance"*. Thus, the conceptual framework delineates a dual-pathway model, illustrating that system performance is directly shaped in two ways: through employees' level of acceptance of collaborative robots, and through their individual interactions with the technology.

4.5.4 Summary of conceptual framework development

The conceptual framework developed in this study demonstrates the critical factors influencing acceptance and system performance in the context of collaborative robot integration within healthcare manufacturing. Developing this conceptual framework was guided by an interpretive and conceptualisation-based approach, as Naeem et al. (2023) proposed. This conceptual framework is structured around the following three principal dimensions.

Input dimension: At the individual level, personal factors—conceptualised as background conditions—shape the influence of other input factors, such as subjective usefulness, user-friendliness, and emotional factors. These personal factors include employees' previous experience with robots, job position, gender, and age, all of which are particularly important for understanding individual perceptions of collaborative robots. These findings highlight the critical role of accounting for individual backgrounds and predispositions when analysing technology acceptance. At the organisational level, input factors encompass broader organisational dynamics, including the inherent characteristics of collaborative robots, contextual factors like workload and managerial support, and workplace dynamics involving team interactions and communication patterns.

Process dimension: The process factors encompass the dynamic interactions between employees and collaborative robots, manifesting at individual and organisational levels. Central to this dimension is the frequency and quality of interaction with collaborative robots and their impact on workplace dynamics. These interactions can alter communication patterns, foster or hinder cooperation among employees, and even influence how employees perceive the value of their work.

Output dimension: This dimension encompasses two themes. At the individual level, the acceptance or resistance to collaborative robots can be active or passive and is influenced by personal experiences and workplace dynamics. At the organisational level, the collective acceptance of collaborative robots drives system performance, thereby illustrating the interconnectedness between individual attitudes and organisational outcomes.

In conclusion, the conceptual framework illustrates the complex interplay between individual predispositions, organisational dynamics, and human-technology interactions in the context of collaborative robot integration. By mapping the interdependencies across input, process, and output dimensions at individual and organisational levels, the framework offers an integrative lens to understand the multifaceted factors that influence the acceptance of collaborative robots, which thus shape system performance. Doing so facilitates the optimisation of system performance and technological benefits while proactively addressing implementation challenges.

Aligning with the conceptual framework, individual acceptance of collaborative robots emerges as a critical determinant in enhancing system performance. Consequently, the following section presents recommendations for creating conditions for favourable user responses and attitudes towards collaborative robots, thereby illustrating the practical relevance of the conceptual framework for real-world implementation strategies.

4.6 Creating conditions for favourable user responses

The conceptual framework developed in this study provides a foundation for formulating recommendations aimed at supporting favourable user responses to collaborative robots and contributing to improved system performance. Accordingly, this section presents a multifaceted, evidence-based strategy to foster user acceptance by specifically addressing the various types of acceptance and resistance identified.

Drawing on the conceptual framework, the matrix in Figure 4-16 illustrates the four identified types of acceptance and resistance using two axes. These axes correspond to two critical factors, *"attitude towards cobots"* and *"interaction with cobots"*, which were previously identified within the input and process dimensions of the conceptual framework. The matrix also integrates the specific influencing factors associated with each dimension. Since these factors fundamentally shape the level of user acceptance across the four groups, their consideration is essential for developing effective strategies to enhance acceptance.

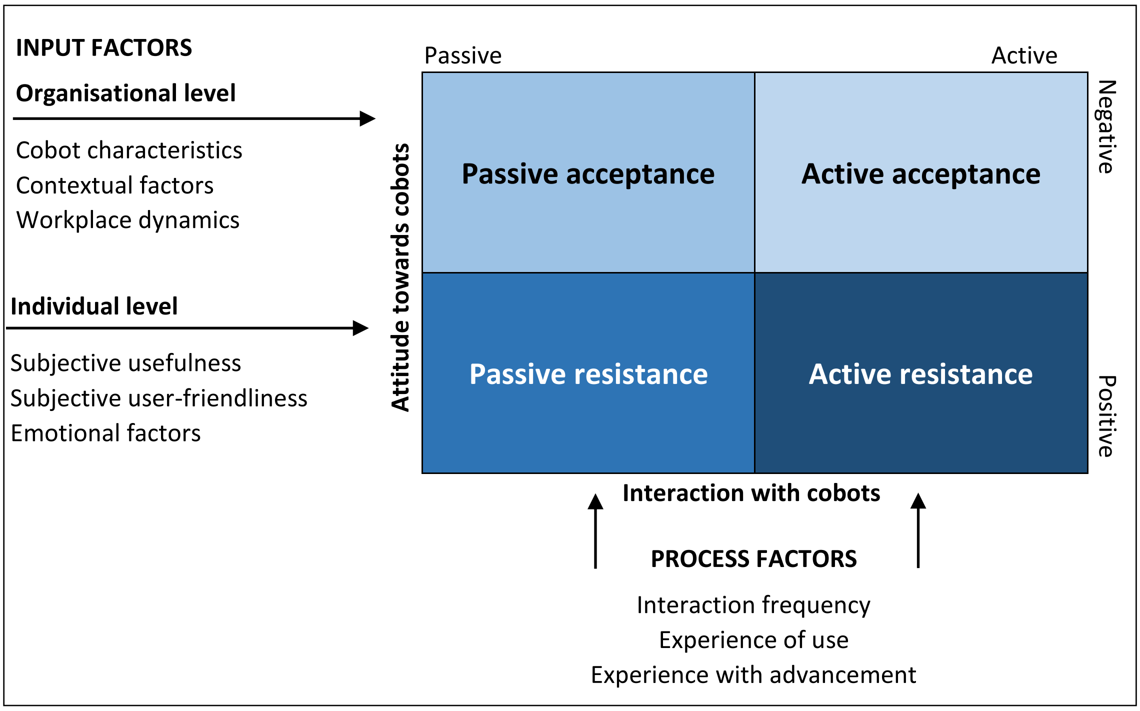


Figure 4-16: Acceptance of collaborative robots (individual level)

Building on the previously developed conceptual framework and its associated dimensions, it can be posited that each of the identified input factors has the potential to influence employees' attitudes towards collaborative robots positively. Similarly, interaction with collaborative robots can be shaped constructively through targeted interventions addressing the process-level factors. Consequently, individual acceptance of collaborative robots can be enhanced by actively shaping the input and process factors. This insight offers organisational decision-makers a well-grounded foundation for designing context-specific strategies to create conditions that foster positive user acceptance of collaborative robots.

The following section presents a series of recommendations grounded in the theoretical constructs of the developed conceptual framework to elucidate its practical application. Critical statements from participants are incorporated to reinforce these recommendations, providing empirical support with a particular emphasis on the four types of acceptance and resistance identified. Accordingly, the following subsections are organised into four main types of acceptance: active acceptance, passive acceptance, active resistance, and passive resistance.

4.6.1 Active acceptance

Active acceptance can be defined as employees' enthusiastic and proactive engagement with collaborative robots. Individuals demonstrating active acceptance are willing to use these technologies, actively explore their potential, and contribute to their successful integration and advancement. Consequently, these employees frequently discover novel ways to use collaborative robots, leading to improved processes and increased productivity. They show initiative in learning and experimenting, and in disseminating positive experiences with others, thereby fostering a supportive environment that promotes technological adoption. Based on participant observations and semi-structured interview data, several employees exemplify this level of acceptance.

Fostering a proactive and enthusiastic attitude towards collaborative robots is crucial for harnessing their full potential within the workplace. Employees who exhibit such attitudes are more inclined to engage in experimentation and optimisation of the technology, leading to improved productivity and fostering innovation. Their positive attitude can inspire and motivate their peers, creating a culture of continuous learning and adaptation.

Considering these employees have already demonstrated active acceptance, the emphasis should shift from further encouraging acceptance to supporting engagement. Consequently, organisational decision-makers must prioritise organisational-level input factors when designing strategies to reinforce the high level of acceptance demonstrated by this group, as outlined in the matrix in Figure 4-16.

An illustrative example of a targeted measure can be derived from the identified critical factor *"workplace dynamics"*, particularly those relating to leadership culture. Managers should ensure employees have sufficient time for ongoing interaction with collaborative robots, supporting both technological refinement and process optimisation. Establishing a community of practice among these employees can further promote peer learning and provide a forum for sharing experiences and addressing implementation challenges. These recommendations are substantiated by interview statements highlighting the necessity of continuous engagement with emerging technologies, which managers must actively enable and support.

> *M23 (employee): Yes, it really is a major step forward […] when someone is involved in a project like this who can fully concentrate on the matter at hand and also has the time to think and reflect.*
>
> *M21 (manager): I think it was the right approach to allow the employees to engage with the concept and then to design the system as a project.*

In addition, further measures based on the critical *"workplace dynamics"* factor—particularly leadership culture—may be beneficial. For example, introducing a reward structure for employees who demonstrate positive interactions with collaborative robots can encourage such behaviour. This can be achieved by defining clear performance objectives and providing active monitoring and support. Recognising and rewarding employees' efforts may motivate them to sustain or increase their engagement with the technology. This strategy was corroborated during the interviews from a variety of viewpoints, as illustrated by Participant M9, who noted that implementing a reward mechanism enhanced active interaction with collaborative robots.

> *M9 (employees): I think (the increase in interaction with the cobots) depends on the objectives of the performance reviews.*

Overall, it is crucial for organisations not to overlook this group of employees, as they are already demonstrating active acceptance. To further strengthen their commitment, management may consider strategies such as providing sufficient time for engagement, fostering a community of practice, or implementing reward systems. Such interventions can reinforce individual commitment to position these employees as change agents who can foster favourable attitudes toward collaborative robots in the workforce.

4.6.2 Passive acceptance

Passive acceptance indicates a willingness to utilise collaborative robots without displaying strong enthusiasm. Individuals exhibiting this level of acceptance are typically receptive to new technology yet lack the motivation or enthusiasm to engage with it actively. Such individuals may utilise collaborative robots as required but do not go beyond their immediate tasks to explore additional functionalities or process improvements. Based on the data collected, this group appears to include several employees in the present case study.

Passive acceptance, while seemingly positive on the surface, can pose significant risks to the successful integration of collaborative robots. Employees who use the technology only out of necessity often remain disengaged, resulting in suboptimal utilisation and limited productivity gains.

To enhance user acceptance within this group, it is recommended to expand active interaction with collaborative robots, as outlined in the matrix in Figure 4-16. This recommendation is further corroborated by critical statements made in the interviews, including excerpts from M15, who advocates for a participatory approach to implementing collaborative robots. Therefore, a gradual increase in employee participation is recommended, allowing them sufficient time to adapt and become comfortable with the new situation.

> *M15 (manager): So, taking a participatory approach, turning those affected into active participants and, in a way, turning the situation around.*

Such an inclusive approach can facilitate employees' comprehension and appreciation of collaborative robots, increasing the likelihood of active interaction. This progressive engagement model facilitates a gradual escalation in the complexity of interaction. At the outset, employees may be introduced to elementary tasks, such as performing simple pick-and-place operations with an experienced colleague, which builds confidence. As proficiency increases, they may progress to more complex tasks, including configuring the collaborative robot and executing novel tasks autonomously. This stepwise approach provides clear guidelines and developmental milestones, enabling employees to discern their progress and build competencies over time.

In addition, organisational-level input factors are critical for this group, such as those related to the technology implementation process. Notably, actively involving employees in the implementation can enhance acceptance and provide opportunities for personal and professional development. It is important that direct managers explicitly communicate these opportunities, as highlighting the benefits of deeper involvement may encourage employees to invest time and effort in acquiring relevant skills and foster greater engagement with the implementation process. A practical strategy could involve creating individualised development plans that articulate specific goals and milestones for integrating collaborative robots and optimising associated workflows. This finding is supported by qualitative data from the interviews, wherein several participants, such as M27 and M15, emphasised development opportunities linked to increased involvement in the implementation phase.

> *M27 (manager): This is a development opportunity for me (as an employee), so that I can take the next step. It is really about user stories, about a collaborative way of working, but also about one's own personal, intrinsic motivation to grow in the workplace.*
>
> *M15 (manager): Well, I naturally involve those who are positive about it in the implementation.*

The primary objective for this group of employees should be to enhance interaction with collaborative robots, which can be achieved through various methods. Practically, this involves increasing direct engagement and gradually raising task complexity to match employees' developing competencies. Managers should create opportunities for greater involvement in the implementation process, fostering professional growth and career advancement.

4.6.3 Passive resistance

The term *"passive resistance"* denotes a more nuanced form of opposition to collaborative robots. Employees exhibiting passive resistance do not overtly reject the technology. Instead, they demonstrate a lack of full engagement. Such individuals may deliberately avoid utilising collaborative robots whenever possible, limit their involvement to the bare minimum required, or exhibit a general disinterest in technology. The classification of employees within this group was derived from empirical data collected during the case study. A few employees were identified as representatives of this group in the current study.

Passive resistance can significantly undermine overall acceptance and productivity by causing inefficiencies and disrupting workflows. This disengagement may subtly erode employee morale and confidence in the technology, weakening collective acceptance. Over time, such effects can hinder the realisation of collaborative robots' full benefits and limit organisational growth.

An appropriate initial step for employees within this group may involve creating conditions that promote a more favourable acceptance of collaborative robots. This approach, as outlined in the matrix in Figure 4-16, focuses on addressing the individual-level input factors. Central to this process is the effective dissemination of information concerning the benefits and opportunities of integrating collaborative robots into manufacturing workflows. This aligns closely with the critical factor of *"subjective usefulness"*, which refers to an individual's perception of the technology's utility in improving task performance.

To this end, it is essential to highlight the positive outcomes achieved through collaborative robot implementation. One effective strategy involves presenting real-world success stories, such as video testimonials that showcase both current applications and employee experiences. These can be shared with all employees, as exemplified by Participant M18. Additional application-based examples can further demonstrate how this technology enables more efficient work practices. Such illustrative materials help make the technology more tangible and reinforce its potential impact on manufacturing processes.

> *M18 (manager): We also showed some videos of what it can do now and so on. I think that is never a bad thing. Especially when you have something new, we should talk about it and show it to everyone.*

To increase employee interaction with collaborative robots, the next phase of integration should encourage identified employees to engage by completing basic tasks. This process should begin incrementally, starting with observational learning—where employees watch demonstrations without active participation—before gradually transitioning to direct interaction. Participant M20 exemplified such a phased approach in the present case study. Tailoring the level of interaction ensures support is aligned with each employee's needs and readiness, fostering a more effective integration experience.

M20 (manager): And that was actually how we established a really effective door opener. At the time, I had the employees sit right next to the cobots.

For this group, one of the principal considerations is providing initial support and assistance, including training and ongoing assistance from individuals with experience in the manufacturing processes involving collaborative robots. This recommendation is derived from the critical factor of *"subjective user-friendliness"*. Organisations may implement mentoring programs or establish peer learning groups to facilitate this process. The relevance of such measures is substantiated by interview data, particularly from Participants F12 and F13, as detailed below.

F12 (employee): Right now, honestly, I am still really unsure. I would actually need a proper introduction and some training.

F13 (employees): I think it would be good to do it step by step [...] with training sessions or something like that, [...] or if I have a production technician next to me, so that I could just ask questions.

Identifying this particular form of refusal presents a significant challenge, as it does not manifest through overt opposition but rather through subtle disengagement. Consequently, it is critical to accurately identify which employees fall within this group. This underscores the necessity of effective communication between managers and employees, particularly emphasising the role of active listening skills. In response, managers should aim to strengthen employees' engagement with collaborative robots by increasing the frequency of interactions. Such behaviour is likely to model a more positive attitude and contribute to a shift in employee acceptance. The overarching objective is to foster a work environment that promotes positive reinforcement of collaborative robot interaction, facilitating open dialogue regarding the technology.

4.6.4 Active resistance

Active resistance refers to the explicit and deliberate opposition to implementing and utilising collaborative robots. Employees exhibiting this form of resistance often voice their concerns openly, resist changes to established workflows, and may even engage in behaviours that obstruct the adoption process. The underlying causes of active resistance can be multifaceted, including fears of job displacement, discomfort with new technology, or prior negative experiences with automation. In the context of this case study, the collected data indicated that only one employee falls within this group.

A refusal to adopt collaborative robots can have a detrimental impact on both operational performance and workplace cohesion. Active resistance may create bottlenecks and disrupt manufacturing processes, leading to delays and reduced efficiency. This can also undermine team performance, as inconsistent adoption of new processes may cause miscommunication and errors. Moreover, such resistance can foster conflict between employees who support and those who oppose new technologies, ultimately impeding the organisation's capacity for innovation and adaptability.

For this group of employees, the concerns associated with implementing collaborative robots constitute a critical area requiring focused managerial attention. As a preliminary step, it is essential to understand the nature of these concerns. The individual-level input factors identified in the conceptual framework, including *"emotional factors*", may serve as a valuable reference point for this purpose. Such understanding can be facilitated through one-on-one meetings or small group discussions. The next step involves delivering transparent and evidence-based information to address misconceptions and psychological fears, particularly those related to job security, which emerged as a recurring issue among many study participants. Proactively managing these emotional concerns helps to promote conditions that mitigate anxiety and reduce resistance, fostering a more transparent and trusting relationship between employees and management. It is vital to acknowledge that emotional reactions are a natural response to perceived threats or uncertainty, as exemplified by the reaction voiced by Participant M2.

> *M2: Let me put it this way: I am standing there […] bashing the cobots with a steel pipe until there is nothing left of them. Even back then, I knew how it would turn out, that it would all go wrong–and I have been proven right.*

Given the critical stance often held by individuals in this group, their feedback should be regarded not merely as resistance but as a potentially valuable source of insight. Such input can inform meaningful improvements when articulated constructively. By focusing on understanding and addressing the root causes of resistance, organisations may reframe opposition as a constructive force, facilitating a transition from resistance to acceptance. However, managers must proceed cautiously, ensuring that implementation does not progress too rapidly, as doing so may risk alienating employees.

4.6.5 Summary of creating conditions for favourable user responses

The preceding subsections outline a systematic approach to supporting user acceptance of collaborative robots, addressing diverse manifestations of acceptance and resistance identified in this study. The first step is to use effective communication to determine which type of acceptance each employee demonstrates—whether it is active acceptance, passive acceptance, passive resistance, or active resistance. Such identification can provide a basis for employee-focused support, tailored to the employee's disposition. Consequently, this responsibility constitutes a crucial function of direct managerial roles.

Figure 4-17 synthesises the actions discussed previously that can foster the acceptance of collaborative robots in manufacturing environments. Each recommendation thereby represents a strategic intervention to enhance user acceptance, ultimately supporting the successful practical integration of collaborative robots in manufacturing settings.

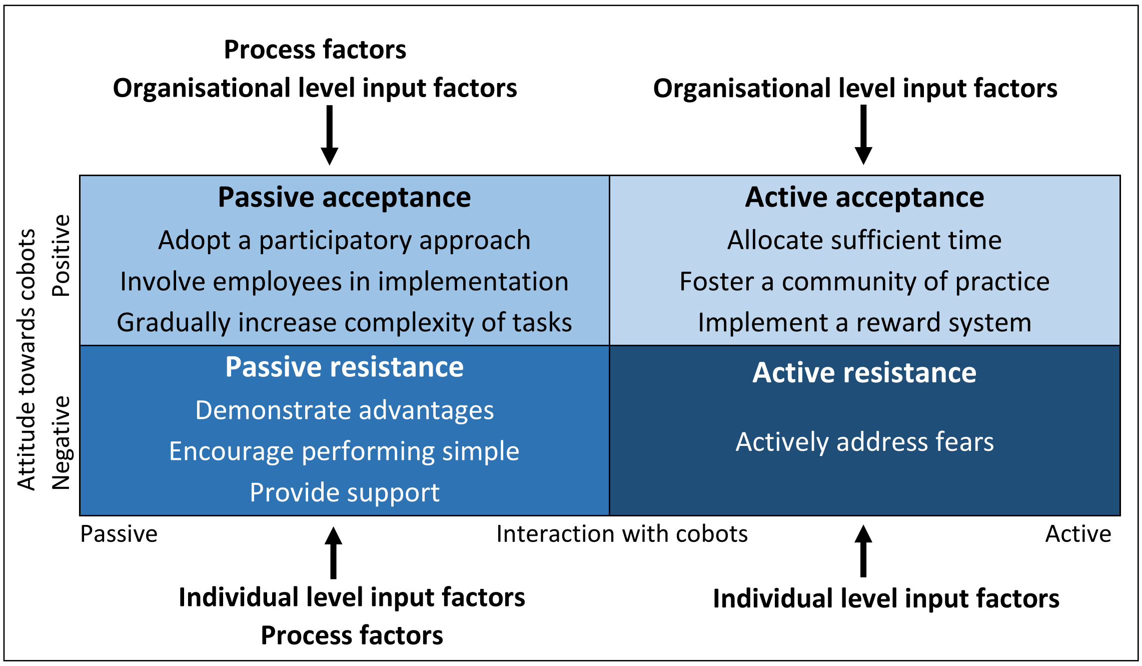


Figure 4-17: Measures to support acceptance of collaborative robots (individual level)

The actions and measures proposed in the previous figure may serve as a foundation for creating conditions for favourable user responses and acceptance in contexts beyond those directly examined in this study. While the presented recommendations offer practical guidance, it is vital to note that this list is not intended to be exhaustive. The next step entails the practical application of the conceptual framework developed in this study, enabling managers to independently derive context-specific measures that go beyond the examples provided, tailored to the distinct requirements of each implementation scenario.

The recommended strategies must be implemented in conjunction with the explicit and sustained support of direct managers, as Breese et al. (2018) advocated. To this end, it is essential that managers actively promote the adoption of collaborative robots by clearly articulating their benefits and aligning them with organisational goals. Crucially, this process should involve proactive engagement with different employee groups and, when appropriate, individualised interactions tailored to specific concerns. Through such targeted implementation, organisations are better positioned to harness the full potential of collaborative robotics, advancing both individual development and organisational performance.

4.7 Chapter summary

This chapter presented the research findings derived from the qualitative data collected during the study. To ensure a clear and logical presentation of these results, the chapter was structured into three main sections, each aligned with one of the central research objectives of this thesis.

The initial categorisation of identified codes and themes was based on input, process, and output factors. A visual representation was developed for each theme to illustrate its salient features derived from the reflexive thematic analysis. These visualisations provided a sound foundation for a holistic description, including precise definitions of each theme and illustrative excerpts from participant statements. Furthermore, an interpretative analysis was conducted for each theme to elucidate the significance of the findings against the research objectives. The relevance of the results was demonstrated through explicit connections to the overarching research question and the broader research context. Consequently, this approach facilitated a nuanced understanding of the complex interrelationships and dynamics among the themes, thereby clarifying the critical factors that influence the acceptance and system performance in collaborative robot applications.

The second part of this chapter focused on developing a conceptual framework. To this end, the identified themes were further categorised at the individual or organisational level, thus providing additional structure and insights. The level-based categorisation facilitates a deeper understanding of employee attitudes towards collaborative robots by distinguishing influences operating at personal and organisational domains. In conclusion, this thesis presents a conceptual framework (see Figure 4-15) that offers a nuanced understanding of the complex interplay between individual and organisational factors influencing the acceptance of collaborative robots and, consequently, system performance.

Building on the developed conceptual framework, this chapter further proposed recommendations to create conditions for favourable user responses to collaborative robots. In this context, a critical inquiry was undertaken to explore strategies and approaches that may contribute to greater acceptance of collaborative robots across diverse employee groups within a healthcare manufacturing environment.

The findings presented in this chapter establish the foundation for the subsequent discussion and conclusions presented in Chapter 5. Accordingly, the following chapter offers a nuanced synthesis and critical evaluation of the research findings.

Chapter 5: Discussion and conclusion

5.1 Introduction

This chapter synthesises the key findings of the study, which lays a solid foundation for the following discussion and conclusions. The research findings are critically examined within extant literature, situating the empirical findings within the broader academic discourse. This process of contextualisation is pivotal in highlighting the theoretical significance and practical implications of the research. A comprehensive evaluation of the study's methodological rigour and limitations is also outlined. Based on these insights, recommendations for future research are provided. The chapter concludes with personal reflections on the research process and the insights gained during this project, followed by the conclusion of the thesis.

5.2 Discussion of research findings with literature

This chapter aims to facilitate a multifaceted discussion of the key research findings within the framework of existing literature. The focal point of the following discourse pertains to the research question underpinning this study: "How do factors influencing the acceptance of collaborative robots (cobots) shape system performance in the healthcare manufacturing sector?" The three research objectives, derived from this overarching research question, serve as critical reference points in structuring and substantiating the response to the research question.

These research objectives are as follows:

1. To explore and identify the critical factors that influence the acceptance of collaborative robots (cobots) in the healthcare manufacturing sector.
2. To develop a conceptual framework that illustrates how acceptance-related factors are associated with system performance, grounded in empirical insights and contextualised within existing theoretical perspectives on human-robot collaboration and technology acceptance.
3. To derive actionable recommendations to create conditions for favourable user responses to collaborative robots (cobots) within the context of healthcare manufacturing.

This study seeks to contribute to bridging the research gap identified at the outset by addressing the outlined research objectives. Recent studies highlight limitations in understanding individual acceptance of collaborative robots, particularly with respect to methodological scope (Liao et al., 2024). In addition, the research gap, as highlighted by Hopko et al. (2022), concerns the limited understanding of system performance in collaborative robot implementation from a holistic perspective, addressing human, robotic, environmental, and organisational factors. Further studies have elaborated on this gap, notably emphasising the neglect of emotional aspects within this context (Çiğdem et al., 2023; Hopko et al., 2022; Liao et al., 2024). Moreover, according to the literature review, previous research is predominantly grounded in laboratory-based investigations. Consequently, there is a clear call within the literature for empirical studies situated in real-world manufacturing settings to capture the complexities and contextual nuances of collaborative robot implementation (Liao et al., 2023; Liu, Caldwell, Rittenbruch, Müge, Burden, & Guertler, 2024; Parvez et al., 2022). The present study responds to this gap by providing empirical insights derived from implementing collaborative robots within the manufacturing department of a leading global healthcare company in Germany.

However, before addressing the individual research objectives, it is imperative to reflect on the appropriate timing for analysing and situating the findings within the context of existing literature. This consideration is particularly relevant given the methodological foundation of the study, which is based on constructivist grounded theory that emphasises the inductive development of theoretical insights grounded in empirical data.

5.2.1 Literature review in grounded theory research

The appropriate timing of a literature review during a research project has been the subject of much debate among grounded theorists (Bryant & Charmaz, 2007; Charmaz, 2014; Dey, 1999). This controversy can be traced back to the seminal work of Glaser and Strauss (1967), who advocated for delaying engagement with extant literature until the initial stages of data collection and analysis were completed. Their rationale was to preserve the researcher's theoretical sensitivity and avoid premature conceptual closure, thereby fostering openness to emergent patterns in the data. However, contemporary perspectives highlight the necessity of situating a study within the broader scholarly discourse. Stern (2007) posits that literature reviews in grounded theory research serve two vital functions: first, to demonstrate how a study contributes to and advances existing knowledge, and second, to recognise and critically engage with prior scholarship.

In this regard, constructivist grounded theory supports previous literature to inform the formulation of research questions and objectives, thereby striking a balance between inductive discovery and scholarly contextualisation.

The literature review for this study was conducted in two phases to ensure that existing scholarship was engaged with at the appropriate stages of the research process. Initially, a preliminary review of the literature was conducted following the structured literature review methodology proposed by Piccarozzi et al. (2018) to establish a detailed overview of the relevant scholarly discourse related to the central topic of the study. This informed the research design and provided contextual grounding before data collection and analysis. In the second phase, the literature review was systematically updated and refined in light of the emergent themes identified through reflexive thematic analysis. This iterative approach ensured the review aligned with the study's evolving insights and interpretive framework.

The initial literature review served to identify the research gap underpinning the present study. The information gathered during this phase was deliberately set aside after the preliminary data analysis phase, aligning with Charmaz's (2014) recommendation that the final literature review should be undertaken after data interpretation. This approach minimises the risk of allowing preconceived theoretical insights to constrain the analysis process, fostering a creative engagement with the data (Charmaz, 2014).

The final literature review, which was conducted between September 2024 and January 2025 and presented in Chapter 2 of this thesis, now forms the conceptual foundation for interpreting the study findings. By integrating relevant scholarly insights post-analysis, the literature review facilitates articulating how this study positions itself within or extends existing literature in line with the constructivist grounded theory principles (Charmaz, 2014). Building on this foundation, delving deeper into critical determinants influencing acceptance and system performance in deploying collaborative robots is essential. The following sections systematically examine the empirical findings in relation to these research objectives and situate them within the relevant scholarly literature.

5.2.2 Research objective one: Critical factors influencing acceptance

The first objective of this study is to explore the critical factors influencing acceptance in human-robot collaboration. These factors were identified through a single-case study design, employing a qualitative approach. The primary data was collected through eight observations and 27 semi-structured interviews conducted with participants across different hierarchical levels within the organisation, using a dyadic approach. Data analysis was conducted using the reflexive thematic analysis outlined by Braun and Clarke (2006), coding over 2,300 participant statements. The following subsections first synthesise the findings related to this research objective, followed by a discussion within the relevant scholarly literature.

5.2.2.1 Summary of research findings

To holistically analyse the critical factors influencing acceptance of collaborative robots, these factors were organised into three categories: input, process, and output. This categorisation provides a structured framework for examining the multifaceted dynamics of human-robot collaboration. Input factors represent elements that influence employees' attitudes towards collaborative robots. Process factors capture the nature of human-robot interactions within the operational workflow, focusing on how collaboration unfolds in practice. Output factors pertain to the outcomes of these interactions, including employee acceptance of collaborative robots and the resulting system performance.

The critical input factors identified in this study are organised into eight themes. Among these, *"personal factors"* constitute a distinct theme that encompasses several background conditions, each influencing the extent to which other input factors affect acceptance of collaborative robots. The three other individual-level input factors, influenced by personal factors, are termed *"subjective usefulness"*, *"subjective user-friendliness"*, and *"emotional factors"*. In addition to the previously discussed input factors, the analysis reveals three further themes related to the organisational level: *"cobot characteristics"*, *"contextual factors",* and *"workplace dynamics"*. The first theme refers to the specific technical features and functional roles of collaborative robots within the organisation. In contrast, the latter two themes pertain to organisational attributes and operational procedures that shape the environment in which human-robot collaboration occurs. These input factors collectively contribute to the emergence of an overarching theme: *"attitude towards cobots"*, which reflects the general perspective employees hold toward collaborative robots.

Moreover, the study identified two themes within the domain of process factors, which capture the dynamic aspects of human-robot collaboration. The first theme, *"interaction with cobots"*, relates to employees' direct experiences with collaborative robots. In this context, interaction frequency emerged as a salient element. The second theme, *"impact on workplace dynamics"*, explores how integrating collaborative robots influences work processes, patterns of communication and cooperation, and the nature of social interactions among employees.

The output factors in this study are encapsulated into two overarching themes: *"acceptance of cobots"* and *"system performance"*. Both themes focus on the tangible outcomes of implementing collaborative robots within manufacturing settings. The first theme relates specifically to employees' acceptance of these robots, while the second encompasses the broader organisational and social context. Importantly, the latter also serves as a conceptual bridge for conceptual framework development and provides a necessary foundation for gaining insight into system performance. Moreover, the *"system performance"* theme captures the outcomes of human-robot collaboration, directly addressing the central research question by synthesising the observed effects of collaborative robotics on acceptance and associating them with overall organisational functioning.

It should be noted that, in Chapter 4, the distinction between individual and organisational-level factors was not made when presenting the research findings related to the first research objective. This differentiation emerged only during the subsequent interpretation. However, it is introduced at this point within this section to ensure a clear and consistent structure throughout the discussion and findings chapters.

Together, the critical factors identified in this study offer a multifaceted overview of how collaborative robots influence acceptance and system performance. Building on these findings, the following subsection rigorously analyses these factors in conjunction with the published literature to contextualise and deepen the discussion.

5.2.2.2 Discussion in relation to extant literature

The generated themes were categorised as input, process, or output factors to facilitate the analysis and classification of the critical factors influencing acceptance and system performance. Prior research on human-robot interaction has demonstrated the utility of the input-process-output model, along with its various extensions, as an effective framework for understanding and improving the dynamics of human-robot collaboration (Wolf & Stock-Homburg, 2023; You & Robert, 2017). In line with existing publications, the structured nature of the input-process-output model makes it particularly well suited for this study, as it organises the identified themes and provides a transparent framework for addressing the multifaceted complexities inherent in human-robot cooperation. However, none of the previously discussed studies has applied the input-process-output model to holistically analyse the critical factors influencing acceptance and system performance within real-world manufacturing environments deploying collaborative robots, as is done in the present study.

Background conditions based on individual-level acceptance frameworks

The present study identified several background conditions influencing employees' attitudes towards collaborative robots, classified under the overarching theme of *"personal factors"*. Specifically, these variables include the main codes *"expertise of employees", "demographic factors",* and *"work preferences"*.

The identified background conditions should be discussed within the context of moderating variables of established individual-level acceptance frameworks. Notably, the variable *"expertise of employees"* identified in this study resonates strongly with the concept of experience as a moderating variable in theoretical frameworks such as TAM2, TAM3, and UTAUT (Venkatesh et al., 2003; Venkatesh & Bala, 2008; Venkatesh & Davis, 2000). Experience has consistently been shown to moderate user attitudes and acceptance towards technology in these frameworks. In this study, one element of expertise is previous experience with robots. This is related to the degree to which an employee is accustomed to automated work processes. Notably, data analysis reveals a link between the absence of prior robotics experience and perceived threats associated with collaborative robots. This observation is derived from the matrix coding query presented in Appendix F.1, indicating that the majority of statements classified under *"cobots perceived as threats"* originated from individuals lacking prior exposure to robotics.

Further notable disparities emerged in the distribution of statements concerning previous experience with robots, particularly in relation to personal development opportunities, flexibility of the collaborative robot, ease of advancement, and trust in collaborative robots. Participants with prior experience with robots consistently referenced these aspects more frequently, indicative of a broader and more nuanced appreciation for collaborative robots. In contrast, individuals without such experience notably emphasised the ease of use of these robots, suggesting a primary concern with the immediate, predefined interactions with the technology rather than exploring its broader, transformative potential. These insights stem from the matrix coding query detailed in Appendix F.1. Collectively, these findings underscore the role of *"expertise of employees"* as a background condition for individual-level input factors within this study. This observation aligns with established literature on TAM2, TAM3 and UTAUT, as discussed by Venkatesh et al. (2003), Venkatesh and Bala (2008), and Venkatesh and Davis (2000).

In addition to the aforementioned background condition, the UTAUT framework incorporates demographic factors such as age and gender as moderating variables (Venkatesh et al., 2003). This aligns with the findings of the analysis based on the main code *"demographic factors"*. In the present study, the distribution of statements from individuals with extensive experience, notably those aged 50 and above, demonstrated a pronounced inclination to prioritise physical relief and usability of collaborative robots. In contrast, younger participants predominantly highlighted aspects such as achieving performance goals, the flexibility of use, and the prospects for further advancements in collaborative robots, alongside trust in the technology. This divergence in focus suggests that individuals with greater experience place a higher value on actual utilisation in established work processes. In contrast, younger individuals adopt a more progressive outlook, considering the established workflows and the potential applications of the technology in future scenarios. The distribution of statements supporting these assertions is illustrated in the matrix coding query presented in Appendix F.3.

Within the UTAUT framework, gender has been identified as a significant moderating variable, alongside age, influencing technology acceptance (Venkatesh et al., 2003). The present case study corroborates this finding, revealing that gender is a background condition influencing perceptions of technology. Notably, female participants frequently mentioned physical relief as a positive aspect, while articulating concerns regarding new demands imposed on employees and perceiving collaborative robots as a potential threat more often than their male counterparts. In contrast, male participants demonstrated a greater inclination to emphasise factors such as trust in collaborative robots, the advancement of technology use, and the flexibility inherent in collaborative robots. These observations are substantiated by the findings presented in the matrix coding query in Appendix F.4.

In addition to age and gender, the study introduces job position within the organisation as another demographic factor for analysing individual-level input factors. As established in the literature review in Chapter 2, previous studies on technology acceptance frameworks such as TAM and UTAUT have not included job position as a moderating variable. However, the influence of job position on individual-level input factors is demonstrated by the matrix coding query in Appendix F.2.

Marked differences emerged between managers, production technicians, and production workers in how they perceive and evaluate collaborative robots. For instance, the findings from the group of managers, who placed particular emphasis on personal development opportunities, indicate that job position may act as an additional background condition, offering a distinct perspective on individual-level input factors. Based on these results, it is proposed that the demographic factors considered in previous studies should be expanded to include job position as a salient background condition. These findings are particularly relevant for real-world manufacturing environments, where organisational roles are clearly defined and can have a substantial impact on how new technologies, such as collaborative robots, are perceived and adopted.

However, the interplay between job position and gender also warrants closer examination. The distribution of statements made by production technicians closely mirrored those of male participants, with frequent mentions of emotional responses, ease of learning the technology, and perceiving technology as an opportunity. Similarly, the distribution of statements from production workers aligned more closely with those from female participants, suggesting potential intersections between gender and role-related experiences. This assertion is grounded in the demographic distribution of male and female employees across various job positions within the study sample. Specifically, production technicians, who were exclusively male, were contrasted with production workers, of whom 70% were female. This overlap makes it difficult to disentangle the effects of job position from those of gender. Thus, while the findings suggest that job position may act as an additional background condition, further research with more balanced samples is needed to clarify its independent effect.

In contrast to well-tested theoretical frameworks such as TAM2, TAM3, and UTAUT, the present study does not incorporate a background condition, *"voluntariness of use"*. This exclusion is justified by the real-world setting analysed, as the use of collaborative robots was predominantly voluntary. In addition to the standard moderating variables proposed in these frameworks, the present study introduces an alternative background condition derived from the main code *"work preferences"*. This variable describes employees' preferences for working in teams or individually, as well as their preferences regarding the use of automated solutions, such as collaborative robots, versus performing tasks manually. Since implementing collaborative robots in the studied setting was voluntary, this background condition holds particular relevance. It should be noted, however, that the introduction of *"work preferences"* as a background condition is based on critical statements rather than a matrix coding query, as was the case for the other background conditions. This suggests that further research is needed to examine this aspect in greater depth.

Building on the background conditions identified in this study, the following subsection presents individual input factors shaped by these contextual influences.

Input factors based on individual-level acceptance frameworks

Two of the individual-level input factors identified in the current study, *"subjective usefulness"* and *"subjective user-friendliness",* are closely aligned with the core constructs of the TAM framework and its subsequent extensions and those of the UTAUT framework.

The *"subjective usefulness"* is defined in the current study as the perceived ability of collaborative robots to support goal attainment, enhance the relevance of technology to specific work processes, and provide operational flexibility. Participants identified opportunities for personal development and the facilitation of work as relevant benefits associated with collaborative robot use. This aligns closely with the concept of performance expectancy in the UTAUT framework, which includes perceived usefulness, extrinsic motivation, and personal outcome expectancy (Benmessaoud, Kharrazi, & MacDorman, 2011). Similarly, TAM identified perceived usefulness as a critical determinant of technology adoption, which refers to increased job performance using a particular technology (Davis, 1989). These theoretical parallels underscore that the theme *"sub-*

jective usefulness" is not an isolated finding identified in the current study but reflects a construct deeply rooted in the extant literature.

Similarly, a comparable alignment can be observed with the theme of *"subjective user-friendliness",* which corresponds to the construct of effort expectancy within the UTAUT framework. Effort expectancy describes the degree to which a user believes a technology is easy to use (Benmessaoud et al., 2011), closely mirroring the construct of perceived ease of use in TAM (Davis, 1989). Both constructs capture users' expectations regarding how easy and effortless a technology is to use. In the present study, this theme was reflected in the primary codes *"ease of use"*, *"ease of advancement", "learner friendliness",* and *"new demands on employees"*. However, the definition of the theme *"subjective user-friendliness"* in this study extends beyond the classical definitions of TAM and UTAUT, as it includes not only the immediate usability of the technology but also encompasses the technology's potential to evolve in tandem with the changing work environment. The flexibility and adaptability inherent in collaborative robot technology can be seen as important characteristics that contribute to its uniqueness compared to other technologies.

In contrast to the individual-level input factors mentioned above, such as perceived usefulness and ease of use, which are well-established constructs in conventional technology acceptance frameworks such as TAM, its extensions, and UTAUT, *"emotional factors"* were not explicitly incorporated into these dominant theoretical models. This omission reflects a notable gap in the current literature, particularly given the growing relevance of emotional responses in human-robot collaboration contexts (Hopko et al., 2022; Liao et al., 2024). The present study seeks to address this gap by exploring the role of emotional factors in shaping human-robot collaboration. The theme *"emotional factors"* emerged as particularly salient in the analysis, accounting for the highest number of participant statements among all individual-level themes identified.

A diverse spectrum of emotions was identified in the collected data, ranging from positive sentiments, such as curiosity and satisfaction, to opposing emotions, characterised by various forms of fears about collaborative robots. Among these fears, job insecurity emerged as the most prominent concern, with many participants expressing anxiety about potential job displacement resulting from increased automation. The theme of *"emotional factors"* was structured around the following main codes: *"cobots perceived* *as opportunity"*, *"cobots perceived as threat"*, *"emotional response to cobots",* and *"trust in cobots"*. Importantly, while traditional technology acceptance frameworks have largely neglected emotional aspects, their relevance in this context has begun to gain recognition. For instance, a recent extension of the UTAUT model incorporates the construct of emotional attachment, acknowledging its role in shaping user engagement with technology (Porubčinová & Fidlerová, 2020).

Drawing on the existing literature, the themes developed in this study, including *"personal factors", "subjective usefulness",* and *"subjective user-friendliness"*, demonstrate strong conceptual alignment with established constructs in widely recognised technology acceptance frameworks, such as TAM and UTAUT. These findings confirm the continued relevance of core individual-level acceptance factors. Nevertheless, the present study contributes meaningfully beyond the validation of existing models by introducing *"emotional factors"* as a salient dimension in human-robot collaboration, an area underrepresented mainly in traditional acceptance theories. Furthermore, the study broadens the scope of potential moderating variables outlined in TAM2 and UTAUT by incorporating job position and work preferences, which emerged as additional relevant background conditions. Beyond individual-level determinants, the findings also call for an integrated discussion of input factors related to organisational-level technology adoption, suggesting the necessity of a multilevel perspective to fully capture the dynamics of collaborative robot integration in real-world work settings.

Input factors based on organisational-level adoption frameworks

Input factors identified at the organisational level are *"cobot characteristics"*, *"contextual factors",* and *"workplace dynamics"*. Hopko et al. (2022) emphasised that such organisational-level factors must be considered in conjunction with individual-level factors to obtain a more holistic understanding of technology adoption processes. However, in the literature on technology adoption, organisational factors have typically been examined separately and have not usually been analysed with individual-level input factors, as shown in the literature review in Chapter 2.

The theme of *"cobot characteristics"* identified in this study corresponds, in part, to the technology-related context described in the DOI theory and TOE framework. Within the TOE framework, the technological context is defined, encompassing a broad spectrum, including the availability and the core characteristics of the technology (Oliveira & Martins, 2011). In contrast, the DOI theory offers a more granular conceptualisation, outlining five key attributes that influence the adoption of innovations: relative advantage, compatibility, complexity, trialability, and observability (Rogers, 2003). These characteristics directly impact the perceived ease or difficulty of integrating technology into existing organisational processes.

This theme encompasses the main code *"technology attributes"*, which is composed of the following four codes: *"collaboration needs"*, *"noise level", "production speed", and "appearance"*. The first two codes correspond closely to the concept of compatibility in the DOI theory, which concerns the degree to which a technology fits with an organisation's current workflows, processes, and human working conditions. In addition, the code *"production speed"* could be conceptually related to the observability dimension in DOI theory, as it reflects the changes in production time attributable to the use of collaborative robots. The *"appearance"* of collaborative robots can be linked to the construct of perceived complexity, given that visual features may influence how challenging or complex users expect a technology to be. Nevertheless, the remaining constructs of the DOI theory are not overlooked in the present study. Instead, they are addressed in themes embedded in individual-level input factors, such as relative advantage, or process-related factors, such as trialability.

While the DOI theory and the TOE framework emphasise the role of technology attributes within the technology context, the present study extends this understanding by identifying the intention of collaborative robot implementation as a critical and previously unexplored aspect. This is captured in the main code *"purpose of cobot deployment"* within the broader theme of *"cobot characteristics"*. The findings indicate that the underlying intentions of employing such technology play a vital role in shaping organisation-wide acceptance. This represents a novel contribution to the literature, as such purposive framing has not been addressed in the organisational-level technology adoption frameworks reviewed in Chapter 2.

Moreover, the *"contextual factors"* theme represents an additional organisational-level input factor identified in the current study. As previously outlined in the extant literature, such factors commonly include management support (Fraboni et al., 2023), organisational readiness (Liu & Cao, 2022), and previous experience with collaborative robots

(Zemlyak et al., 2022). In this study, four of the seven main codes identified under this theme can be directly mapped onto the organisational context construct in the TOE framework (Simões et al., 2020). These main codes are *"management support"*, *"organisational conditions"*, *"operational restrictions",* and *"previous automation experience"*. Additionally, two other main codes identified in this study about economic aspects, such as investment in terms of time and budget, are also conceptualised as contextual factors. While some prior research has situated these aspects within the technological context (Simões et al., 2020), the current analysis argues for their organisational relevance. This is grounded in the inherently organisational nature of resource allocation decisions, which are shaped by internal budgeting, strategic prioritisation, and implementation timelines associated with implementing collaborative robots. In doing so, the present study refines the interpretation of contextual factors within the TOE framework, emphasising their deep embeddedness in organisational settings and work processes.

Furthermore, the present study identified another main code relating to the utilisation of employees, which is based on the volume of work. This finding aligns with recent research showing that workload is critical in shaping human-robot collaboration, influencing job satisfaction, acceptance, and performance of collaborative robots (Paliga, 2023). The current study revealed that workload influences employees' attitudes towards collaborative robots. While consistent with prior literature, the study also significantly extends previous research by identifying a lower willingness to utilise collaborative robots in instances where the volume of work is already insufficient to fully occupy the human workforce, even without the assistance of such robots.

Another organisational-level input factor identified in the current study is captured by the theme *"workplace dynamics"*. This theme contains the main codes *"leadership culture"*, *"peer influence"*, and *"technology implementation process"*. While prior research, such as the work by Meissner et al. (2020), has acknowledged the relevance of these factors in shaping technology adoption, the dynamic and interactive nature of these elements, as conceptualised in the present study, has not been sufficiently addressed in the existing literature.

Resulting input factor: Attitude towards cobots

Taken together, the input factors developed in the current study collectively influence attitudes towards collaborative robots. In the literature, such attitudes are frequently conceptualised through the lens of trust in technology (Hoff & Bashir, 2015), with trust primarily discussed as a human factor (Hopko et al., 2022). Additionally, the TAM framework and its extensions, UTAUT, and TPB include a comparable component, namely behavioural intention or intention to use, which focuses on the individual-level determinant of technology acceptance (Venkatesh & Bala, 2008; Venkatesh & Davis, 2000). The current study takes a broader and more integrative perspective by encompassing individual and organisational-level determinants as formative elements of attitudes towards collaborative robots. This conceptual shift responds directly to recent scholarly calls for a multilevel understanding of trust and acceptance by Hopko et al. (2022).

Having thoroughly examined the input factors, the following subsection focuses on the process-related factors developed. In this context, the present study delineates two distinct process factors.

Process factors

The first process factor is conceptualised under the theme *"interaction with cobots"*, which refers to the direct engagement between employees and collaborative robots. The second is captured by the theme *"impact on workplace dynamics"*, which describes emergent organisational states resulting from such interactions.

From an individual-level perspective, the theme *"interaction with cobots"* aligns with the outcome construct in conventional technology acceptance models, such as TAM, UTAUT, and TPB. These frameworks conceptualise behavioural intention as the immediate antecedent of actual system use, with use behaviour representing the behavioural manifestation—and ultimate outcome—of acceptance (Ajzen, 1991; Davis, Bagozzi, & Warshaw, 1989; Venkatesh et al., 2003). However, the present study extends this conceptualisation by demonstrating that *"interaction with cobots"* is not solely examined from an individual-level perspective but is also influenced by organisational-level conditions. Thus, this theme contributes to an expanded interpretation of usage behaviour by integrating individual and organisational-level perspectives.

Furthermore, this theme characterises employees' lived experiences with collaborative robots. This perspective is further clarified by their degree of involvement in advancement processes and the frequency of their interactions with the technology. Accordingly, the present study extends beyond focusing on executing pre-defined tasks. It also examines the flexibility of collaborative robots and their potential to enhance existing and future work processes.

The second process factor, *"impact on workplace dynamics"*, is grounded in the main codes *"alterations in social interaction"*, *"changes in communication and cooperation"*, *"changes in perception of work"*, and *"transformation of organisational processes"*. These types of transformations triggered by the implementation of emerging technologies such as collaborative robots are extensively examined in the extant literature, particularly in terms of their implications for organisational structure, culture, and workflows (Di Pasquale et al., 2023; Heinold et al., 2023; Szalavetz, 2023). The present theme reflects these developments by capturing the evolving state of organisational processes and social interactions that emerged following the integration of collaborative robots. As such, it seeks to conceptualise the workplace dynamics precipitated by technological adoption. In light of this discourse of process-related factors, the analysis now transitions to considering output factors.

Output factors

The individual-level output factor defined in this study categorises the acceptance of collaborative robots into four distinct typologies: *"active acceptance"*, *"passive acceptance"*, *"passive resistance",* and *"active resistance"*. The distinction between these typologies is derived from the factors *"attitude towards cobots"* within the input dimension and *"interaction with cobots"* within the process dimension.

In previous literature, the level of acceptance of collaborative robots has been conceptualised through a comparable framework that distinguishes between attitudinal acceptance and behavioural acceptance into four categories (Meissner et al., 2020). A critical determinant within this framework is the degree of voluntariness associated with technology use, whether technology deployment is perceived as mandatory or voluntary (Meissner et al., 2020).

In mandatory use contexts, the actual use of the technology is not a significant component in measuring acceptance (Brown, Massey, Montoya-Weiss, & Burkman, 2002). Conversely, behavioural acceptance is valid for assessing acceptance across voluntary and mandatory settings (Brown et al., 2002). As this study is conducted in an organisational context where the use of collaborative robots is predominantly voluntary, it is particularly well-suited to account for both dimensions of acceptance: the level of interaction, as reflected in active versus passive behaviours, and the attitude towards the technology.

The organisational-level output factor is conceptualised as *"system performance"*, which serves as the central outcome measure aligned with the research question. In extant literature, system performance is a multifaceted construct influenced by various human, robotic, organisational, and environmental factors (Hopko et al., 2022; Picco et al., 2024). Building on this foundation, the present study adopts the concept of human-robot team productivity as a core component of system performance, as proposed by Chen et al. (2022). Accordingly, system performance is defined from a holistic perspective, capturing the synergy, interconnectivity, and reciprocal influence among all system components on the overall productivity and efficiency of the production process.

In the existing literature, the throughput rate per unit of work effort time is frequently employed as a critical performance metric for evaluating system efficiency (Enrique et al., 2023; Zhang, Liu, Huang, Radwin, & Li, 2021). This aligns with the definition of key performance indicators for performance measurement, as defined by Kang, Zhao, Li, and Horst (2016). In the present study, this conceptualisation is operationalised through the main codes *"reduction of human effort"* and *"reduction of production time"*.

Moreover, the extant literature extensively discusses product quality as a critical dimension in assessing the outcomes of human-robot collaboration (Charalambous et al., 2015; Enrique et al., 2023; Rinaldi et al., 2023). This is consistent with the key performance indicators established to evaluate production performance (Kang et al., 2016). The current study captures this dimension by the main code *"impact on product quality"*.

In addition to the well-established components of system performance discussed in the literature, the present study introduces an additional main code that has not yet been sufficiently addressed: *"future orientation of work"*. Participants assert that the flexibility of collaborative robots and their potential to facilitate the optimisation of manufacturing processes are instrumental in enhancing organisational competitiveness. This finding extends beyond conventional, narrowly defined system performance metrics, such as productivity and efficiency, and reflects the broader strategic orientation adopted in this study.

The themes identified in this study serve as analytical lenses for understanding organisational system performance, with employee acceptance of collaborative robots acting as a foundational dimension. Although many of these individual themes are addressed in current research—drawing on diverse technology acceptance and adoption frameworks—the extant literature rarely integrates them within a unified framework that explicitly links these determinants to system performance outcomes. This gap underscores the original contribution of the present study and provides a robust foundation for discussing research objective two: the development of a conceptual framework.

5.2.3 Research objective two: Development of a conceptual framework

Based on the 12 themes generated during the analysis, a conceptual framework was developed to illustrate the critical factors influencing acceptance and system performance in collaborative robot implementation. This framework is structured along two dimensions: input, process, and output factors on the one hand and the distinction between individual and organisational-level factors on the other hand. The development of this framework adheres to the methodological approach outlined by Naeem et al. (2023), which involves the systematic conceptualisation of qualitative data through the interpretation of keywords, codes, and themes. Subsequently, the framework was operationalised visually using arrows and boxes to capture the interrelationships among the identified factors.

5.2.3.1 Summary of research findings

The proposed conceptual framework is presented visually to synthesise and communicate the research findings. Initially introduced in Chapter 4 and depicted in Figure 4-15, the framework is reproduced below to enhance the readability of the thesis.
At the core of the framework lies the interrelationships among the critical factors identified in this study. The *"personal factors"* are conceptualised as background conditions influencing individual-level input factors. The individual and organisational-level input factors jointly shape attitudes towards collaborative robots. Within the process dimension, the interaction between the collaborative robots and the employees is central, which acts as a mediating construct leading to changes in workplace dynamics. These

workplace dynamics, in turn, exert a reciprocal influence on subsequent interactions, reflecting the iterative nature of technology integration in real-world organisational settings. Over time, these interactions can also reshape and redefine the organisational-level input factor, workplace dynamics, as these evolving patterns of interaction feed back into the broader process of technology integration. Finally, the framework posits that this dynamic process culminates in the degree of acceptance of collaborative robots at the individual level, which in turn influences system performance at the organisational level.

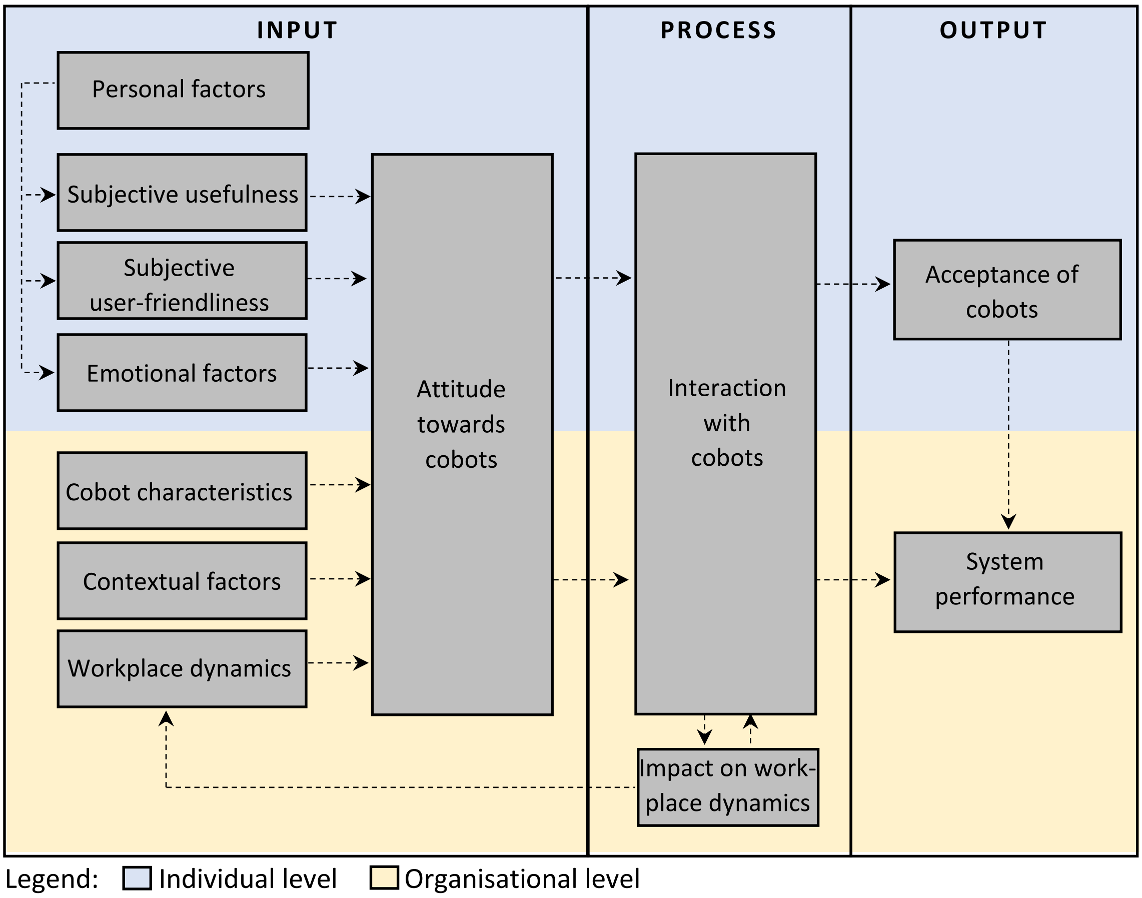


Figure 5-1: Conceptual framework of cobot acceptance and system performance

A defining feature of the conceptual framework is its recursive structure, as illustrated by the feedback loop from the process-level dimension back to the input-level dimension. This unique design signifies that integrating collaborative robots is not a linear, one-time event but an iterative process. The framework thus captures the implementation dynamics, whereby changes in input factors, whether driven by external contingencies or emerging from interactions with collaborative robots, trigger a renewed cycle of adaptation and evaluation.

5.2.3.2 Discussion in relation to extant literature

The conceptual framework developed in this study aligns with previous literature, which recognises that human factors, robot factors, and environmental factors collectively shape system performance (Hopko et al., 2022). The overarching structure of the framework linking input factors to process-level dynamics and ultimately to performance outcomes reflects a widely accepted conceptualisation in the field of team effectiveness (Mathieu, Maynard, Rapp, & Gilson, 2008). However, the developed conceptual framework advances this linear paradigm by incorporating recursive and interactive effects. In doing so, it extends the contributions of Hopko et al. (2022), who primarily focused on human factors and only briefly mentioned robot-related and environmental factors as additional influences on system performance.

In addition to the linear impact of human, robot, organisational, and environmental factors on system performance, as discussed by Hopko et al. (2022), the proposed conceptual framework illustrates the interrelationships between the process and input factors. Specifically, the theme *"impact on workplace dynamics"* positioned at the process dimension emerges as a consequence of employee interaction with collaborative robots, exerting a direct influence on the input factor *"workplace dynamics"*. Such a relationship aligns with the concept of episodic cycles, as Mathieu et al. (2008) articulated.

For instance, an episodic cycle observed in this study can be described as follows: The introduction of a collaborative robot initially led to changes in work routines and fostered new forms of cooperation among employees. Following its implementation for the first product, workflows and processes were continuously refined based on employee feedback and practical experience. As development progressed, additional products suitable for collaborative production were identified, and both the interaction with the collaborative robot and its programming were further enhanced. Another example of this recursive process is that these ongoing improvements not only increased positive experiences among staff but also prompted consideration of expanding the number of collaborative robots within the organisation. Taken together, these instances demonstrate how the recursive interplay between input and process dimensions—central to the conceptual framework—unfolds in practice.

Thus, the conceptual framework developed in this study extends beyond the traditional linear input, process, and output model by incorporating the recursive nature of organisational change through episodic cycles. This recursive structure enables the framework to capture the ongoing developmental trajectory that emerges as employees gain experience and adapt to working with collaborative robots. This approach draws on the work of Mathieu et al. (2008), who emphasise the importance of episodic and cyclical processes in shaping team development and effectiveness. The recursive configuration embedded within the conceptual framework is illustrated in Figure 5-2. This figure presents a simplified depiction of the developed conceptual framework, illustrating the episodic cycle and the developmental process within the organisational context.

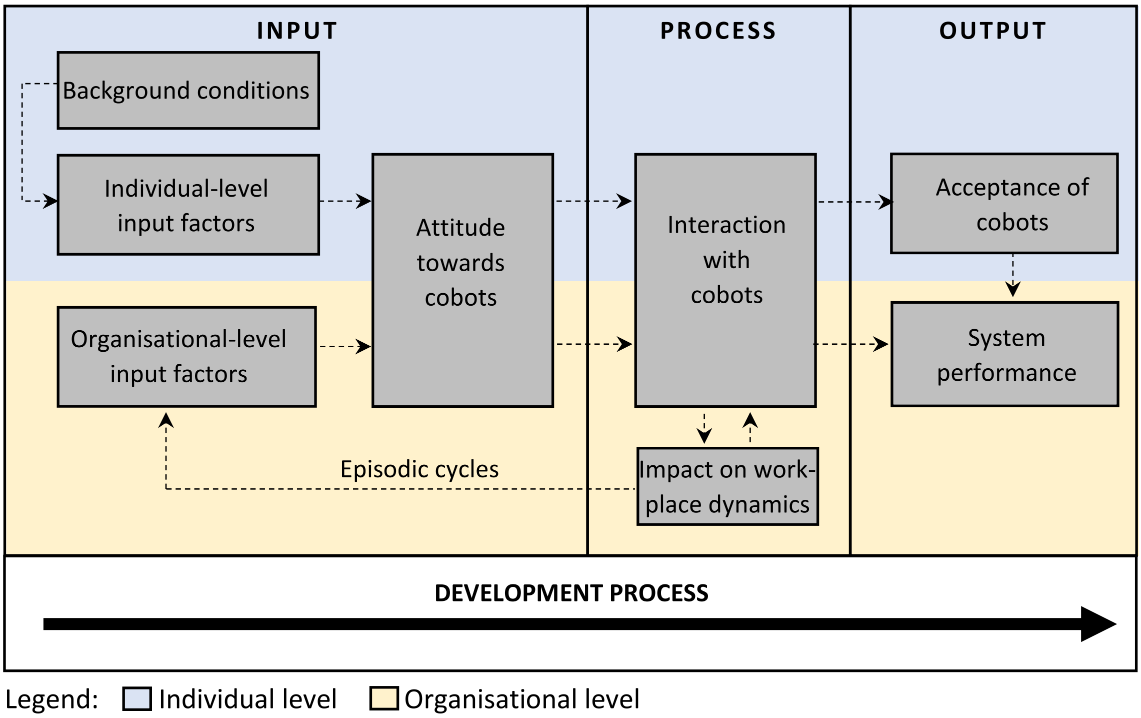


Figure 5-2: Recursiveness of the conceptual framework of cobot acceptance and system performance

In the border context of team performance, the interplay of input, process, and output cycles operating sequentially and concurrently has been conceptualised by Marks, Mathieu, and Zaccaro (2001) and Mathieu et al. (2008). The episodic nature is characterised by the end of one episode marking the beginning of another (Marks et al., 2001). This theoretical perspective is the fundamental underpinning of the developed conceptual framework proposed in this study. Thus, the conceptual framework highlights that any modification of input variables—whether triggered by external influences or evolving workplace dynamics—initiates a new episodic cycle, thereby reinforcing the recursive nature of collaborative robot integration.

Structuring the identified influencing factors on acceptance and system performance—including human, robot, and organisational elements—was not limited to the approach presented in this study; these factors could have equally been mapped within a dynamic network, as in ANT. However, the intention here was to organise these factors at a more abstract, process-oriented level, in order to develop a framework that is not tied solely to the present case but can be transferred to similar contexts and could be further refined in comparative research.

Aligned with the conceptual framework proposed, practical recommendations to create conditions for favourable user responses and attitudes toward collaborative robots can be derived, forming the basis for addressing the third research objective.

5.2.4 Research objective three: Creating conditions for favourable user responses

In addition to addressing the first two objectives, which primarily focus on theoretical aspects, discussing the practical implications of the research findings derived from the conceptual framework is essential. The following subsection, therefore, adopts a managerial perspective and provides actionable recommendations grounded in the critical influencing factors identified in this study. These insights are intended to support decision-makers in fostering acceptance and system performance when implementing collaborative robots within their organisations.

5.2.4.1 Summary of research findings

The research findings are operationalised through recommendations aligned with the four typologies of acceptance identified at the individual-level output within the conceptual framework, specifically under the theme of *"acceptance of cobots"*. These types comprise active acceptance, passive acceptance, passive resistance, and active resistance, which are structured by the axes *"attitude towards cobots"* and *"interaction with cobots"* in a matrix (see Figure 4-16). These axes reflect key factors previously identified within the input and process dimensions of the conceptual framework.

The critical factor, *"attitude towards cobots"*, is shaped by the full spectrum of input factors identified in this study and systematically integrated into the developed conceptual framework. For employees classified as active acceptors, the findings indicate that the initial focus should be on organisational-level input factors in reinforcing positive attitudes. Conversely, the research findings suggest that the focus should be on individual-level input factors for employees actively resistant to collaborative robots.

The critical factor of *"interaction with cobots"* is particularly pertinent for employees who are passive towards the technology. For those with passive acceptance, strategic emphasis should be placed on gradually increasing the complexity and relevance of tasks when deploying collaborative robots. In the context of employees displaying passive resistance, the priority should be to gradually enhance the quality and frequency of interaction with collaborative robots in order to foster positive experiential sentiments.

The conceptual framework developed in this study is designed to serve as a strategic tool for organisations, enabling them to implement tailored actions and measures to enhance employee acceptance of this technology. A central tenet is that employees should not be considered a homogeneous group; thus, a one-size-fits-all approach is unlikely to be effective. Instead, managers are encouraged to adapt their approach based on employees' attitudes towards the collaborative robot and their use of it.

5.2.4.2 Discussion in relation to extant literature

As highlighted in the literature, several strategies have been proposed to increase the acceptance of collaborative robots in organisational settings. Among these, a prominent approach involves simultaneously promoting enablers and mitigating barriers to adoption, as Charalambous et al. (2015) outlined. The following six enablers were identified as being of critical importance for the implementation of collaborative robots: (1) communication of the change, (2) employee participation in implementation, (3) training and development of the workforce, (4) existence of process champions, (5) organisational flexibility through employee empowerment, and (6) management commitment and support (Charalambous et al., 2015). The following discussion contextualises these enablers in light of both recent empirical findings and the results of the present study.

Lambrechts et al. (2021) posited that open and honest communication is critical in implementing collaborative robots, aiming to enhance employees' willingness to engage in this change. This finding aligns with the results of the present study, in which the theme of *"workplace dynamics"* encompasses *"communication"*, particularly relating to the technology implementation process.

Moreover, prior literature has identified employee participation in the implementation process as a critical determinant of technology acceptance, particularly in the context of collaborative robots (Meissner et al., 2020). This was also reflected in the current study under the theme of *"workplace dynamics"*, notably with regard to the degree of involvement in implementation.

Another key enabler identified in the existing literature is training for employees using collaborative robots. Such training has been shown to increase employees' confidence and sense of ownership (Fraboni et al., 2023). In the present study, participants similarly emphasised the importance of support mechanisms and training initiatives, particularly regarding the novel competencies required for effective human-robot collaboration, captured under *"subjective user-friendliness".*

Employee empowerment has been identified as another critical enabler for technology acceptance, including collaborative robots (Eimontaite et al., 2022; Meissner et al., 2020). The present study also identified this aspect under the *"workplace dynamics"* theme, specifically within the main code *"leadership culture".*

Moreover, employees encountering collaborative robots for the first time often express a desire for assistance from more experienced colleagues to help them navigate the initial stage of adoption (Meissner et al., 2020). This dynamic was captured in the present study within the theme of *"subjective user-friendliness"*, specifically within the code *"support and assistance"*.

Another critical enabler identified in the extant literature is the role of managerial support in facilitating the successful integration of collaborative robots. This notion has been substantiated by Zemlyak et al. (2022) and Liu and Cao (2022). The present case study further corroborates this assertion, encompassing management support within the *"contextual factors"* theme.

All enablers for successful human-robot collaboration outlined by Charalambous et al. (2015) are reflected within the input factors of the developed conceptual framework. This alignment underscores the breadth and empirical grounding of the conceptual framework, holistically capturing the broad spectrum of possible determinants of collaborative robot integration. Charalambous et al. (2015) primarily focus on human factors and organisational and environmental factors. However, this perspective does not encompass the whole spectrum of influences on human-robot collaboration, particularly omitting robot-related factors, which were defined as significant determinants for productive human-robot collaboration (Di Pasquale et al., 2024; Hopko et al., 2022). The present framework addresses this gap by explicitly incorporating *"cobot characteristics"* as a theme.

Consequently, this research offers managers a more holistic perspective for fostering user acceptance of collaborative robots. In contrast to previous studies that predominantly offer generalised recommendations, the present study introduces a differentiated approach by categorising employees based on their acceptance levels. This stratification enables the formulation of context-specific strategies tailored to the distinct needs of different user groups, thereby enhancing the effectiveness of managerial recommendations.

Following an extensive review of the current literature regarding the three research objectives and an in-depth analysis of the empirical findings, it is now possible to articulate the study's contributions to theoretical advancement and practical application.

5.3 Contribution to theory

The theoretical contribution of this research begins with identifying and exploring critical factors that enable a deeper understanding of acceptance and system performance in collaborative robot implementation. Adopting an exploratory qualitative approach, this study extends beyond the scope of the determinants investigated in conventional information systems literature by uncovering distinctive determinants emerging specifically within human-robot collaboration. These determinants are analysed from individual and organisational perspectives, offering a more holistic understanding of system performance. The findings are grounded in an extensive empirical dataset comprising over 2,300 participant statements, systematically coded into 84 initial codes, which were subsequently classified into main codes, codes, and sub-codes.

The theme of *"emotional factors"* developed in this study represents an aspect that has remained relatively underexplored, as Hopko et al. (2022) stated. This study responds to this gap, which has also been emphasised by several other scholars, including Arslan et al. (2022), Rinaldi et al. (2023), and Ronzoni et al. (2021). In particular, the findings of the present analysis emphasise the central role of the emotional dimension as a major driver in shaping attitudes towards collaborative robots. Notably, this theme received the highest number of coded statements among all identified themes, highlighting its empirical prominence. Accordingly, *"emotional factors"* have to be considered a critical determinant influencing acceptance and system performance when deploying collaborative robots. The significance of this theme is further reinforced by recent theoretical developments, such as the extension of the UTAUT framework, which explicitly incorporates this aspect (Porubčinová & Fidlerová, 2020).

Moreover, the present study delineates a multifaceted array of background conditions influencing the identified individual-level input factors shaping the acceptance of collaborative robots. Several of these background conditions align with moderating variables of well-established technology acceptance frameworks, including TAM2, TAM3 and UTAUT, with regard to demographic factors such as age and gender, as well as other moderators such as experience (Venkatesh et al., 2003; Venkatesh & Bala, 2008; Venkatesh & Davis, 2000). In addition to these well-documented moderators, the current study identifies novel background conditions, such as employees' job position and work preference, which have not been systematically addressed in existing frameworks.

In addition, the study incorporates the aspect of flexibility of collaborative robot technology—a facet particularly salient in this context—in a manner that extends beyond the scope of well-established individual-level technology acceptance models, such as UTAUT. Specifically, this aspect is examined through *"subjective user-friendliness"* and *"interaction with cobots"*. In both themes, the scope encompasses the current utilisation of technology and the potential to evolve and be integrated into future work processes. Thus, the stance taken in this study extends beyond the perspective in the extant literature, such as the work of Venkatesh et al. (2003). The adopted approach is particularly pertinent for collaborative robots, whose flexibility enables continuous optimisation of production systems. The findings thus underscore the importance of viewing technological acceptance as an ongoing developmental trajectory shaped by evolving work practices and technological capabilities.

Second, the most significant theoretical contribution of the current thesis lies in developing a holistic conceptual framework that advances scholarly understanding of acceptance and system performance in the context of collaborative robots. This framework is grounded in the empirically derived themes identified as critical factors influencing acceptance and how they are associated with system performance. It offers a holistic perspective by incorporating individual and organisational variables, extending conventional technology acceptance models. Notably, the framework addresses a gap in the literature by explicitly including characteristics of collaborative robots as a distinct dimension, an aspect acknowledged by scholars, including Di Pasquale et al. (2024), Rinaldi et al. (2023), and Hopko et al. (2022), that has not been effectively addressed in the literature. Moreover, the framework's recursive nature, highlighted by incorporating episodic cycles in workplace dynamics, introduces a non-linear understanding of human-robot interaction. This recursive character reflects the evolving nature of input and process variables in response to changing contextual and experiential conditions, offering a novel theoretical lens for examining the integration of collaborative robots in organisational settings.

Thirdly, the present study offers novel insight into implementing collaborative robots from an industry-based perspective. These insights were derived through the empirical analysis of a real-world manufacturing application that had been operational for nearly one year at the commencement of primary data collection. Consequently, this study responds to the call for real-world empirical data articulated by several scholars, including Liao et al. (2023), Liu, Caldwell, Rittenbruch, Müge, Burden, and Guertler (2024), Parvez et al. (2022), and Rossato et al. (2021). This demand arises from recognising that a substantial portion of research has been conducted in laboratory settings. Such a setting might lead to overlooking critical variables that emerge in operational environments due to their controlled nature (Liu, Caldwell, Rittenbruch, Müge, Burden, & Guertler, 2024).

The present study distinguishes itself from conventional laboratory-based research by adopting a real-world organisational setting within the healthcare manufacturing sector. In this context, collaborative robots have been fully integrated into established and routine manufacturing operations. The study draws on insights from employees and managers who have engaged with these technologies over an extended period, capturing experiences beyond the initial stages of adoption. This contrasts with most extant studies conducted in real-world environments, which focus on the early implementation phase (Dornelles et al., 2023). As such, the methodological design of this study significantly advances theoretical understanding while offering meaningful, practical implications for industry practitioners and decision-makers.

5.4 Contribution to practice

The contribution to practice is grounded in managerial and practitioner-oriented recommendations derived from the proposed conceptual framework. These recommendations are specifically designed to foster favourable user responses towards collaborative robots, thus influencing acceptance and system performance, as outlined in the conceptual framework.

Given these implications, it is imperative for organisations to acknowledge the strategic importance of collaborative robotics within the contemporary business landscape. This recognition is underscored by the steady increase in the adoption of this technology and the robust growth trajectories of the collaborative robotic market. Recent market projections predict that the global collaborative robotics market will reach approximately USD 12 billion by 2029, with a compound annual growth rate of over 30% between 2024 and 2029 (The Business Research Company, 2025b).

In order to support the deployment of collaborative robots, the conceptual framework yielded practical implications for the healthcare industry, particularly in processes such as packaging medical and diagnostic products, producing reagents, and automating laboratories. Integrating collaborative robots into these processes can increase productivity and ensure consistent product quality, enhancing operational efficiency and addressing patient needs. In addition, collaborative robots also relieve skilled staff from routine and repetitive tasks, allowing them to focus on more complex and value-adding activities, which is particularly important given the current shortage of qualified personnel in healthcare settings (Bhuwane et al., 2023). Furthermore, the flexibility and ease of integration of collaborative robots enable healthcare companies to quickly adapt to new regulatory requirements and product changes, thereby maintaining compliance and competitiveness in a highly dynamic market.

The main practical contribution of this thesis lies in developing tailored recommendations for distinct employee groups, differentiated according to their level of acceptance of collaborative robots. The level of acceptance is categorised into four categories: active acceptance, passive acceptance, passive resistance, and active resistance. Tailored recommendations were formulated for each group, grounded in the conceptual framework developed around *"attitude towards cobots"* and *"interaction with cobots"*. These recommendations, presented in Section 4.6, are not intended to be exhaustive. Instead, the objective is to provide managers with initial measures to enhance user acceptance and to motivate them to develop specific actions tailored to their circumstances, based on the conceptual framework and the described employee groups. This approach recognises individual differences and incorporates them into developing strategies to foster favourable user responses and attitudes towards collaborative robots, as Lu et al. (2022) suggested.

The applicability of the proposed conceptual framework is most relevant to organisational settings analogous to those examined in this study, particularly within the healthcare sector, including pharmaceutical and diagnostics companies. The context that most closely reflects the study's circumstances involves the use of collaborative robots in the packaging processes within this industry.

The global pharmaceutical packaging market was valued at over USD 150 billion in 2024 and is expected to grow at a compound annual growth rate of over 15% from 2025 to 2034 (Global Market Insights, 2025). A practical example of how collaborative robots can be applied to pharmaceutical packaging is provided by George and George (2023). While traditional pharmaceutical production lines are designed for high-volume production, collaborative robots can increase efficiency in the small to medium-batch-size segment. It is imperative to acknowledge that the ongoing trend toward personalised healthcare is expected to significantly increase the number of manufacturing processes characterised by smaller batch sizes. In this context, the integration of collaborative robots in the domain of pharmaceutical packaging has the potential to act as a transformative catalyst for the industry.

The conceptual framework developed in this study offers practical guidance for managers seeking to integrate collaborative robots, particularly for promoting system performance. The findings can inform both the enhancement of existing applications and the strategic planning of future implementations. The capacity of collaborative robots to operate synergistically with human operators yielded several benefits. These include potential reductions in labour costs, increased production speed, decreased production downtime, and lower error rates. Furthermore, the integration of collaborative robots can enhance the qualitative aspects of work by increasing job value and reducing the physical fatigue experienced by employees.

Consequently, organisations operating in environments similar to the case study context may consider the insights from this thesis highly relevant and applicable. While the research is grounded in packaging, the critical factors identified may also resonate with other manufacturing processes, such as the filling and compounding of diagnostics and pharmaceutical products. However, the successful deployment of collaborative robots is contingent upon establishing a compelling business case. Where such a case exists, the effective adaptation of the workforce becomes a critical success factor in fully realising performance improvements associated with collaborative robot integration. As the findings presented herein are grounded in real-world manufacturing applications, they offer actionable insights for organisations.

Following the discussion of the practical implications of the research, the subsequent section critically evaluates its quality. In this context, the concept of trustworthiness is of central importance for assessing the credibility and rigour of the findings (Ghafouri & Ofoghi, 2016; Tierney & Clemens, 2011).

5.5 Assessment of research quality

The trustworthiness of qualitative research can be rigorously assessed through the four key criteria: (1) credibility, (2) transferability, (3) dependability, and (4) confirmability (Guba, 1981; Tierney & Clemens, 2011). Additionally, the criterion of authenticity, particularly relevant within the study's epistemological paradigm, was incorporated as an additional quality criterion that merits further consideration (Guba & Lincoln, 1994). The following discussion elaborates on these dimensions, highlighting their specific application within the context of the present study.

Credibility

Credibility refers to the degree of confidence in the truthfulness of the research findings and the extent to which they accurately represent the participants' experiences and views (Tobin & Begley, 2004). In the present study, several strategies were employed to enhance the credibility of the study findings.

Data triangulation was employed at two distinct levels, following the recommendations from Flick (2018b). After a detailed analysis, a high degree of consistency was observed across the data sources. First, convergence was identified between data obtained through participant observations and semi-structured interviews conducted with the same individuals. This concordance reinforced the credibility of the research findings by indicating alignment between observed behaviours and participants' articulated opinions, experiences, and perceptions. The absence of an identified discrepancy between the findings from the two data collection methods serves as an indicator, ruling out the possibility of hidden or unconscious factors. Second, consistency was noted when comparing findings across different data collection methods. Integrating multiple data sources and methodological approaches facilitated a more holistic and nuanced understanding of the phenomenon under investigation (Yin, 2018). This triangulation strategy is instrumental in minimising bias and strengthening the overall trustworthiness of the research outcomes.

The credibility of the study findings was further reinforced through probing techniques during semi-structured interviews (Lim, 2024). These efforts were complemented by trust-based relationships between the researcher and participants and prolonged engagement with both the participants and the research topic, as recommended by Ahmed (2024). The period of data collection in this study was 14 months. In addition, credibility was improved due to member checking, as advocated by Tobin and Begley (2004). Participants were invited to review the interview transcripts and verify the translation of key statements to ensure the accuracy and authenticity of the data interpretation.

Recognising and critically reflecting on personal biases and perceptions throughout the research process enables the researcher to take a more objective and balanced stance regarding data collection, analysis and interpretation (Ahmed, 2024). This was achieved in the current research through reflexive memos and discussions with supervisors, which encouraged critical thinking about assumptions and interpretations, uncovered blind spots, and deepened reflexive practices.

Furthermore, adherence to established ethical principles significantly enhances the credibility and overall trustworthiness of the research. The present study received formal approval from the university's research ethics committee, ensuring all procedures complied with institutional and disciplinary ethical standards. The ethical principles underpinning the study included the provision of informed consent, maintaining confidentiality, and upholding the right to withdraw from the study at any time, thereby enhancing the integrity of the data collection process.

Transferability

In this regard, transferability refers to the extent to which research findings can be meaningfully applied to other contexts or groups (Malterud, 2001; Maxwell, 2021). In order to ensure transferability and the potential applicability of the findings to other groups or contexts, several measures were taken to support informed judgment by future researchers and practitioners. These include a detailed description of the context-specific details associated with the case study provided, as Nowell et al. (2017) suggested, outlining the structural, organisational, and operational characteristics of the environment in which the research was conducted. Such contextual details enable readers to assess the relevance of the findings to other settings. Furthermore, the study engaged in ongoing reflexive analysis throughout the research process, critically examining the researcher's assumptions and positionality. This reflexivity further enhanced the transferability of the results by promoting transparency in interpreting findings.

Dependability

According to Tobin and Begley (2004), dependability refers to the stability and consistency of the research process over time and is contingent upon a logical, traceable, well-documented methodological approach. This includes the explicit recording and justification of decisions made throughout the study. In the present research, dependability was ensured through comprehensive documentation of the research design, data collection procedures, and analysis methods. Additionally, using reflexive memos to record methodological decisions and any adjustments made during the research process reinforces the dependability of the study findings.

Confirmability

Confirmability refers to the extent to which research findings are shaped by the participants' responses and the data collected rather than by researcher bias or preconceptions (Tobin & Begley, 2004). In the present study, confirmability was supported through meticulous documentation of the data analysis process. The researcher's use of clarifying questions during data collection further ensured that interpretations were grounded in participants' intended meanings. Additionally, the inclusion of critical verbatim statements and the systematic documentation of the relationships among keywords, codes, and themes presented in the findings chapter serve to reinforce that the conclusions are firmly grounded in empirical evidence.

Authenticity

Authenticity refers to the extent to which a research study faithfully represents the diverse perspectives and lived experiences of participants, thereby contributing to the richness and depth of the data (Tobin & Begley, 2004). In this study, several strategies were implemented to promote authenticity.

To foster authenticity, the research design intentionally created an environment in which participants were encouraged to reflect deeply on and share their experiences related to the research topic, as Tobin and Begley (2004) recommended. This environment was facilitated by using semi-structured interviews, which allowed participants to express their thoughts and feelings in their own words freely. In addition to the interviews, participant observation provided further opportunities to capture authentic perspectives and behaviours in real-world contexts. Throughout the research process, particular emphasis was placed on ensuring that participants could engage with and reflect on their viewpoints, thereby contributing to a deep and nuanced understanding of the phenomenon under investigation. Questions designed to elicit social perspectives, including the influence of peers and the viewpoints of managers, played a key role in this process.

The authenticity of the study was further enhanced by incorporating different participant groups, including both employees directly interacting with the collaborative robot and their line managers, following a dyadic approach. This diversity of perspectives enabled a more nuanced and in-depth understanding of the phenomenon under investigation. Additionally, the broad age range and the inclusion of both female (n=10) and male (n=17) participants further contributed to capturing a wide spectrum of experiences and viewpoints, thereby strengthening the authenticity and depth of the research findings.

Taken together, these measures ensure the trustworthiness and authenticity of the research findings, contributing to the overall rigour and credibility of the study. Thus, the research offers meaningful insights into the research topic under investigation by grounding the analysis in systematically collected and transparently documented data.

Nevertheless, it is crucial to recognise that no study is without limitations. It is, therefore, vital to acknowledge these limitations to contextualise the findings and establish a solid foundation for future research.

5.6 Limitations of the research

This section outlines the key limitations of the study, focusing primarily on methodological and substantive dimensions. Recognising these limitations is essential for a critical interpretation of the findings and a nuanced understanding of their implications.

From a methodological perspective, the present study is subject to limitations concerning transferability. This constraint is primarily attributable to the qualitative research design, which inherently limits the transferability of findings. It is acknowledged that the research findings derived from qualitative case studies may not be directly transferable to other organisations operating under substantially different contexts (Dimmock & Lam, 2016). This limitation is discussed in detail in Section 3.6, and several strategies were employed to ensure the transferability of research findings—including a detailed description of the study context and the use of reflexive memos throughout the research process to document the researcher's perspective and reflections—as described in Section 5.5.

In addition, the single case study design employed in this research presents a further limitation regarding transferability, as the data were collected from a single organisational setting. Consequently, the results cannot be assumed to represent broader populations or alternative industrial settings (Yin, 2018). While this restricts transferability, the limitation is offset by the depth of empirical insights uncovered through an in-depth investigation of a real-world manufacturing application, allowing for a rich understanding of the phenomenon under study.

Moreover, using the theoretical sampling strategy may further limit the transferability of research findings (Charmaz, 2014). This strategy inherently introduces subjectivity, given that participant selection is based on the researcher's evaluative judgment regarding theoretical relevance, and thus may result in sampling bias (Charmaz, 2014).

Finally, it is imperative to acknowledge the temporal constraints imposed on the data collection process. The investigation was conducted within a defined time frame, restricting the capacity to observe longitudinal developments such as evolving perceptions, adaptation processes, or changes in organisational dynamics over time. Consequently, the findings represent a time-bound view, which may fail to reflect evolving dynamics, as Marinescu et al. (2023) highlighted.

In addition to methodological constraints, the study is subject to several substantive limitations that further warrant consideration regarding the transferability of its findings. First, the study focuses on a single model of a collaborative robot, which limits the transferability, particularly in aspects such as anthropomorphism. Different collaborative robots may possess varying degrees of humanoid features and interaction capabilities, which could significantly shape user perceptions and interactions (Liao et al., 2023). Moreover, the study was conducted in an organisational context where the use of collaborative robots was largely voluntary, a factor known to influence behavioural intention regarding technology use, as Venkatesh et al. (2003) emphasised. Finally, the sample consisted exclusively of German participants, which imposes limitations on the cultural and geographical transferability of the results.

Acknowledging these limitations offered a balanced and critical perspective, allowing for a nuanced interpretation of the study findings. While these constraints define the scope of the study, they underscore the theoretical and practical relevance of the findings within the research context. Moreover, they provide promising avenues for future research, particularly in enhancing transferability, exploring longitudinal effects, and validating the findings across diverse industrial settings.

5.7 Recommendations for future research

The conceptual framework developed in this thesis offers an integrative illustration of the critical factors influencing acceptance and thus shaping system performance in deploying collaborative robots, addressing and narrowing the identified research gap. In addition to its explanatory value, it suggests potential avenues for future inquiry by delineating key variables and their interrelationships. Consequently, it holds promise as a well-grounded starting point for subsequent research, thereby narrowing the identified research gap further.

First, an analysis of the various organisational setups within the healthcare manufacturing sector is required to assess the applicability and relevance of the findings within this domain. It is recommended that further studies explore both voluntary and mandatory contexts of the utilisation of collaborative robots. While the present study was conducted in a voluntary use setting, examining mandatory implementation scenarios—as discussed in Meissner et al. (2020) and Venkatesh et al. (2003)—is critical for understanding how voluntariness may influence user acceptance and system performance. Such comparative analyses would enhance the transferability of findings across diverse organisational setups and use conditions within the healthcare manufacturing sector. In addition, future research should systematically examine the newly identified background conditions—namely, employees' job position and work preference—to clarify their specific impact and integration within human-robot collaboration across different organisational and implementation contexts.

Additionally, the study's findings should be validated through quantitative methodologies applied across diverse manufacturing contexts. To this end, researchers should examine a range of manufacturing settings employing various types of collaborative robots, differentiated by their degrees of anthropomorphism. This recommendation stems from persistent ambiguities observed in existing literature regarding the impact of anthropomorphism in studies such as Liao et al. (2023), Liu, Zou, and Greene (2024), and Sinha et al. (2020).

Second, given that the present study was limited to participants based in Germany, future research should be conducted in more diverse cultural contexts. One potential approach would be to conduct studies within Germany with participants from diverse national and cultural backgrounds. Alternatively, cross-cultural comparative studies across multiple countries would offer valuable insights into how cultural norms and values shape perceptions and interactions with collaborative robots. This is important because the significance of cultural factors in shaping research outcomes concerning human-robot collaboration is well-documented (Liao et al., 2023; Sinha et al., 2020). For instance, Bröhl, Nelles, Brandl, Mertens, and Nitsch (2019) found notable cultural differences in anxiety exhibited by individuals in the context of robots in Japan compared to Germany and the United States. Their findings underscore the importance of cultural variability in emotional responses to robots (Bröhl et al., 2019). The current study further supports this claim, as emotional factors, particularly those associated with the thematic code *"fears associated with cobots"*, emerged as a salient dimension, reflected in the frequency and depth of participant statements. Thus, the prominence of emotional responses in the present data highlights the necessity of future research in culturally diverse contexts.

Third, the necessity of incorporating longitudinal design in the study of human-robot collaboration is reaffirmed, as previously stated by Fraboni et al. (2023) and Liao et al. (2024). Longitudinal studies involving data collection across multiple time points could be advantageous, particularly in analysing acceptance and system performance over time. The conceptual framework developed in the present study is based on findings derived from a specific temporal and contextual time frame. By adopting a longitudinal design, future research can more effectively examine the dynamic interplay between contextual factors and workplace dynamics in shaping system performance. For instance, analysing the effects of management decisions or changes in employee attitudes related to ongoing interactions with collaborative robots could yield deeper insights into the evolving nature of human-robot interactions.

After outlining the study limitations and recommendations for future research, critically reflecting on the research journey is crucial. The process of conducting this study has yielded numerous insights, both on a professional and personal level. The following section presents the researcher's personal reflections on the research process, including the challenges encountered and the knowledge acquired throughout this academic endeavour. As Braun et al. (2022) emphasise, such reflexive engagement is fundamental to sound thematic analysis.

5.8 Personal reflections

The personal reflections on the research journey undertaken over the past nearly seven years can be categorised into two distinct phases: the period dedicated to complementary studies and the process of creating the current thesis. Willig (2022) asserts that personal reflexivity plays a vital role in this process, underscoring the knowledge and skills acquired throughout the research journey and how the research process has influenced and potentially transformed the researcher.

The period dedicated to complementary studies has established a robust foundation for the subsequent steps in the research journey by enabling the researcher to deepen her understanding of research methodologies and engage in meaningful discussions surrounding key substantive topics relevant to this thesis. Moreover, it facilitated introspection on various situations and experiences within academia and the business sector. Thus, the period of complementary studies has significantly shaped the researcher's academic, professional, and personal development across multiple dimensions. A noteworthy aspect of this journey pertains to the capacity to engage in reflection and critical thinking, a capacity that underwent a substantial enhancement during the course of the complementary studies.

The second phase of the research journey—the development of the thesis—was substantially informed and enriched by the period of complementary studies. Despite this preparatory foundation, the initial stages of creating this thesis appeared daunting at the outset, mainly due to the breadth of the research domain and the inherent complexity of the subject matter. These challenges necessitated a methodical and systematic approach. Commencing with a structured literature review and engaging with previous studies and theories on implementing collaborative robots in manufacturing settings provided a solid foundation. This foundational work was crucial in formulating the research question and objectives, providing a clear roadmap for the study. Additionally, developing a detailed timeline supported effective workload management and the establishment of realistic milestones, which ensured steady progress throughout the research process.

During the data collection phase, the significance of a robust methodological framework became increasingly evident. Given the subjectivist nature of the research, which demanded an understanding of individuals' perspectives within the context of collaborative robot work environments, a qualitative approach was deemed most suitable. Participant observations and semi-structured interviews were utilised to gather primary data, yielding nuanced insights into the organisational dynamics of working with collaborative robots. This strategy demanded considerable effort, patience, adaptability, and meticulous attention to detail. Each interaction with participants enriched the depth of the findings and provided critical context, ultimately enhancing the overall quality and rigour of the research endeavour.

The subsequent phase of data analysis, grounded in the six stages of reflexive thematic analysis, emerged as intellectually stimulating and demanding. The interpretation of the qualitative data necessitated a critical acknowledgement of personal biases and preconceived notions, emphasising the vital role of reflexivity and the ability to synthesise complex information. The iterative process of the reflexive thematic analysis yielded valuable findings and illuminated the intricate interplay of various critical factors influencing acceptance and system performance within human-robot collaboration. Consequently, it was paramount to remain open-minded and flexible during this phase, as the emergence of unexpected patterns and themes provided richer insights into the research context.

Several obstacles were encountered throughout the writing process, notably effective time management and the maintenance of motivation during periods of self-doubt. However, these challenges proved to be instrumental in fostering resilience and discipline. The support provided by the supervisors, who actively engaged in discussions and critically challenged ideas, was of inestimable value. Their encouragement and constructive criticism were instrumental in facilitating the continuous development of this thesis, thereby ensuring that the process remained firmly grounded in the collected data.

Completing the thesis has been a transformative experience that has significantly advanced the researcher's analytical skills and deepened the understanding of organisational behaviour. It has underscored the critical importance of employing a rigorous methodological approach to address the research questions posed effectively. Beyond the academic milestones achieved, this journey has engendered a profound sense of accomplishment and confidence in scholarly abilities. Personal values, including a commitment to continuous learning and a belief in the importance of thorough research, have been reinforced throughout this process. Looking ahead to future research endeavours, the lessons learned from this experience will undoubtedly serve as a cornerstone.

5.9 Conclusion of the thesis

This dissertation makes a significant contribution to the field of technology acceptance research by exploring how acceptance-related factors shape system performance within the healthcare manufacturing industry. This study offers a nuanced understanding of human-robot collaboration by applying the constructivist grounded theory methodology, supported by reflexive thematic analysis. Drawing on an in-depth case study of a leading global healthcare manufacturer in Germany, the research employed document analysis, eight participant observations, and 27 semi-structured interviews with employees and managers.

The core contribution of this study is developing a conceptual framework that holistically captures the interplay among individual and organisational factors influencing acceptance and shaping system performance. By mapping input, process, and output factors, this framework offers nuanced insights into the dynamics of collaborative robotics in real-world manufacturing settings. A significant finding stems from the study identifying the critical role of emotional factors in shaping technology acceptance and system performance, an aspect overlooked mainly in extant literature, as noted by Hopko et al. (2022).

These findings deepen the theoretical understanding of collaborative robots in Industry 4.0 environments and establish a solid foundation for future investigations into the integration of artificial intelligence and collaborative robots, an essential step toward realising the vision of Industry 5.0, as outlined by Wang et al. (2025). Despite the study's limitations, the proposed conceptual framework offers scholars and industry practitioners valuable guidance. It provides a practical tool for managers aiming to implement collaborative robotics in manufacturing environments and gives scholars a basis for further conceptual development.

In sum, this study substantially contributes to the evolving scholarly discourse on technology acceptance and human-robot collaboration. The insights generated here pave the way for more impactful, interdisciplinary research, bridging theory and practice. As collaborative robot adoption evolves, this study serves as a vital stepping stone for future exploration in understanding their impact on system performance, advancing academic inquiry and practical implementation.

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Appendices

Appendix A: Results of the structured literature review

Appendix A.1: Overview of the selected publications for literature review (sorted by year of publication)

Authors	Title	Journal	Year
Wang, W., Chen, Y., Li, R., Jia, Y.	Learning and comfort in human-robot interaction: A review	Applied Sciences	2019
Eimontaite, I., Gwilt, I., Cameron, D., Aitken, J. M., Rolph, J., Mokaram, S., Law, J.	Language-free graphical signage improves human performance and reduces anxiety when working collaboratively with robots	International Journal of Advanced Manufacturing Technology	2019
Sinha, N., Singh, P., Gupta, M., Singh, P.	Robotics at workplace: An integrated Twitter analytics–SEM based approach for behavioral intention to accept	International Journal of Information Management	2020
Meissner, A., Trübswetter, A., Conti-Kufner, A. S., Schmidtler, J.	Friend or Foe? Understanding Assembly Workers' Acceptance of Human-robot Collaboration	ACM Transactions on Human-Robot Interaction	2020
Simões, A. C., Soares, A. L., Barros, A. C.	Factors influencing the intention of managers to adopt collaborative robots (cobots) in manufacturing organizations	Journal of engineering and technology management	2020
Gervasi, R., Mastrogiacomo, L., Franceschini, F.	A conceptual framework to evaluate human-robot collaboration	International Journal of Advanced Manufacturing Technology	2020
Kopp, T., Baumgartner, M., Kinkel, S.	Success factors for introducing industrial human-robot interaction in practice: an empirically driven framework	International Journal of Advanced Manufacturing Technology	2021
Javaid M., Haleem A., Singh R.P., Suman R.	Substantial capabilities of robotics in enhancing industry 4.0 implementation	Cognitive Robotics	2021
Ronzoni, M., Accorsi, R., Botti, L., Manzini, R.	A support-design framework for Cooperative Robots systems in labor-intensive manufacturing processes	Journal of Manufacturing Systems	2021
Rossato, C., Pluchino, P., Cellini, N., Jacucci, G., Spagnolli, N., Gamberini, L.	Facing with collaborative robots: The subjective experience in senior and younger workers	Cyberpsychology, Behavior, and Social Networking	2021
Leesakul, N., Oostveen, A.-M., Eimontaite, I., Wilson, M. L., Hyde, R.	Workplace 4.0: Exploring the implications of technology adoption in digital manufacturing on a sustainable workforce	Sustainability	2022

Authors	Title	Journal	Year
Muller, T., Subrin, K., Joncheray, D., Billon, A., Garnier, S.	Transparency Analysis of a Passive Heavy Load Comanipulation Arm	IEEE Transactions on Human-Machine Systems	2022
Lu, Y., Zheng, H., Chand, S., Xia, W., Liu, Z., Xu, X., Wang, L., Qin, Z., Bao, J.	Outlook on human-centric manufacturing towards Industry 5.0	Journal of Manufacturing Systems	2022
Gualtieri, L., Fraboni, F., De Marchi, M., Rauch, E.	Development and evaluation of design guidelines for cognitive ergonomics in human-robot collaborative assembly systems	Applied ergonomics	2022
Simões, A. C., Pinto, A., Santos, J., Pinheiro, S., Romero, D.	Designing human-robot collaboration (HRC) workspaces in industrial settings: A systematic literature review	Journal of Manufacturing Systems	2022
Tausch, A., Peifer, C., Kirchhoff, B. M., Kluge, A.	Human–robot interaction: how worker influence in task allocation improves autonomy	Ergonomics	2022
Arslan, A., Cooper, C., Khan, Z., Golgeci, I., Ali, I.	Artificial intelligence and human workers interaction at team level: a conceptual assessment of the challenges and potential HRM strategies	International Journal of Manpower	2022
Hopko, S., Wang, J., Mehta, R.	Human factors considerations and metrics in shared space human-robot collaboration: A systematic review	Frontiers in Robotics and AI	2022
Eimontaite, I., Cameron, D., Rolph, J., Mokaram, S., Aitken, J. M., Gwilt, I., Law, J.	Dynamic Graphical Instructions Result in Improved Attitudes and Decreased Task Completion Time in Human-Robot Co-Working: An Experimental Manufacturing Study	Sustainability	2022
Liu, D., Cao, J.	Determinants of collaborative robots innovation adoption in small and medium-sized enterprises: an empirical study in China	Applied Sciences	2022
Zemlyak, S., Gusarova, O., Sivakova, S.	Assessing the Influence of Collaborative Technology Adoption—Mediating Role of Sociotechnical, Organizational, and Economic Factors	Sustainability	2022
Baumgartner, M., Kopp, T., Kinkel, S.	Analysing factory workers' acceptance of collaborative robots: a web-based tool for company representatives	Electronics	2022
You, S., Robert, L. P.	Trusting and Working with Robots: A Relational Demography Theory of Preference for Robotic over Human Co-Workers	MIS Quarterly: Management Information Systems	2023
Liu, L., Zou, Z., Greene, R. L.	The effects of type and form of collaborative robots in manufacturing on trustworthiness, risk perceived, and acceptance	International Journal of Human–Computer Interaction	2023

Authors	Title	Journal	Year
Özköse, H., Güney, G.	The effects of industry 4.0 on productivity: A scientific mapping study	Technology in Society	2023
Rinaldi, M., Caterino, M., Fera, M.	Sustainability of Human-Robot cooperative configurations: Findings from a case study	Computers and Industrial Engineering	2023
Liao, S., Lin, L., Chen, Q.	Research on the acceptance of collaborative robots for the industry 5.0 era – The mediating effect of perceived competence and the moderating effect of robot use self-efficacy	International Journal of Industrial Ergonomics	2023
Jacob, F., Grosse, E. H., Morana, S., König, C. J.	Picking with a robot colleague: A systematic literature review and evaluation of technology acceptance in human–robot collaborative warehouses	Computers and Industrial Engineering	2023
Heinold, E., Funk, M., Niehaus, S., Rosen, P. H., Wischniewski, S.	OSH related risks and opportunities for industrial human-robot interaction: results from literature and practice	Frontiers in Robotics and AI	2023
Leichtmann, B., Hartung, J., Wilhelm, O., Nitsch, V.	New short scale to measure workers' attitudes toward the implementation of cooperative robots in industrial work settings: Instrument development and exploration of attitude structure	International Journal of Social Robotics	2023
Zakeri, Z., Arif, A., Omurtag, A., Breedon, P., Khalid, A.	Multimodal Assessment of Cognitive Workload Using Neural, Subjective and Behavioural Measures in Smart Factory Settings	Sensors	2023
Wang, Q., Liu, H., Ore, F., Wang, L., Hauge, J. B., Meijer, S.	Multi-actor perspectives on human robotic collaboration implementation in the heavy automotive manufacturing industry-A Swedish case study	Technology in society	2023
Cherubini, A., Navarro, B., Passama, R., Tarbouriech, S., Elprama, S. A., Jacobs, A., Niehaus, S., Wischniewski, S., Tönis, F. J., Siahaya, P. L.	Interdisciplinary evaluation of a robot physically collaborating with workers	Plos one	2023
Çiğdem, S., Meidute-Kavaliauskiene, I., Yıldız, B.	Industry 4.0 and industrial robots: A study from the perspective of manufacturing company employees	Logistics	2023
Hostettler, D., Mayer, S., Hildebrand, C.	Human-Like Movements of Industrial Robots Positively Impact Observer Perception	International Journal of Social Robotics	2023

Authors	Title	Journal	Year
Fraboni, F., Brendel, H., Pietrantoni, L.	Evaluating organizational guidelines for enhancing psychological well-being, safety, and performance in technology integration	Sustainability	2023
Probst, T. M., Lindgren, R. J., Dorosh, R. J., Allen, J. C., Pascual, L. S., Luo, M.	Effects of Prior Robot Experience, Speed, and Proximity on Psychosocial Reactions to a Soft Growing Robot	IISE Transactions on Occupational Ergonomics and Human Factors	2023
Apraiz, A., Mulet Alberola, J. A., Lasa, G., Mazmela, M., Nguyen, H. N.	Development of a new set of Heuristics for the evaluation of Human-Robot Interaction in industrial settings: Heuristics Robots Experience (HEUROBOX)	Frontiers in Robotics and AI	2023
Zigart, T., Zafari, S., Stürzl, F., Kiesewetter, R., Kasparick, H.-P., Schlund S.	Multi-assistance systems in manufacturing - a user study evaluating multi-criteria impact in a high-mix low-volume assembly setting	Computers and Industrial Engineering	2023
Enrique, D. V., Marodin, G. A., Santos, F. B. C., Frank, A. G.	Implementing industry 4.0 for flexibility, quality, and productivity improvement: technology arrangements for different purposes	International Journal of Production Research	2023
Karuppiah, K., Sankaranarayanan, B., Ali, S. M., Bhalaji, R. K. A.	Decision modeling of the challenges to human–robot collaboration in industrial environment: a real world example of an emerging economy	Flexible Services and Manufacturing Journal	2023
Dornelles, J. A., Ayala, N. F, Frank, A. G	Collaborative or substitutive robots? Effects on workers' skills in manufacturing activities	International Journal of Production Research	2023
Riedelbauch, D., Höllerich, N., Henrich, D.	Benchmarking Teamwork of Humans and Cobots-An Overview of Metrics, Strategies, and Tasks	IEEE Access	2023
Panchetti, T., Pietrantoni, L., Puzzo, G., Gualtieri, L., Fraboni, F.	Assessing the relationship between cognitive workload, workstation design, user acceptance and trust in collaborative robots	Applied Sciences	2023
Pluchino, P., Pernice, G. F. A., Nenna, F., Mingardi, M., Bettelli, A., Bacchin, D., Spagnolli, A., Jacucci, G., Ragazzon, A., Migliorанzi, L.	Advanced workstations and collaborative robots: exploiting eye-tracking and cardiac activity indices to unveil senior workers' mental workload in assembly tasks	Frontiers in Robotics and AI	2023
Di Pasquale, V., De Simone, V., Giubileo, V., Miranda, S.	A taxonomy of factors influencing worker's performance in human–robot collaboration	IET Collaborative Intelligent Manufacturing	2023
Steijn, W. M. P., Van Gulijk, C., Van der Beek, D., Sluijs, T.	A System-Dynamic Model for Human–Robot Interaction; Solving the Puzzle of Complex Interactions	Safety	2023

Authors	Title	Journal	Year
Verna, E., Puttero, S., Genta, G., Galetto, M.	A Novel Diagnostic Tool for Human-Centric Quality Monitoring in Human-Robot Collaboration Manufacturing	Journal of Manufacturing Science and Engineering	2023
Liao, S., Lin, L., Chen, Q., Pei, H.	Why not work with anthropomorphic collaborative robots? The mediation effect of perceived intelligence and the moderation effect of self-efficacy	Human Factors and Ergonomics In Manufacturing	2024
Liu, Y., Caldwell, G., Rittenbruch, M., Belek Fialho Teixeira, M., Burden, A., Guertler, M.	What Affects Human Decision Making in Human–Robot Collaboration?: A Scoping Review	Robotics	2024
Leichtmann, B., Meneweger, T., Busch, C., Reiterer, B., Meyer, K., Rammer, D., Haring, R., Mara, M.	Teaming with a Robot in Mixed Reality: Dynamics of Trust, Self-Efficacy, and Mental Models Affected by Information Richness	International Journal of Human–Computer Interaction	2024
Picco, E., Miglioretti, M., Le Blanc, P. M.	Sustainable employability, technology acceptance and task performance in workers collaborating with cobots: a pilot study	Cognition, Technology & Work	2024
Lutin, E., Elprama, S. A., Cornelis, J., Leconte, P., Van Doninck, B., Witters, M., De Raedt, W., Jacobs, A.	Pilot Study on the Relationship Between Acceptance of Collaborative Robots and Stress	International Journal of Social Robotics	2024
Di Pasquale, V., Farina, P., Fera, M., Gerbino, S., Miranda, S., Rinaldi, M.	Human Robot-Interaction: a conceptual framework for task performance analysis	IFAC-PapersOnLine	2024
Tomidei, L., Guertler, M., Sick, N., Paul, G., Carmichael, M.	Design Principles for Safe Human Robot Collaboration	Interaction Design and Architecture(s)	2024
Montini, E., Daniele, F., Agbomemewa, L., Confalonieri, M., Cutrona, V., Bettoni, A., Rocco, P., Ferrario, A.	Collaborative Robotics: A Survey From Literature and Practitioners Perspectives	Journal of Intelligent & Robotic Systems	2024
Rahman, M. M., Khatun, F., Jahan, I., Devnath, R., Bhuiyan, M.A.-A.	Cobotics: The Evolving Roles and Prospects of Next-Generation Collaborative Robots in Industry 5.0	Journal of Robotics	2024
Gualtieri, L., Fraboni, F., Brendel, H., Pietrantoni, L., Vidoni, R., Dallasega, P.	Updating design guidelines for cognitive ergonomics in human-centred collaborative robotics applications: An expert survey	Applied Ergonomics	2024

Authors	Title	Journal	Year
Heo, I. S., Putri, A. K. H., Kim, B. S., Kwon, M. S., Kim, S. H.	Analysis of quality standards for industrial collaborative robots based on user-centered design framework	Human Factors and Ergonomics in Manufacturing	2024
Ranasinghe, T., Grosse, E. H., Lerher, T.	Aging in Industry 5.0: Enhancing Human–Robot Synergy in Manufacturing and Logistics	IFAC-PapersOnLine	2024
Fournier, E., Jeoffrion, C., Hmedan, B., Pellier, D., Fiorino, H., Landry, A.	Human-cobot collaboration's impact on success, time completion, errors, workload, gestures and acceptability during an assembly task	Applied Ergonomics	2024
Du Plooy, H., Tommasi, F., Furlan, A., Nenna, F., Gamberini, L., Ceschi, A., Sartori, R.	A human-centered perspective on individual risks for digital innovation management: an integrative conceptual review	European Journal of Innovation Management	2024
de Nobile A., Bibbo D., Russo M., Conforto S.	A focus on quantitative methods to assess human factors in collaborative robotics	International Journal of Industrial Ergonomics	2024

Table A-1: Overview of the selected publications for literature review

Appendix A.2: Overview of journals for the selected publications in the literature review (sorted by subject area)

Journal	SJR 2023 Subject area	SJR 2023 Ranking	AJG 2024 Ranking	Number of publications
Sensors	Analytical Chemistry	Q1	-	1
Cyberpsychology, Behavior, and Social Networking	Applied Psychology	Q1	-	1
Interaction Design and Architecture(s)	Architecture	Q2	-	1
International Journal of Information Management	Artificial Inteligence	Q1	2	1
Frontiers in Robotics and AI	Artificial Inteligence	Q2	-	4
ACM Transactions on Human-Robot Interaction	Artificial Inteligence	Q1	-	1
Technology in Society	Business and International Management	Q1	-	2
Electronics	Computer Networks and Communications	Q2	-	1
IEEE Transactions on Human-Machine Systems	Computer Networks and Communications	Q1	-	1
IEEE Access	Computer Science	Q1	-	1
Computers and Industrial Engineering	Computer Science	Q1	2	3
International Journal of Social Robotics	Computer Science	Q1	-	3
Journal of Robotics	Computer Science	Q2	-	1
MIS Quarterly: Management Information Systems	Computer Science Applications	Q1	4*	1
International Journal of Advanced Manufacturing Technology	Computer Science Applications	Q2	-	3
International Journal of Human–Computer Interaction	Computer Science Applications	Q1	-	2
Journal of Manufacturing Systems	Control and Systems Engeneering	Q1	1	3
Cognitive Robotics	Control and Systems Engeneering	Q1	-	1
Robotics	Control and Systems Engeneering	Q1	-	1
Journal of Intelligent & Robotic Systems	Electrical and Electronical Engeneering	Q1	-	1
Applied Ergonomics	Engeneering	Q1	3	3
Journal of Engineering and Technology Management	Engeneering	Q1	-	1
Applied Sciences	Engeneering	Q2	-	3
Sustainability	Geography, Planning and Development	Q1	-	4

Cognition, Technology & Work	Human Factors and Ergonomics	Q1	-	1
Human Factors and Ergonomics In Manufacturing	Human Factors and Ergonomics	Q2	-	2
IISE Transactions on Occupational Ergonomics and Human Factors	Human Factors and Ergonomics	Q3	-	1
Ergonomics	Human Factors and Ergonomics	Q2	-	1
International Journal of Industrial Ergonomics	Human Factors and Ergonomics	Q2	-	2
International Journal of Production Research	Industrial and Manufacturing Engeneering	Q1	3	2
Flexible Services and Manufacturing Journal	Industrial and Manufacturing Engeneering	Q1	1	1
IET Collaborative Intelligent Manufacturing	Industrial and Manufacturing Engeneering	Q1	-	1
Journal of Manufacturing Science and Engineering	Industrial and Manufacturing Engeneering	Q1	-	1
International Journal of Manpower	Industrial Relations & Labor	Q1	2	1
Logistics	Information Systems and Management	Q2	-	1
European Journal of Innovation Management	Management of Technology & Innovation	Q1	1	1
Plos one	Multidisciplinary	Q1	-	1
Safety	Safety, Risk, Reliability and Quality	Q2	-	1
IFAC-PapersOnLine	-	-	-	2

Table A-2: Overview of journals for the selected publications in the literature review

Appendix B: Interview protocol

Appendix B.1: Interview protocol for employees (pilot study)

Interview protocol for employees (Interview Leitfaden für Mitarbeitende)
Version 1 (23.10.2023)

Formal aspects (Formale Aspekte)

- **Explanation/description of the study via the participant information sheet**
  Erklärung der Studie über Teilnehmer-Informationsblatt
- **Obtain agreement for the participant consent form**
  Einholung der Zustimmung zur Einwilligungserklärung
- **Obtain consent to record the interview**
  Einholung der Zustimmung zur Aufzeichnung des Interviews
- **Additional information about the interview**
  Zusätzliche Informationen zum Interview

Background / Demographic questions
(Hintergrundinformationen / Demographische Fragen)

- **Age / gender** (Alter / Geschlecht)
- **Educational level** (Bildungsgrad)
- **Position** (Tätigkeitsbezeichnung)
- **Does the training relate to the current position?**
  Steht Ausbildung / Studium im Zusammenhang mit aktueller Tätigkeit?
- **Length of experience in the department**
  Dauer der Berufserfahrung innerhalb der Abteilung
- **Work experience in current position**
  Berufserfahrung in der aktuellen Tätigkeit
- **Experience working with industrial robots**
  Erfahrung im Umgang mit Industrierobotern
- **Frequency of interaction with cobots in the last year (categorised as high/medium/low)**
  Frequenz der Zusammenarbeit mit Cobots im letzten Jahr
  (Kategorisiert als hoch/mittel/niedrig)

  Definition (Definition)
  High: regular interaction (min. 1x per week)
  Hoch: regelmäßige Zusammenarbeit (min. 1x pro Woche)
  Medium: regular interaction (min. 1x per month)
  Mittel: regelmäßige Zusammenarbeit (min. 1x pro Monat)

Low: occasional interaction (min. 1x per year)
Niedrig: punktuelle Zusammenarbeit (min. 1x pro Jahr)

Structural perspective (Strukturelle Perspektive)

Q1: In which steps of the work process are you supported by cobots?
(knowledge question)*
F1: Bei welchen Arbeitsschritten wirst du durch Cobots unterstützt?

Q2: How good or confident do you feel when using the cobots?
(feeling question)*
F2: Wie gut bzw. sicher (routiniert) fühlst du dich bei der Verwendung der Cobots?

Q3: What do you see as positive or negative about working with cobots?
(sensory question)*
F3: Was nimmst du bei der Zusammenarbeit mit den Cobots als gut/schlecht wahr?

Individual perspective (Individuelle Perspektive)

Q4: How valuable do you consider the support provided by the cobots? Have the cobots met your expectations?
(opinion and value question)*
F4: Wie wertvoll empfindest du die Unterstützung durch die Cobots? Haben die Cobots deine Erwartungen erfüllt?

Q5: To what extent did the cobots relieve you physically?
(experience and behaviour question)*
F5: Inwiefern stellten die Cobots für dich eine körperliche Entlastung dar?

Q6: How were you trained to use the cobots? How long did the training take?
(knowledge question)*
F6: Wie wurdest du im Umgang mit den Cobots eingearbeitet/geschult? Wie lange hat die Einarbeitung gedauert?

Q7: If you needed help working with the cobots, how were you supported?
(knowledge question)*
F7: Wie wurdest du unterstützt, wenn du Hilfe bei der Arbeit mit den Cobots benötigt hast?

Q8: If you have the choice of running a production with or without cobots, how would you decide and why?
(opinion and value question)*
F8: Wenn du die Wahl hast, eine Produktion mit bzw. ohne Cobots zu machen, wie entscheidest du dich und warum?

Q9: Should the cobots be removed from the production process? (and why/why not)

(opinion and value question)* F9: Sollten die Cobots wieder aus dem Arbeitsablauf entfernt werden? (und warum/warum nicht) **Q10: What did you think (or feel) when you first saw cobots? (fears, hopes) How has it changed since then?** *(feeling question*)* F10: Was hast du gedacht (bzw. gefühlt), als du die Cobots das erste Mal gesehen hast? (Ängste, Hoffnungen) Wie hat sich dies bis heute verändert? **Q11: Have you developed an emotional connection with the cobots (similar to a colleague) or how does it feel to work with the cobots (compared to working with a human colleague)?** *(feeling question*)* F11: Hast du eine emotionale Bindung zu den Cobots aufgebaut (ähnlich wie bei einem Kollegen)? oder wie fühlt es sich an, mit den Cobots zusammenzuarbeiten (im Vergleich zur Zusammenarbeit mit einem menschlichen Kollegen)? **Q12: How has the implementation of the cobots changed your motivation in regard to your work/tasks? (Link also to assessment of the value of own work)** *(opinion and value question*)* F12: Wie hat sich deine Motivation hinsichtlich deiner Arbeit/Aufgaben durch die Etablierung der Cobots verändert? (Link auch zu Einschätzung des Werts der Arbeit)
Social perspective (Soziale Perspektive)
Q13: How has collaboration within the group changed because of the implementation of the cobots? *(experience and behaviour question*)* F13: Wie hat sich durch die Cobots die Zusammenarbeit in der Gruppe verändert? **Q14: Have there been any improvements in the collaboration/working process with the cobots, or do you have any additional ideas for improvements? (adjustments to the cobots if necessary)** *(experience and behaviour question*)* F14: Gab es bereits Verbesserungen bei der Zusammenarbeit/dem Arbeitsablauf mit den Cobots bzw. Hast du weitere Ideen für Verbesserungen? (ggf. Anpassungen der Cobots)
Productivity (Produktivität)
Q15: How has the productivity of the relevant production lines changed as a result of the cobots (What do you attribute the increase in productivity to? / How do you define efficiency?) *(experience and behaviour question*)*

F15: Wie hat sich die Produktivität der entsprechenden Produktionen durch die Cobots verändert? (An was machst du die Produktivitätssteigerung fest? / Wie definierst du effizient?)
Additional questions (Weitere Fragen)
Q16: Additional questions (not included in the protocol of the interview) *(experience and behaviour question*)* F16: Weitere Frage (zusätzlich zum Interview Leitfaden)
Abbreviation (Abkürzung) Q: Question (F: Frage) * Interview questions categorised according to Patton (2015, p. 444 f.)

Table B-1: Interview protocol for employees (pilot study)

Appendix B.2: Interview protocol for employees (main study)

Interview protocol for employees (Interview Leitfaden für Mitarbeitende) **Version 2 (20.11.2023)**
Formal aspects (Formale Aspekte)
➢ **Explanation/description of the study via the participant information sheet** Erklärung der Studie über Teilnehmer-Informationsblatt ➢ **Obtain agreement for the participant consent form** Einholung der Zustimmung zur Einwilligungserklärung ➢ **Obtain consent to record the interview** Einholung der Zustimmung zur Aufzeichnung des Interviews ➢ **Additional information about the interview** Zusätzliche Informationen zum Interview
Background / Demographic questions (Hintergrundinformationen / Demographische Fragen)
➢ **Age / gender** (Alter / Geschlecht) ➢ **Educational level** (Bildungsgrad) ➢ **Position** (Tätigkeitsbezeichnung) ➢ **Does the training relate to the current position?** Steht Ausbildung / Studium im Zusammenhang mit aktueller Tätigkeit? ➢ **Length of experience in the department** Dauer der Berufserfahrung innerhalb der Abteilung ➢ **Work experience in current position** Berufserfahrung in der aktuellen Tätigkeit ➢ **Experience working with industrial robots** Erfahrung im Umgang mit Industrierobotern ➢ **Frequency of interaction with cobots in the last year (categorised as high/medium/low)** Frequenz der Zusammenarbeit mit Cobots im letzten Jahr (Kategorisiert als hoch/mittel/niedrig) **Definition** (Definition) **High: regular interaction (min. 1x per week)** Hoch: regelmäßige Zusammenarbeit (min. 1x pro Woche) **Medium: regular interaction (min. 1x per month)** Mittel: regelmäßige Zusammenarbeit (min. 1x pro Monat) **Low: occasional interaction (min. 1x per year)** Niedrig: punktuelle Zusammenarbeit (min. 1x pro Jahr)

Structural perspective (Strukturelle Perspektive)
Q1: In which steps of the work process are you supported by cobots? *(knowledge question*)* F1: Bei welchen Arbeitsschritten wirst du durch Cobots unterstützt? **Q2: How good or confident do you feel when using the cobots?** *(feeling question*)* F2: Wie gut bzw. sicher (routiniert) fühlst du dich bei der Verwendung der Cobots? **Q3: What do you see as positive or negative about working with cobots?** *(sensory question*)* F3: Was nimmst du bei der Zusammenarbeit mit den Cobots als gut/schlecht wahr?
Individual perspective (Individuelle Perspektive)
Q4: How valuable do you consider the support provided by the cobots? Have the cobots met your expectations? *(opinion and value question*)* F4: Wie wertvoll empfindest du die Unterstützung durch die Cobots? Haben die Cobots deine Erwartungen erfüllt? **Q5: To what extent did the cobots relieve you physically?** *(experience and behaviour question*)* F5: Inwiefern stellten die Cobots für dich eine körperliche Entlastung dar? **Q6: How were you trained to use the cobots? How long did the training take?** *(knowledge question*)* F6: Wie wurdest du im Umgang mit den Cobots eingearbeitet/geschult? Wie lange hat die Einarbeitung gedauert? **Q7: If you needed help working with the cobots, how were you supported?** *(knowledge question*)* F7: Wie wurdest du unterstützt, wenn du Hilfe bei der Arbeit mit den Cobots benötigt hast? **Q8: If you have the choice of running a production with or without cobots, how would you decide and why?** *(opinion and value question*)* F8: Wenn du die Wahl hast, eine Produktion mit bzw. ohne Cobots zu machen, wie entscheidest du dich und warum? **Q9: Should the cobots be removed from the production process? (and why/why not)** *(opinion and value question*)* F9: Sollten die Cobots wieder aus dem Arbeitsablauf entfernt werden? (und warum/warum nicht)

Q10: What did you think (or feel) when you first saw cobots? (fears, hopes) How has it changed since then? *(feeling question*)* F10: Was hast du gedacht (bzw. gefühlt), als du die Cobots das erste Mal gesehen hast? (Ängste, Hoffnungen) Wie hat sich dies bis heute verändert? **Q11a (ADAPTED): How does it feel to work with the cobots (compared to working with a human colleague)?** *(feeling question*)* F11a (ADAPTIERT): Wie fühlt es sich an, mit den Cobots zusammenzuarbeiten (im Vergleich zur Zusammenarbeit mit einem menschlichen Kollegen)?? **Q12a (REPLACED): Is it more or less enjoyable to do the tasks (at work) with the cobot than without the cobot? Have the development opportunities for your role/activity changed? If so, how?** *(opinion and value question*)* F12a (ERSETZT): Macht die Erledigung der Aufgaben (bei der Arbeit) zusammen mit dem Cobot mehr oder weniger Spaß als ohne Cobot? Haben sich die Entwicklungsmöglichkeiten für deine Rolle/Tätigkeit verändert? Und wenn ja, wie? **F18 (NEW): What would it be like if additional cobots were to be introduced into your workplace? What would it be like if you only worked with cobots?** *(opinion and value question*)* F18 (NEU): Wie wäre es, wenn zusätzlich Cobots in deinem Arbeitsbereich etabliert werden würden? Wie wäre es, wenn du nur noch mit Cobots zusammenarbeiten würdest? **Q19 (NEW): To what extent do you think a cobot can replace a human?** *(opinion and value question*)* F19 (NEU): Inwieweit denkst du, dass ein Cobot einen Menschen ersetzen kann?
Social perspective (Soziale Perspektive)
Q13: How has collaboration within the group changed because of the implementation of the cobots? *(experience and behaviour question*)* F13: Wie hat sich durch die Cobots die Zusammenarbeit in der Gruppe verändert? **Q14: Have there been any improvements in the collaboration/working process with the cobots, or do you have any additional ideas for improvements? (adjustments to the cobots if necessary)** *(experience and behaviour question*)* F14: Gab es bereits Verbesserungen bei der Zusammenarbeit/dem Arbeitsablauf mit den Cobots bzw. Hast du weitere Ideen für Verbesserungen? (ggf. Anpassungen der Cobots)

Productivity (Produktivität)
Q15: How has the productivity of the relevant production lines changed as a result of the cobots (What do you attribute the increase in productivity to? / How do you define efficiency?) *(experience and behaviour question*)* F15: Wie hat sich die Produktivität der entsprechenden Produktionen durch die Cobots verändert? (An was machst du die Produktivitätssteigerung fest? / Wie definierst du effizient?)
Additional questions (Weitere Fragen)
Q16: Additional questions (not included in the protocol of the interview) *(experience and behaviour question*)* F16: Weitere Frage (zusätzlich zum Interview Leitfaden). **Q17 (NEW): Ask for more information about the cobots.** *(experience and behaviour question*)* F17 (NEU): Frage nach weiteren Informationen zu den Cobots.
Abbreviation (Abkürzung) Q: Question (F: Frage) * Interview questions categorised according to Patton (2015, p. 444 f.)

Table B-2: Interview protocol for employees (main study)

Appendix B.3: Interview protocol for managers

Interview protocol for managers *(Interview Leitfaden für Führungskräfte)* **Version 1 (24.01.2024)**
Formal aspects (Formale Aspekte)
➢ **Explanation/description of the study via the participant information sheet** Erklärung der Studie über Teilnehmer-Informationsblatt ➢ **Obtain agreement for the participant consent form** Einholung der Zustimmung zur Einwilligungserklärung ➢ **Obtain consent to record the interview** Einholung der Zustimmung zur Aufzeichnung des Interviews ➢ **Additional information about the interview** Zusätzliche Informationen zum Interview
Background / Demographic questions (Hintergrundinformationen / Demographische Fragen)
➢ **Age / gender** (Alter / Geschlecht) ➢ **Educational level** (Bildungsgrad) ➢ **Position** (Tätigkeitsbezeichnung) ➢ **Does the training relate to the current position?** Steht Ausbildung / Studium im Zusammenhang mit aktueller Tätigkeit? ➢ **Length of experience in the department** Dauer der Berufserfahrung innerhalb der Abteilung ➢ **Work experience in current position** Berufserfahrung in der aktuellen Tätigkeit
Structural perspective (Strukturelle Perspektive)
Q1: How has the use of cobots changed over time? *(knowledge question*)* F1: Wie hat sich die Häufigkeit der Verwendung der Cobots über die Zeit verändert? **Q2: How have cobots changed your human resources management?** *(opinion and value question*)* F2: Wie hat sich die/deine Personalführung durch die Cobots verändert? **Q3: Are there any current constraints/limitations in the organisation that you are aware of? If so, what are they? How is the implementation of cobots supported by senior management?** *(opinion and value question*)*

F3: Gibt es aktuell im Bereich (d.h. der Organisation) gewisse Zwänge / Restriktionen, die du wahrnimmst? Und wenn ja, welch? Wie wird die Etablierung von Cobots durch das höhere Management unterstützt?
Individual perspective (Individuelle Perspektive)
Q4: What is your perception of the cobots? How valuable do you think the cobots are to the department? *(sensory question*)* F4: Wie ist deine Wahrnehmung der Cobots? Wie wertvoll siehst du die Unterstützung durch die Cobots für die Abteilung? **Q5: What fears or hopes did you or your employees have at the beginning of the implementation of cobots? How has this changed to date?** *(feeling question*)* F5: Welche Ängste bzw. Hoffnungen gibt es bzw. gab es am Anfang der Implementierung von Cobots bei dir bzw. bei den Mitarbeitern? Wie hat sich dies bis heute verändert? **Q6: How are cobots currently perceived by employees (especially in terms of forming an emotional bond comparable to a colleague)?** *(experience and behaviour question*)* F6: Wie werden die Cobots heute von den Mitarbeitenden gesehen (v.a. hinsichtlich einer emotionalen Bindung vergleichbar zu einem Kollegen)? **Q7: Has the implementation of the cobot changed employees' perceptions of the value of their work? If so, how or why?** *(experience and behaviour question*)* F7: Hat sich durch die Etablierung der Cobots, bei den Mitarbeitern, die Einschätzung zum Wert deren Arbeit verändert? Und wenn ja, wie bzw. warum?
Social perspective (Soziale Perspektive)
Q8: How has collaboration within the group changed as a result of the implementation of cobots? *(experience and behaviour question*)* F8: Wie hat sich durch die Cobots die Zusammenarbeit in der Gruppe verändert? **Q9: How has working with cobots changed the working atmosphere?** *(experience and behaviour question*)* F9: Inwiefern hat sich durch die Zusammenarbeit mit Cobots das Betriebsklima verändert? **Q10: In your opinion, what has been done / what can be done to increase the acceptance of cobots?** *(opinion and value question*)*

F10: Was wurde aus deiner Sicht gemacht / was kann aus deiner Sicht gemacht werden, um die Akzeptanz des Cobots zu steigern?

Q11: To what extent are the employees interested in the further development of the cobots and the processes related to them? How are employees involved in improvement projects?
(experience and behaviour question)*
F11: Inwieweit sind die Mitarbeiter an der Weiterentwicklung des Cobots bzw. der entsprechenden Prozessabläufe interessiert? Wie werden die Mitarbeiter bei Verbesserungsprojekten einbezogen?

Q12: In your opinion, is the acceptance of employees as a social group heterogeneous or rather homogeneous? And why is this the case?
(opinion and value question)*
F12: Ist aus deiner Sicht die Akzeptanz bei den Mitarbeitern als soziale Gruppe heterogen oder eher homogen? Und warum ist das so?

Q13: Is there a (conflicting) positioning within the group (pro/con cobot)? If so, why and how do you deal with it?
(experience and behaviour question)*
F13: Gibt es innerhalb der Gruppe eine (unversöhnliche) „Lager"-Bildung (in pro/contra Cobot)? Und wenn ja, warum gibt es diese und wie gehst du damit um?

Q14: Do you think there are opinion leaders in the group? How do they behave?
(experience and behaviour question)*
F14: Gibt es aus deiner Sicht in der Gruppe Meinungsbildner? Wie agieren diese?

Productivity (Produktivität)

Q15: How has the productivity of the relevant production lines changed as a result of cobots (What do you attribute the increase in productivity to? / How do you define efficiency?)
(experience and behaviour question)*
F15: Wie hat sich die Produktivität der entsprechenden Produktionen durch die Cobots verändert? (An was machst du die Produktivitätssteigerung fest? / Wie definierst du effizient?)

Q16: To what extent did the product quality change as a result of cobots?
(experience and behaviour question)*
F16: Inwiefern hat sich durch die Cobots die Qualität der Produkte verändert?

Additional questions (Weitere Fragen)
Q17: Ask for more information about the cobots. *(experience and behaviour question*)* F17: Frage nach weiteren Informationen zu den Cobots. **Q18: Additional questions (not included in the protocol of the interview)** F18: Weitere Frage (zusätzlich zum Interview Leitfaden).
Abbreviation (Abkürzung) Q: Question (F: Frage) * Interview questions categorised according to Patton (2015, p. 444 f.)

Table B-3: Interview protocol for managers

Appendix C: Participant information sheet and participant consent form

Appendix C.1: Participant information sheet

PARTICIPANT INFORMATION SHEET

1. Title of project

Exploring the social implications of collaborative robots on the shop floor: a case study

2. Legal basis for research for studies

The University undertakes research as part of its function for the community under its legal status. Data protection allows us to use personal data for research with appropriate safeguards in place under the legal basis of public tasks that are in the public interest. A full statement of your rights can be found at: www.shu.ac.uk/about-this-website/privacy-policy/privacy-notices/privacy-notice-for-research. However, all University research is reviewed to ensure that participants are treated appropriately and their rights are respected. This study was approved by the University's Research Ethics Committee with reference number ER29288395. Further information at: www.shu.ac.uk/research/excellence/ethics-and-integrity.

3. Opening statement

The research aims to analyse social implications that arise from the use of collaborative robots. As part of this dissertation, the researcher is conducting direct observations and in-depth interviews. In order to achieve this objective, the researcher would welcome your participation in this study.

4. Why have you asked me to take part?

You either directly (as an employee) or indirectly (as a supervisor or manager) work closely with a collaborative robot in a real-world setting. In order to generate a valid research result, direct observations and in-depth interviews must be conducted with sufficient participants.

5. Do I have to take part?

It is up to you to decide if you want to take part. A copy of the information provided here is yours to keep, along with the consent form if you do decide to take part. You can still decide to withdraw at any time without giving a reason, or you can decide not to answer a particular question.

6. What will I be required to do?

You are asked to talk about e.g. your experiences and perceptions in relation to the collaborative robot.

7. Where will this take place?

The observations and the conversations take place on the premises of the organisation you work for.

8. How often will I have to take part, and for how long?

A direct observation (including informal conversations) is expected to last up to 45 minutes, and an in-depth interview is expected to last 90 minutes. After the initial interview, the recording will be transcribed, and the researcher may come back to you with further (clarifying) questions.

9. Is deception involved in the study?

There is no deception involved in the study.

10. Are there any possible risks or disadvantages in taking part?
There are no possible risks or disadvantages in taking part.

11. What are the possible benefits of taking part?
There are no possible benefits of taking part.

12. When will I have the opportunity to discuss my participation?
There will be a short debriefing after each direct observation and each in-depth interview where you can discuss your participation in the study with the researcher.

13. Will anyone be able to connect me with what is recorded and reported?
The anonymity of the participants will be achieved by changing the participant's names into pseudonyms.

14. Who will be responsible for all of the information when this study is over?
The researcher, Stefanie Trinkwalder, will be responsible for all of the information.

15. Who will have access to it?
Feld notes and recordings based on direct observations (including informal conversations) and in-depth interviews will be made available as a complete data set only to the research team and audit committee. Publication of this data is not permitted.

16. What will happen to the information when this study is over?
This study will be completed mid of 2025. The raw data will be kept for two years. They will not be made available to anyone even after the study has been completed.

17. How will you use what you find out?
The gathered data will be published as part of the dissertation.

18. How long is the whole study likely to last?
The study takes place between 2023 and 2025.

19. How can I find out about the results of the study?
Please contact Stefanie Trinkwalder.

20. Do you have any other questions?
At this point in time, you have the opportunity to ask any further questions or seek clarification regarding the study.

21. Details of who to contact with any concerns or if adverse effects occur after the study.

Researcher/ research team details:
Stefanie Trinkwalder

You should contact the Data Protection Officer if:	You should contact the Head of Research Ethics (Dr Mayur Ranchordas) if:
• you have a query about how your data is used by the University • you would like to report a data security breach (e.g. if you think your personal data has been lost or disclosed inappropriately) • you would like to complain about how the University has used your personal data	• you have concerns with how the research was undertaken or how you were treated
DPO@shu.ac.uk	ethicssupport@shu.ac.uk
Postal address: Sheffield Hallam University, Howard Street, Sheffield S1 1WBT	

TEILNEHMER-INFORMATIONSBLATT

1. Titel des Dissertation (Forschungsstudie)
Untersuchung der sozialen Auswirkungen von kollaborativen Robotern auf Mitarbeiterebene *(Exploring the social implications of collaborative robots on the shop floor: a case study)*

2. Rechtsgrundlage für Forschungsstudien
Die Universität betreibt Forschung als Teil ihrer Funktion für die Gemeinschaft im Rahmen ihrer Rechtsstellung. Der Datenschutz erlaubt es uns, personenbezogene Daten für die Forschung zu verwenden, wobei angemessene Schutzmaßnahmen auf der Rechtsgrundlage öffentlicher Aufgaben im öffentlichen Interesse vorgesehen sind. Eine vollständige Erklärung Ihrer Rechte finden Sie unter: www.shu.ac.uk/about-this-website/privacy-policy/privacy-notices/privacy-notice-for-re search. Alle Forschungsarbeiten der Universität werden jedoch überprüft, um sicherzustellen, dass die Teilnehmer angemessen behandelt und ihre Rechte respektiert werden. Diese Studie wurde von der Forschungsethikkommission der Universität unter der Referenznummer ER29288395 genehmigt. Link für weitere Informationen: www.shu.ac.uk/ research/excellence/ ethics-and-integrity

3. Zielsetzung der Dissertation
Ziel der Forschung ist es, soziale Auswirkungen zu analysieren, die durch den Einsatz von kollaborativen Robotern entstehen. Im Rahmen dieser Dissertation führt die Forscherin direkte Beobachtungen und ausführliche Interviews durch. Um dieses Ziel zu erreichen, würde die Forscherin Ihre Teilnahme an dieser Studie begrüßen.

4. Warum haben Sie mich gebeten, daran teilzunehmen?
Sie arbeiten entweder direkt (als Mitarbeitender) oder indirekt (als Vorgesetzter) eng mit einem kollaborativen Roboter in einer realen Umgebung zusammen. Um ein valides Forschungsergebnis zu erzielen, müssen direkte Beobachtungen und ausführliche Interviews mit genügend Teilnehmern durchgeführt werden.

5. Muss ich mitmachen?
Es ist Ihre freie Entscheidung, ob Sie teilnehmen möchten. Sie erhalten eine Kopie der hier bereitgestellten Informationen sowie des Einwilligungsformulars, wenn Sie sich für eine Teilnahme entscheiden. Sie können jederzeit ohne Angabe von Gründen von der Teilnahme zurücktreten oder auf die Beantwortung einer bestimmten Frage verzichten.

6. Was werde ich tun müssen?
Sie werden gebeten, z. B. über Ihre Erfahrungen und Wahrnehmungen im Zusammenhang mit dem kollaborativen Roboter zu sprechen.

7. Wo wird die Datenerhebung stattfinden?
Die Beobachtungen und Gespräche finden am Firmenstandort statt.

8. Wie oft und wie lange muss ich daran teilnehmen?
Für eine direkte Beobachtung (einschließlich informeller Gespräche) werden bis zu 45 Minuten veranschlagt, für ein ausführliches Interview bis zu 90 Minuten. Nach dem ersten Gespräch wird die Aufnahme transkribiert und der Forscher kann mit weiteren (klärenden) Fragen auf Sie zurückkommen.

9. Ist die Studie mit Täuschung verbunden?
Die Studie beinhaltet keine Täuschung.

10. Gibt es mögliche Risiken oder Nachteile bei der Teilnahme?
Die Teilnahme ist mit keinerlei Risiken oder Nachteilen verbunden.

11. Was sind die möglichen Vorteile einer Teilnahme?
Es gibt keine möglichen Vorteile einer Teilnahme.

12. Wann werde ich die Möglichkeit haben, meine Teilnahme zu besprechen?
Nach jeder direkten Beobachtung und jedem ausführlichen Interview findet eine kurze Nachbesprechung statt, in der Sie Ihre Teilnahme an der Studie mit dem Forscher besprechen können.

13. Kann mich jemand mit dem in Verbindung bringen, was ich gesagt habe?
Die Anonymität der Teilnehmer wird erreicht, indem die Namen der Teilnehmer in Pseudonyme umgewandelt werden.

14. Wer wird nach Abschluss der Studie für alle Daten verantwortlich sein?
Die Forscherin Stefanie Trinkwalder wird für alle Daten verantwortlich sein.

15. Wer wird Zugang zu den erhobenen Daten haben?
Notizen und Aufzeichnungen, die auf direkten Beobachtungen (einschließlich informeller Gespräche) und ausführlichen Interviews beruhen, werden als vollständiger Datensatz nur dem Forschungsteam und dem Prüfungsausschuss zur Verfügung gestellt. Eine Veröffentlichung dieser Daten ist nicht gestattet.

16. Was wird mit den Informationen geschehen, wenn die Studie abgeschlossen ist?
Diese Studie wird Mitte 2025 abgeschlossen sein. Die Rohdaten werden zwei Jahre lang aufbewahrt. Sie werden auch nach Abschluss der Studie niemandem zugänglich gemacht.

17. Wie werden Sie das, was Sie herausfinden, nutzen?
Die gesammelten Daten werden im Rahmen der Dissertation veröffentlicht.

18. Wie lange wird die gesamte Studie voraussichtlich dauern?
Die Studie findet in den Jahren 2023 bis 2025 statt.

19. Wie kann ich mich über die Ergebnisse der Studie informieren?
Bitte kontaktieren Sie dazu Stefanie Trinkwalder.

20. Haben Sie noch weitere Fragen?
Zu diesem Zeitpunkt haben Sie die Möglichkeit, weitere Fragen zu stellen oder sich über die Studie zu informieren.

21. Angaben darüber, an wen Sie sich wenden können, falls es Bedenken bezüglich der Studie gibt.

Forscher/ Forschungsteam Details:
Stefanie Trinkwalder

Sie sollten sich an den Datenschutzbeauftragten wenden, wenn:	Wenden Sie sich bitte an den Leiter der Abteilung Forschungsethik (Dr. Mayur Ranchordas), wenn:
• Sie eine Frage zur Verwendung Ihrer Daten durch die Universität haben. • Sie eine Verletzung der Datensicherheit melden möchten (z. B. wenn Sie glauben, dass Ihre personenbezogenen Daten verloren gegangen sind oder unberechtigt weitergegeben wurden). • Sie sich über die Verwendung ihrer persönlichen Daten durch die Universität beschweren möchten. DPO@shu.ac.uk	• Sie Bedenken oder Beschwerden haben, wie die Forschung durchgeführt wurde oder wie Sie behandelt wurden. ethicssupport@shu.ac.uk
Postanschrift: Sheffield Hallam University, Howard Street, Sheffield S1 1WBT	

Appendix C.2: Participant consent form

PARTICIPANT CONSENT FORM

TITLE OF RESEARCH STUDY:
Exploring the social implications of collaborative robots on the shop floor: a case study

Please answer the following questions by ticking the response that applies

	YES	NO
I have read the Information Sheet for this study and have had details of the study explained to me.	☐	☐
My questions about the study have been answered to my satisfaction and I understand that I may ask further questions at any point.	☐	☐
I understand that I am free to withdraw from the study within the time limits outlined in the Information Sheet, without giving a reason for my withdrawal or to decline to answer any particular questions in the study without any consequences to my future treatment by the researcher.	☐	☐
I agree to provide information to the researchers under the conditions of confidentiality set out in the Information Sheet.	☐	☐
I wish to participate in the study under the conditions set out in the Information Sheet.	☐	☐

Participant's Signature: ______________________________ Date: ________________

Participant's Name (Printed): ____

Contact details: ____

____

Researcher's Name (Printed):
____

Researcher's Signature:
____

Researcher's contact details:
Stefanie Trinkwalder

Please keep your copy of the consent form and the information sheet together.

EINWILLIGUNGSFORMULAR FÜR TEILNEHMER

TITEL DER DISSERTATION:
Untersuchung der sozialen Auswirkungen von kollaborativen Robotern auf Mitarbeiterebene. *(Exploring the social implications of collaborative robots on the shop floor: a case study)*

Bitte beantworten Sie die folgenden Fragen, indem Sie die zutreffende Antwort ankreuzen

	Ja	**Nein**
Ich habe das Informationsblatt zu dieser Studie gelesen und mir die Einzelheiten der Studie erklären lassen.	☐	☐
Meine Fragen zur Studie sind zu meiner Zufriedenheit beantwortet worden und ich weiß, dass ich jederzeit weitere Fragen stellen kann.	☐	☐
Mir ist bekannt, dass es mir freisteht, innerhalb der im Informationsblatt genannten Fristen aus der Studie auszusteigen, ohne einen Grund für meinen Ausstieg zu nennen oder die Beantwortung bestimmter Fragen im Rahmen der Studie zu verweigern, ohne dass dies Konsequenzen für meine zukünftige Behandlung durch die Forscherin hat.	☐	☐
Ich erkläre mich damit einverstanden, der Forscherin Informationen unter den im Informationsblatt genannten Bedingungen zur Verfügung zu stellen.	☐	☐
Ich möchte an der Studie unter den im Informationsblatt genannten Bedingungen teilnehmen.	☐	☐

Unterschrift des Teilnehmers: ___________________________ Datum: ____________

Name des Teilnehmers (in Druckbuchstaben): _________________________________

Kontaktinformationen: ____

____

Name der Forscherin (in Druckbuchstaben):

____

Unterschrift der Forscherin:

____

Kontaktdaten der Forscherin:
Stefanie Trinkwalder

Bitte bewahren Sie Ihr Exemplar der Einverständniserklärung und das Informationsblatt zusammen auf.

Appendix D: Ethics overview and approval

Appendix D.1: Ethics table

Title of research study	Ethics review reference	Approval date	Thesis chapter(s)
A case study of cyber-physical production systems and implications for organisational change	ER29288395	14/01/2021	All chapters

Appendix D.2: Ethics approval (Converis)

A case study of cyber-physical production systems and implications for organisational change

Ethics Review ID: ER29288395

Workflow Status: Application Approved

Type of Ethics Review Template: Very low risk human participants studies

Primary Researcher / Principal Investigator

Stefanie Trinkwalder
(Sheffield Business School)

Converis Project Application:

Q1. Is this project ii) Doctoral research

Director of Studies

Sarah Fidment
(Sheffield Business School)

Appendix E: Thematic table with critical statements

Name	Description *(Critical statements)*
Personal factors	**This theme addresses the individual attributes and characteristics that influence employees' perceptions of collaborative robots. These include demographic factors, personal expertise, familiarity with technology, self-help capabilities, and individual work preferences. (theme)**
Demographic factors	References from participants on the impact of demographic factors on employees' perceptions of cobots. (main code) **F3 (employee): And maybe it is also because of my age, but at first, I was a bit apprehensive.** *F3 (Mitarbeitende): Und vielleicht ist es auch mein Alter, aber da habe ich schon erstmal Respekt gehabt.* **F6 (employee): I belong to a generation that is more familiar with new technologies.** *F6 (Mitarbeitende): Ich bin in der Generation, die technisch mit Neuem eher vertraut ist.* **M21 (manager): Of course, it also depends on personal factors such as educational background and age. If someone belongs to a younger generation, they may also be more tech-savvy and more interested in technology than an employee who has only known traditional manual work for years or decades.** *M21 (Führungskraft): Es liegt natürlich auch an persönlichen Faktoren wie Bildungshintergrund, Alter vielleicht auch. Wenn jemand der jüngeren Generation angehört, ist er vielleicht auch technisch affiner, technologisch interessierter als ein Mitarbeiter, der über Jahre, Jahrzehnte ausschließlich die klassische manuelle Arbeit gekannt hat.*
Expertise of employees	References from participants on employee expertise regarding cobots, based on familiarity with cobots and self-help capabilities. (main code)
Familiarity with technology	References from participants about employees' familiarity and level of comfort when handling cobots. (code) **M2 (employee): I do not feel confident; when I am alone with the cobot, I do not know how to operate it.** *M2 (Mitarbeitende): Ich fühle mich nicht sicher; wenn ich alleine am Cobot bin, weiß ich nicht, wie ich ihn bedienen muss.* **F4 (employee): Very experienced.** *F4 (Mitarbeitende): Sehr routiniert.* **M5 (employee): I arrive in the morning and switch it (cobot) on if there is a work order and it is running.** *M5 (Mitarbeitende): Ich komme in der Früh und mache ihn an (Cobot), falls ein Auftrag da ist und der läuft.*
Self-help capability	References from participants about their self-help capabilities when using cobots. (code)

	F6 (employee): Yes, if it is an easy fix—like if it has just lost a Sarstedt vial or something—then I just restart it. *F6 (Mitarbeitende): Ja, wenn es eine einfache Lösung ist, weil er jetzt zum Beispiel, ein Sarstedt oder irgendwas verloren hat, dann starte ich ihn halt neu.* **M5 (employee): From time to time, we have been able to fix the little things ourselves so that it keeps running.** *M5 (Mitarbeitende): Ab und zu haben wir, sag ich mal, die Kleinigkeiten selber richten [reparieren] können, dass er weiterläuft.* **M23 (employee): What I have noticed now, but that could also be changed, as I said, if people are trained intensively. That would be better for us and also good for the company, I would say. Then everyone would be autonomous.** *M23 (Mitarbeitende): Was ich jetzt mitbekommen habe, aber das könnte man auch ändern, wie gesagt, wenn man die Leute intensiv anlernt [einarbeitet]. Besser für uns und auch gut für die Firma, sag ich mal. Dann ist halt jeder selbstständig.*
Work preferences	References from participants on employees' work preferences. (main code) **M10 (employee): I am the kind of person […], I could not sit alone in a room; it would be a bit too monotonous and boring for me.** *M10 (Mitarbeitende): Ich bin ja so ein Mensch, ich könnte jetzt nicht alleine in einem Raum sitzen, es wäre mir dann ein bisschen zu monoton, zu langweilig.* **M11 (employee): I do not want to sit around machines all day. I like dealing with people, but that is just me.** *M11 (Mitarbeitende): Also ich möchte nicht den ganzen Tag bei Maschinen hocken [sitzen]. Ich habe gerne mit Menschen zu tun, aber das ist auch nur, das bin ich.* **F6 (employee): Preferably alone. Of course, it is nice to do something together sometimes, but I do not think it would be good for me to always work in a team.** *F6 (Mitarbeitende): Eher alleine. Also klar ist es auch mal schön, wenn man zusammen etwas macht. Aber dauerhaft nur im Team arbeiten, wäre glaube ich für mich nicht gut.*
Subjective usefulness	**This theme reflects participants' perceptions of the value and effectiveness of cobot technology, including its contribution to goal achievement, task relevance, physical relief, personal development, and flexible use. It summarises users' views on the practical benefits of using cobots in their work environment. (theme)**
Goal achievement with cobots	References from participants on how the cobots supported them in reaching their goals. (main code) **F6 (employee): Well, I think it is great, especially with sensitive products or hazardous goods, because it practically does half of the work for me.** *F6 (Mitarbeitende): Also ich finde es halt schön, dass wie gesagt, gerade bei Produkten, die empfindlich sind oder bei Gefahrgutprodukten zum Beispiel, dass er mir praktisch die Hälfte von der Arbeit einfach abnimmt.*

	M1 (employee): But the more I can bring in via a pick, the more effective I become (with the cobot). It makes no sense if I can only bring in one Sarstedt vial at a time. A worker can do that much faster. *M1 (Mitarbeitende): Aber umso mehr ich über einen Pick einbringen kann (mit dem Cobot), umso effektiver werde ich ja. Wenn ich jetzt immer nur ein Sarstedt einbringe, dann macht es keinen Sinn. Das kann der Bearbeiter viel schneller.* **F4 (employee): It does the same work that we do. It cannot do everything, but it can do parts of it, and for that reason, I really see it as a good co-worker.** *F4 (Mitarbeitende): Er macht ja auch die Arbeit, die wir machen. Nicht alles kann er, aber einen Teilbereich davon und von dem sehe ich ihn wirklich als guten Zuarbeiter.* **F8 (employee): If you look at it, you do about half now. Before, you had to do everything yourself, but now you only have to do 50%.** *F8 (Mitarbeitende): Weil wenn du schaust ungefähr macht man Hälfte, Hälfte. Und vorher hast du ja 100% gehabt und jetzt machst du nur noch 50%.*
Relevance of cobots	References from participants on the relevance of using a cobot for a given task. (main code) **F6 (employee): For example, having the cobot plug in a single module does not make much sense, because it could only plug in two out of four vials. By the time I have set it up and everything, I have already done about half […] of the work myself.** *F6 (Mitarbeitende): Also ein 1er-Modul macht zum Beispiel nicht viel Sinn, vom Cobot stecken zu lassen, weil er könnte von vier Flaschen zwei Stück stecken. Bis ich das eingerichtet habe usw., habe ich die Hälfte […] von der Sache schon gesteckt.* **M5 (employee): Small jobs are not worth doing with the cobot. Each time, we spend more time selecting and setting up the programme and making sure it is running.** *M5 (Mitarbeitende): Kleine Aufträge lohnt sich nicht am Cobot zu machen. Jedes Mal, wenn wir mehr Zeit verbringen, mit dem Programm raussuchen und einstellen und schauen, dass er läuft.* **F13 (employee): I think it is a huge relief, especially when it comes to large quantities. Otherwise, one of us would be working on it for several days, just sitting there and inserting vials.** *F13 (Mitarbeitende): Gerade bei den großen Mengen, glaube ich, ist es eine wahnsinnige Erleichterung, wenn ich mir denke, einer von uns würde ja mehrere Tage dran sitzen und du sitzt ja dann wirklich nur da und bist am Stecken* **F22 (employee): And that it can take care of these huge order volumes so that the employees do not have to do these monotonous tasks for days on end.** *F22 (Mitarbeitende): Und dass er uns eben diese Dinge abnehmen kann bei diesen riesen Auftragsmengen und nicht die Mitarbeiter tagelang diese Tätigkeit, diese stupide, machen müssen.*
Physical relief	References from participants about the physical relief provided by the cobots. (main code)

	F8 (employee): If you stand there like that all day, you get neck pain, headaches, or something like that, and you just do not have that (with the cobot). *F8 (Mitarbeitende): Wenn du den ganzen Tag so dastehst dann hast du Gnackweh [Schmerzen im Genick] oder Kopfweh [Kopfschmerzen] oder keine Ahnung und das hast du halt dann nicht (mit dem Cobot).* **F6 (employee): Well, I notice that when I have been doing a lot of work, I feel my wrists ache sometimes in the evening. And I think that when you put less strain on them, you really notice the difference. It is not physically demanding work but relatively strenuous for the joints.** *F6 (Mitarbeitende): Also, ich merke, dass wenn ich viel gesteckt habe, es abends an meinen Handgelenke schon das eine oder andere Mal. Und ich finde schon, dass wenn man die Belastung dann weniger hat, wie sehr man das eigentlich merkt. Es ist jetzt zwar nicht körperlich schwer arbeiten, aber es ist doch relativ anstrengend für die Gelenke.* **M9 (employee): The cobot makes my work easier.** *M9 (Mitarbeitende): Ich sehe den Cobot als Arbeitserleichterung.* **M25 (employee): But every tray we do not have to do ourselves is also a physical relief in some way.** *M25 (Mitarbeitende): Aber jedes Tableau, das wir im Prinzip nicht selber stecken müssen, ist ja irgendwo auch eine körperliche Entlastung.*
Personal development	References from participants on the personal development opportunities of working with cobots. (main code) **M1 (employee): That was a big challenge, but I think it really helped me to grow.** *M1 (Mitarbeitende): Das war schon eine große Herausforderung, aber hat mich auch wirklich, glaube ich, weitergebracht.* **M10 (employee): So working with the cobot is fun because it also challenges you a bit.** *M10 (Mitarbeitende): Also mit dem Cobot zu arbeiten, das macht Spaß, weil er dich auch ein bisschen herausfordert.* **M15 (manager): Of course, it is development in many ways—personal development, professional, perhaps even financial, building up know-how and unique expertise.** *M15 (Führungskraft): Das ist natürlich in vielerlei Hinsicht Entwicklung, persönlicher Entwicklung, sowie fachlich, vielleicht auch finanzieller Art, Aufbau von Know-how, Alleinstellungsmerkmale.* **M27 (manager): Well, I say, maybe it takes away the job of a less skilled worker, but on the other hand, it creates a job for a highly qualified worker. Because the thing (cobot) also needs to be looked after, sometimes something breaks, and sometimes it needs to be programmed.** *M27 (Führungskraft): Also ich sag mal, vielleicht nimmt er einen einfacheren Arbeitsplatz weg, aber auf der anderen Seite wird dann wieder ein hochqualifizierter Arbeitsplatz geschaffen. Weil das Ding (Cobot) muss ja auch betreut werden, da geht auch mal was kaputt, das muss auch mal programmiert werden.*

	M27 (manager): This is a development opportunity for me (as an employee), so that I can take the next step. It is really about user stories, about a collaborative way of working, but also about one's own personal, intrinsic motivation to grow in the workplace. *M27 (Führungskraft): Das ist jetzt genau eine Entwicklungsmöglichkeit für mich (als Mitarbeiter), dass ich den nächsten Schritt gehen kann. Also wirklich über User Stories, über eine kollaborative Arbeitsweise, aber auch über die eigene persönliche, intrinsische Motivation, sich weiterzuentwickeln am Arbeitsplatz.*
Flexibility of cobots	References from participants on the flexibility of cobot technology. (main code) **M10 (employee): When I look at the cobots now, I think that you can do many things with cobots.** *M10 (Mitarbeitende): Und wenn ich halt die Cobots jetzt anschaue, dann denke ich mir, mit den Cobots kann man halt viele Sachen machen.* **M17 (employee): I think that the cobot's greatest strength is that it is incredibly flexible. It can insert modules today and close bottles tomorrow or whatever.** *M17 (Mitarbeitende): Ich glaube, das ist ja gerade eigentlich die größte Stärke vom Cobot, dass er halt unglaublich flexibel ist. Und er kann heute Module stecken und morgen Flaschen zudrehen oder was auch immer.* **M27 (manager): You can react very flexibly and quickly to minor requirements. That is the advantage—the major advantage—of the cobot.** *M27 (Führungskraft): Und du kannst sehr flexibel auf kleine Anforderungen gut und schnell reagieren. Das ist der Vorteil, der Riesenvorteil an dem Cobot.*
Subjective user-friendliness	**This theme captures participants' perceptions of the user-friendliness and accessibility of cobot technology. It includes assessments of the ease of technological advancement, ease of use, learner-friendliness, and the impact of new demands on employees. (theme)**
Ease of use	References from participants on the ease of use of cobots. (main code) **F3 (employee): You do not have to do anything complicated. I think it is relatively easy to understand.** *F3 (Mitarbeitende): Du musst nicht wunder was machen, der ist halt, denk ich mal, relativ schnell zum Begreifen.* **M5 (employee): Just switch it on; there is really nothing complicated about it.** *M5 (Mitarbeitende): Das Teil anmachen und eigentlich ist nichts Kompliziertes dabei.* **M16 (manager): The operation itself is very, very simple.** *M16 (Führungskraft): Die reine Bedienung ist sehr, sehr simpel.*
Ease of advancement	References from participants on the ease of developing and adapting cobots in practical application. (main code)

	M19 (manager): Well, I do not need a certified robotics expert to set it up. I think that is very positive. It is like a smartphone. That makes it very easy, or at least much easier, to integrate into work processes. *M19 (Führungskraft): Also ich brauche jetzt keinen studierten Roboter Fachmann, um das Ding einzurichten. Das finde ich sehr positiv. Es ist so Smartphone mäßig. Das macht es auf alle Fälle sehr leicht oder viel leichter, das zu integrieren im Alltag.* **M11 (employee): For example, you teach the arm (the cobot) at this point by pressing a small button, then you move it to the other side, where it should go, press the button again, and then it is programmed.** *M11 (Mitarbeitende): Du sagst zum Beispiel okay, du teachst den Arm (Cobot) hier ein an diesem Punkt mit so einem kleinen Knopf, dann tust du ihn an die andere Seite, da wo er hin soll, drückst noch mal drauf, dann ist er programmiert.* **M1 (employee): It was more difficult at the beginning. It got easier and easier as you learned the first few things. Once I started to understand how the program works, or the programming itself, it became easier relatively quickly.** *M1 (Mitarbeitende): Am Anfang schwerer. Es wurde dann immer einfacher, wenn man sich die ersten Sachen so ein bisschen angeeignet hat, beginnt, zu verstehen, wie dieses Programm funktioniert oder die Programmierung an sich, dann wird es relativ schnell einfacher.*
Learner friendliness	References from participants on learner-friendliness based on the training set-up, as well as the support and assistance provided to staff. (main code)
Support and assistance	References from participants made to support and assistance when working with cobots. (code) **M1 (employee): I have two colleagues who have also been trained. They can also programme the cobot, and we can exchange ideas with each other.** *M1 (Mitarbeitende): Ich habe noch zwei Kollegen, die auch eingearbeitet sind. Die auch den Cobot programmieren können und da tauschen wir uns auch untereinander aus.* **F3 (employee): So you are not alone. I have never been on my own.** *F3 (Mitarbeitende): Also du stehst nicht alleine da. Also ich bin noch nie alleine dagestanden.* **F8 (employee): If there is an error […] you are not on your own. There is always someone there if you do not know what to do.** *F8 (Mitarbeitende): Wenn man einen Fehler hat […] bist du nicht auf dich alleine gestellt. Sondern da ist immer jemand da, wenn du nicht weiter weißt.*
Training setup	References from participants about the training setup. (code) **M11 (employee): Yes, we actually visited the company where the cobots are produced, had the cobots explained to us, and received basic training there.**

	M11 (Mitarbeitende): Ja, wir waren bei der, Firma wo die Cobots produziert werden persönlich dort vor Ort und haben uns quasi die Cobots erklären lassen und hatten dort einen Grundkurs. **M25 (employee): I remember very clearly when the cobot arrived. I think we simply had a group training session about how it works in general.** *M25 (Mitarbeitende): Ich weiß noch ganz genau, als der Cobot am Anfang gekommen ist, hatten wir, glaube ich, einfach so eine Gruppenschulung, wie er grob funktioniert.* **F14 (manager): I do not think it was a bad idea to take everyone by the hand and say, let us just give it a try.** *F14 (Führungskraft): Also ich glaube, dass das nicht verkehrt war, dass man alle mal an die Hand genommen hat, gesagt hat, wir probieren das jetzt mal aus.* ***F12 (employee): Right now, honestly, I am still really unsure. I would actually need a proper introduction and some training.*** *F12 (Mitarbeitende): Jetzt im Moment ganz ehrlich, noch sehr unsicher. Also da bräuchte ich wirklich eine richtige Einweisung, eine Schulung.* ***F13 (employees): I think it would be good to do it step by step [...] with training sessions or something like that, [...] or if I have a production technician next to me, so that I could just ask questions.*** *F13 (Mitarbeitende): Ich denke, wenn man das Schritt für Schritt machen würde. Mit […] Schulungen oder eher so, […] oder ich einen Maschinisten […] neben mir habe, wo man einfach doch noch mal anders Fragen stellen kann.*
New demands on employees	References from participants about new demands on employees. (main code) **F12 (employee): Well, I can imagine that some people would definitely have the confidence to do it and could do it, certainly, even if not everyone could do it. But for some (employees), in any case, especially production technicians or those who have a certain technical understanding.** *F12 (Mitarbeitende): Also ich kann mir schon vorstellen, bei einigen, die sich das auf jeden Fall zutrauen würden und es auch könnten, mit Sicherheit, wenn auch nicht bei jedem. Aber bei einigen (Mitarbeitenden) auf jeden Fall, gerade Maschinisten oder die, die wirklich auch ein gewisses technisches Verständnis haben.* **M17 (employee): Of course, robotics has been added, which we hardly had before. And especially with this teaching and programming, that is something completely different compared with the other machines.** *M17 (Mitarbeitende): Es ist natürlich die Robotik dazugekommen, was wir vorher halt recht wenig hatten. Und gerade mit diesem Teaching und Programmieren, das ist etwas komplett anderes als bei den anderen Anlagen.* **F26 (manager): That is why I was not sure whether they (the employees) would really be able to operate a robot. I was a bit sceptical at first, but I was proven wrong.**

	F26 (Führungskraft): Deswegen war ich mir da nicht sicher, schaffen die (Mitarbeitenden) das wirklich, einen Roboter zu bedienen? Da war ich einfach am Anfang ein bisschen skeptisch, aber ich habe mich eines Besseren belehren lassen.
Emotional factors	**The theme captures the range of emotional responses, perceptions, and attitudes individuals hold towards cobots. It includes both positive and negative emotions, such as viewing cobots as opportunities or threats, along with trust in the technology and aspects related to the humanisation and objectification of cobots. (theme)**
Cobots perceived as opportunity	References from participants about cobots being perceived as an opportunity. (main code)
Curiosity about cobots	References from participants on their curiosity about cobots. (code) ***F4 (*employee): Because it is actually quite fascinating how the cobot works.** *F4 (Mitarbeitende): Weil es irgendwie schon faszinierend ist, wie der Cobot arbeitet.* **M11 (employee): Just this future-oriented work–that we finally have a robot that automates something you can see in real life, and that also works collaboratively.** *M11 (Mitarbeitende): Einfach diese, diese zukunftsorientierte Arbeit, dass wir endlich einen Roboter haben, der was automatisiert, den man live angucken [anschauen] kann und dann auch noch kollaborierend.* **M17 (employee): When it collaborates, it is really impressive. I was actually [...] pleasantly surprised.** *M17 (Mitarbeitende): Wenn er kollaboriert, dann ist es schon beeindruckend. Da wurde ich eher […] positiv überrascht.*
Positive expectations	References from participants regarding positive expectations of cobots. (code) **M19 (manager): On the one hand, there is definitely the hope that it will take over some of the work that is just monotonous.** *M19 (Führungskraft): Auf der einen Seite bestimmt die Hoffnung, dass er, dass er was abnimmt, was einfach nur eintönig ist.* **M21 (manager): Even if there is a bit of worry in the back of some employees' minds, I see it more as an opportunity than something to be afraid of.** *M21 (Führungskraft): Selbst wenn im Hinterkopf beim ein oder anderen Mitarbeiter da was mitschwingt, sehe ich es eher als Chance statt als Angst.* **M10 (employee): So now my hopes are actually quite high, because I think maybe we can do many, many things with this device (cobot) that, keep us from working.** *M10 (Mitarbeitende): Also und jetzt ist halt meine Hoffnung schon groß, weil ich mir denke, vielleicht können wir mit dem, mit dem Ding (Cobot) halt viele, viele Sachen machen, was ja, was halt uns abhält.*
Reduction of fear	References from participants about a reduction or absence of fear of cobots. (code)

	F8 (employee): Well, it is good that you just lose your fear and that you can simply get into working with it. *F8 (Mitarbeitende): Also, das ist halt gut, dass man einfach die Angst verliert und dass man sich da einfach einarbeiten hat können.* **F4 (employee): But it does not take long before you realise that it does not run without people. So I did not have any fears.** *F4 (Mitarbeitende): Aber es dauert ja nicht lange, bis du kapierst, dass der ja nicht ohne Menschen läuft. Von dem her habe ich keine Ängste gehabt.* **M17 (employee): I do not think they are going to take our jobs away.** *M17 (Mitarbeitende): Ich glaube jetzt nicht, dass die uns die Arbeit wegnehmen.*
Satisfaction	References from participants on the satisfaction of using cobots. (code) **F7 (employee): But in total, I have to say, Adam and Eve are actually doing a good job.** *F7 (Mitarbeitende): Aber im Großen und Ganzen, muss ich sagen, machen Adam und Eva das eigentlich gut.* **M10 (employee): If you look at it now, what it can actually do and has done a few times, I would say it is working well.** *M10 (Mitarbeitende): Wenn man ihn halt jetzt so anschaut, was er so alles eigentlich drauf hat und auch ein paar Mal gemacht hat, würde ich schon sagen, es ist ein gutes Ding.* **F12 (employee): Otherwise, I feel that once it is up and running, everyone will be quite satisfied and things will just work out.** *F12 (Mitarbeitende): Ansonsten ich habe das Gefühl, wenn es dann mal läuft, dann sind auch alle ganz zufrieden und dann klappt es halt auch.* **M17 (employee): Well, I think it works pretty well.** *M17 (Mitarbeitende): Also ich finde, das funktioniert ziemlich gut.*
Cobots perceived as threat	References from participants about cobots being perceived as a threat. (main code)
Fears around cobots	References from participants on different types of fears associated with cobots. (code)
Damage concerns	References from participants regarding concerns of damaging the cobots. (sub-code) **F3 (employee): The worry is that you just touch it and then something breaks, because you have no experience with a machine like that.** *F3 (Mitarbeitende): Die Angst ist halt, dass du, du langst hin und dann ist da was kaputt, weil du so einen Automaten nicht kennst.* **F8 (employee): I do not dare to use it because I think, it is all programmed, and if I do something wrong, then everything will be gone.** *F8 (Mitarbeitende): Da traue ich mich nicht hin, weil ich mir denke, na ja ok, das ist alles programmiert, mach ich da irgendwas falsch und dann ist alles weg.*

		F13 (employee): I quickly feel insecure because I am often afraid that something might break. Or I just think it costs an insane amount of money, and you do not want to be the one who breaks its arm or something. *F13 (Mitarbeitende): Und ich bin dann schon schnell unsicher, weil ich oft Angst habe, dass was kaputtgehen könnte. Oder ich denke mal, die kosten einfach wahnsinnig viel Geld und man will nicht derjenige sein, der den Arm abreißt oder so.*
	Doubts about value	References from participants regarding doubts about the added value of a cobot. (sub-code) **M1 (employee): I was afraid that the whole thing I had come up with would not work.** *M1 (Mitarbeitende): Natürlich hatte ich Angst, dass das Ganze nicht funktioniert, was ich mir da ausgedacht habe.* **F4 (employee): Because then the whole thing really slows me down in production. You lose a lot of time that way.** *F4 (Mitarbeitende): Weil dann, dann bremst mich die ganze Geschichte enorm aus (in der Produktion). Da geht viel Zeit dran verloren.* **M15 (manager): They often showed errors. Therefore, the added value was not there at first or could not be seen immediately.** *M15 (Führungskraft): Die haben öfters Störungen gezeigt, wo dann der Mehrwert natürlich erst mal nicht da war, nicht sofort gesehen wurde.*
	General anxiety	References from participants on a general fear of cobot technology. (sub-code) **M5 (employee): In the beginning, not being computer literate and having to start the programme and then make it work made me feel a bit insecure and reluctant.** *M5 (Mitarbeitende): In der ersten Zeit, da ich kein Computer Mensch bin, in das Programm reinzugehen, um den dann zum Laufen zu bringen, das hat mich ein bisschen verunsichert und ein bisschen abgestoßen.* **M9 (employee): Maybe it is because some people are actually afraid of technology, of working with it or having to work with it.** *M9 (Mitarbeitende): Vielleicht liegt es daran, dass Manche tatsächlich Angst vor der Technik haben, damit zu arbeiten oder arbeiten zu müssen.* **F13 (employee): Well, I would definitely choose to do it (production) by myself, but just because I have a lot of respect for these machines, these robots.** *F13 (Mitarbeitende): Also ich würde mich bestimmt für das, das ich es (Produktion) selber mache entscheiden, aber einfach nur, weil ich einfach wahnsinnigen Respekt vor diesen Maschinen, Robotern habe.*
	Job loss fears	References from participants about the fear of losing their jobs due to the implementation of cobots. (sub-code) **F3 (employee): So you started thinking that we have less and less work. So now is it taking over everything?**

	F3 (Mitarbeitende): Da hast du dir schon gedacht, unsere Arbeit wird immer irgendwie weniger. Also übernimmt der jetzt alles? **F12 (Mitarbeitende): Hopefully, it will not replace us.** *F12 (employee): Hoffentlich ersetzt er uns nicht.* **F13 (employee): On the one hand, of course, you worry about it because you are obviously afraid that you might be replaced by all these robots and cobots at some point.** *F13 (Mitarbeitende): Also auf der einen Seite, klar macht man sich Gedanken darüber, weil man natürlich Angst hat, dass man vielleicht irgendwann durch diese ganzen Roboter, Cobots ersetzt wird.*
Frustration	References from participants about frustration when using cobots. (code) **F3 (employee): If it does not work, then it is really frustrating because, in that case, you lose time.** F3 (*Mitarbeitende*): Wenn er halt nicht funktioniert, dann ist es halt ekelhaft [sehr frustrierend], weil dann verliert man Zeit. **M2 (employee): The cobot is not a machine colleague, as I was promised, but a hindrance.** M2 (*Mitarbeitende*): Der Cobot ist kein maschineller Kollege, wie man es mir versprochen hat, sondern ein Störfaktor. **M21 (manager): Of course, everyone's tolerance for frustration varies.** M21 (*Führungskraft*): Und natürlich ist die Frustrationstoleranz auch unterschiedlich ausgeprägt bei jedem Einzelnen. **M2: Let me put it this way: I am standing there […] bashing the cobots with a steel pipe until there is nothing left of them. Even back then, I knew how it would turn out, that it would all go wrong– and I have been proven right.** M2: Das muss ich bildlicher formulieren: Ich stehe da […] dresche [schlage] mit einem Stahlrohr auf die Cobots ein, bis nichts mehr übrig bleibt. Ich habe schon damals gewusst, auf was es rausläuft und dass es schief läuft und alles ist bestätigt worden.
Scepticism	References from participants regarding scepticism towards cobots. (code) **M2 (employee): I feel like I have to watch it (cobot) all the time, otherwise it does nothing or does not do it properly.** *M2 (Mitarbeitende): Ich habe das Gefühl, ich muss ihn permanent überwachen, sonst macht er nichts oder macht es nicht richtig.* **F4 (employee): Effective, productive, and useful if it is running. Emphasis on the if.** *F4 (Mitarbeitende): Effektiv, produktiv und sinnvoll, wenn er läuft. Immer dieses wenn.* **F8 (employee): Sometimes, it (cobot) simply does not work properly. It is just a machine. It is also not infallible.** *F8 (Mitarbeitende): Keine Ahnung, also manchmal spinnt er (Cobot) halt [funktioniert er nicht richtig]. Maschine halt. Ist auch nicht unfehlbar.*

Emotional response to cobots	References from participants on emotional responses to cobots in terms of humanisation and objectification. (main code)
Humanisation	References from participants on the humanisation of cobots. (code) **F7 (employee): Then […] I said, they are just two lovers. Either Adam does not want to or Eve does not want to.** *F7 (Mitarbeitende): Dann […] habe ich gesagt, das sind halt zwei Verliebte, entweder der Adam mag nicht oder die Eva mag nicht.* **F4 (employee): Well, I have already stroked it and things like that.** *F4 (Mitarbeitende): Also, ich habe ja den auch schon gestreichelt und so.* ***M10* (employee)*: Personally, I just love machines.*** *M10 (Mitarbeitende): Ich persönlich, ich liebe halt Maschinen.* **M23 (employee): It is a typical machine, but over time it becomes your friend somehow. That was the case for me; you develop a bond with it.** *M23 (Mitarbeitende): Es ist ja eine typische Maschine, aber mit der Zeit ist es dein Freund irgendwie. So war es bei mir, dann hat man eine Bindung.*
Objectification	References from participants on the objectification of cobots. (code) **M25 (employee): It is more of a tool or a machine that you operate.** *M25 (Mitarbeitende): Das ist dann schon eher ein Werkzeug oder eine Maschine, die du halt bedienst.* **M16 (manager): The cobot is simply too much of an object for it to cause a major conflict within the team.** *M16 (Führungskraft): Dafür ist der Cobot einfach zu sehr Sache, als dass er jetzt groß einen Konflikt innerhalb der Mannschaft auslösen würde.* **F8 (employee): Well, I think it is a machine, and the other one is a person, and you cannot have a relationship with it. At least, I cannot build a relationship with a machine. No, that is not possible.** *F8 (Mitarbeitende): Also da finde ich, es ist eine Maschine und das andere ist ein Mensch und da kann man keine Beziehung haben, also ich jedenfalls kann keine Beziehung zu einer Maschine aufbauen. Nein, das geht nicht.*
Trust in cobots	References from participants on the level of trust in cobots. (main code) **M1 (employee): The cobot works. It had to convince us first.** *M1 (Mitarbeitende): Der Cobot funktioniert. Er hat auch erst überzeugen müssen.* **M5 (employee): It was important to me that it runs and does not constantly stop because of minor issues.** *M5 (Mitarbeitende): Mir war es wichtig, dass er läuft und nicht permanent stehen bleibt wegen Kleinigkeiten.* **M10 (employee): Yes, because for me, the cobot is more of a burden than a help. That is why I say personally. Yes. The cobot has to run reliably.**

	M10 (Mitarbeitende): Ja, dann ist für mich der Cobot eher ein Klotz am Bein als eine Unterstützung. Deswegen sage ich persönlich. Ja. Der Cobot muss solide laufen.
Cobot characteristics	**The theme encompasses the various features and characteristics of cobots as well as the intentions behind their implementation. This includes technical, operational, ergonomic, and economic aspects. (theme)**
Purpose of cobot deployment	References from participants regarding their intentions and purposes when implementing cobots. (main code)
Collaborative use	References from participants regarding joint human-cobot work as an objective of the implementation. (code) **F26 (manager): The employees can do something else at the same time and thus be more productive in that respect. You might say, well, they could be assembling other components that the machine cannot process. Or perhaps they are already filling out production paperwork.** *F26 (Führungskraft): Dann können ja die Mitarbeiter nebenzu [nebenbei] etwas anders machen und sind dann in der Hinsicht wieder produktiv. Wo man sagt, na ja, sie machen dann vielleicht schon mal andere Komponenten, die man nicht über die Maschine machen kann. Oder sie füllen vielleicht schon Papiere aus.* **M24 (manager): That is a huge advantage because a production worker can then, of course, take care of things like highly complex kits, for example.** *M24 (Führungskraft): Ein enormer Vorteil, weil ein Produktionsmitarbeiter kann sich natürlich dann um Sachen kümmern, wie hochkomplexe Kits zum Beispiel.* **M21 (manager): The employee can do other tasks while the robot is working.** *M21 (Führungskraft): Der Mitarbeiter kann in der Zeit, in der der Roboter arbeitet, andere Tätigkeiten machen.*
Economic efficiency	References from participants regarding economic efficiency as a goal of the implementation. (code) **M16 (manager): Of course, this also means that you can either reduce staff or assign them to more meaningful activities. Let us put it this way: not reduce staff.** *M16 (Führungskraft): Und dadurch kann man sich natürlich auch Leute einsparen bzw. Leute für sinnvollere Tätigkeiten einsetzen, sagen wir es so rum, nicht einsparen.* **M20 (manager): But of course, our annual cost reduction targets, which we had to and still have to achieve, were essentially the original trigger for automation.** *M20 (Führungskraft): Aber natürlich unsere Kostenreduktion, die jährliche, die wir reinholen mussten und müssen, das war im Prinzip unser ursprünglicher Trigger für die Automatisierung.* **M21 (manager): Automation is always welcome, provided it is clear or demonstrable that it has generated added value.**

	M21 (Führungskraft): Automatisierung wird immer gern gesehen, vorausgesetzt, es ist auch offensichtlich oder nachweisbar, dass da Mehrwert generiert wurde.
Work quality	References from participants regarding the improvement of employees' quality of work through the use of cobots as an objective of the implementation. (code) **M16 (manager): It is an appropriate tool for easily performing monotonous tasks.** *M16 (Führungskraft): Es ist ein adäquates Mittel, um eintönige Arbeit leicht zu erledigen.* **M20 (manager): And these are assembly tasks, always repetitive. These are actually great patterns that you could teach directly to the cobot.** *M20 (Führungskraft): Und das sind Konfektionierungstätigkeiten, immer repetitive Themen. Das sind eigentlich tolle Muster, die du genau dem Cobot beibringen konntest.* **M24 (manager): Yes, because the insertion processes are highly monotonous, and you can now assign them to the cobots.** *M24 (Führungskraft): Ja, denn die Steckprozesse sind halt sehr monoton, die man jetzt den Cobots übertragen kann.*
Technology attributes	References from participants regarding the technological attributes of cobots. (main code)
Appearance	References from participants regarding the cobot's appearance and its movement patterns. (code) **M2 (employee): The cobot imitates human movement, and that cannot work.** *M2 (Mitarbeitende): Der Cobot imitiert die menschliche Bewegung und das kann nicht funktionieren.* **M11 (employee): Let me put it this way: they are not industrial robots, and that makes them a bit more susceptible to [...] joint pain since they are not as professionally designed as an industrial robot.** *M11 (Mitarbeitende): Ich sage mal so, es sind halt keine Industrieroboter und dadurch sind sie natürlich auch ein bisschen anfälliger für, ich sag jetzt mal Gelenkschmerzen, weil die natürlich nicht so hochprofessionell verarbeitet wurden, wie jetzt bei einem Industrieroboter.* **M17 (employee): Well, you cannot really equate the two, but I would say it is much more human-like than any other production line.** *M17 (Mitarbeitende): Also man kann das ja jetzt nicht gleichsetzen, aber er ist deutlich menschenähnlicher, sage ich mal, als eine andere Anlage.*
Collaboration needs	References from participants on collaboration needs with the cobot. (code) **M9 (employee): Well, the cobot can only do the simplest tasks, and you always need a human as well. And a human to operate it.** *M9 (Mitarbeitende): Nun, der Cobot kann nur einfachstes stecken und man braucht immer einen Menschen dazu. Und einen Menschen, der wo ihn bedient.*

		M11 (employee): It always needs a human to tell it what to do. And no matter how often I want something from it, I have to tell it to start the programme. *M11 (Mitarbeitende): Er braucht immer einen Menschen, der ihm sagt, wo es langgeht. Und egal, wie oft ich etwas von ihm will, ich muss ihm sagen das Programm zu starten.* **M21 (manager): And so there will always be a need for supervision and certain areas of focus, which may shift but remain within the same general field.** *M21 (Führungskraft): Und somit wird es immer eine Betreuung geben und immer gewisse Tätigkeitsschwerpunkte, zwar verlagert aber im selben Aufgabenfeld.*
	Production speed	References from participants on the cobot's production speed. (code) **M5 (employee): During coffee breaks or lunch, for example, it keeps working. That way, I do not experience any downtime during packaging.** *M5 (Mitarbeitende): Während der Brotzeit zum Beispiel oder während den Pausen steckt er immer noch weiter. Und dann habe ich keinen Stillstand in dem Sinne beim Verpacken.* **M10 (employee): And above all, it just keeps going and works continuously.** *M10 (Mitarbeitende): Und vor allem, er macht es halt konstant, der macht es dann dauerhaft.* **M25 (employee): It does not have the same speed that we have as human workers. It is somewhat slower, but as support, it is a great thing.** *M25 (Mitarbeitende): Er hat auch nicht die gleiche Geschwindigkeit, die wir jetzt haben, also die wir als menschliche Arbeitskraft haben, sondern er ist da schon ein bisschen langsamer, aber so als Unterstützung ist es eine super Sache.*
	Noise level	References from participants on the noise level of the cobots. (code) **M5 (employee): The noise level, sometimes it is annoying. Not the air, because everything is powered by air, but the distributor at the front. That iron sound. Click, click, click. And that is damn loud.** *M5 (Mitarbeitende): Der Geräuschpegel, ab und zu nervt er. Nicht die Luft, weil es wird alles mit Luft betrieben, sondern der Verteiler vorne. Das Eisengeräusch. Klack, klack, klack. Und das ist verdammt laut.* **F22 (employee): And then there are days when it is annoying because of the noise—as we actually noticed today—the noise is different when it is malfunctioning.** *F22 (Mitarbeitende): Und dann gibt es aber auch Tage und das nervt auch, weil das Geräusch, das haben wir heute tatsächlich festgestellt, das Geräusch ein anderes ist, wenn er eine Störung hat.* **F7 (employee): I do not need to stand next to it (cobot) because of the noise. The noise level is just too much for me.** *F7 (Mitarbeitende): Dazustehen brauche ich nicht, weil das Geräusch, der Geräuschpegel mir zu groß ist.*

Contextual factors	**The theme refers to the various external and internal conditions and influences that affect the implementation and use of cobots in an organisational setting. This includes financial, managerial, and operational aspects related to cobots and previous experience with automation. (theme)**
Management support	References from participants related to management support in the implementation/use of cobots. (main code) **M15 (manager): Of course, I know from senior management that they want to promote new technologies so that things can also be automated, because labour costs are naturally a major issue.** *M15 (Führungskraft): Von der Bereichsleitung weiß ich natürlich, dass die so neue Technologien anschieben will, dass man sowas auch automatisiert. Weil Lohnkosten natürlich ein großes Thema sind.* **M15 (manager): We always present the technology, and I have consistently received positive feedback. I also feel this provides support to push this forward.** *M15 (Führungskraft): Wir zeigen ja immer die Technologie und ich habe da eigentlich durchweg positives Feedback gekriegt [bekommen]. Ich empfinde es auch als Rückendeckung, das voranzutreiben.* **M19 (manager): Our former senior manager was really enthusiastic about automation, and we used this enthusiasm to come up with a few ideas.** *M19 (Führungskraft): Also unser, unser damaliger Bereichsleiter war ganz begeistert von Automatisierung und wir haben dann auch diese Begeisterung genutzt und sind mit ein paar Ideen dann angetreten.* **M9 (employees): I think (the increase in interaction with the cobots) depends on the objectives of the performance reviews.** *M9 (Mitarbeitende): Ich glaube (die Steigerung der Interaktion mit den Cobots), liegt an den Zielen der Performance Gespräche.*
Organisational conditions	References from participants on the existing organisational conditions. (main code) **F4 (employee): Well, we have also had phases where we simply did not have enough people in labelling.** *F4 (Mitarbeitende): Also, wir haben ja auch Phasen gehabt, wo wir einfach zu wenig Leute in der Etikettierung hatten.* **M21 (manager): Automation only makes sense if the forecast figures for a particular product are reliable.** *M21 (Führungskraft): Die Automatisierung macht ja dann erst Sinn, wenn Forecast Zahlen verlässlich sind zu einem gewissen Produkt.* **F6 (employee): I would say, until I have set everything up—including fetching the goods, starting the programmes, booting up the PC, starting the programmes—it takes about fifteen to twenty minutes. Depending on how many goods there are, it can take up to half an hour.** *F6 (Mitarbeitende): Ich würde sagen, bis ich alles eingerichtet habe. Also auch mit Ware holen, die Programme starten, also PC hochfahren, Programme starten: Viertelstunde, 20 Minuten, je nachdem wie viel, wie viel Ware es ist, eine halbe Stunde ungefähr.*

	M1 (employee): On the one hand, the quantity plays a very important role. I think that for 50 pieces, I do not need any automation, and I would probably be faster if I just did it quickly by hand. *M1 (Mitarbeitende): Einmal spielt die Stückzahl eine ganz große Rolle. Ich meine, für 50 Stück brauche ich keine Automatisierung, da bin ich wahrscheinlich schneller, wenn ich es einfach geschwind [schnell] von Hand mache.*
Time investment	References from participants on the amount of time spent implementing cobots. (main code) **M2 (employee): In addition, people are taken out of the machine room, and then we are missing them in production. It takes far too much time for it to work.** *M2 (Mitarbeitende): Außerdem werden Personen aus dem Maschinenraum abgezogen, die uns bei der Produktion fehlen. Es braucht viel zu viel Zeit, dass es funktioniert.* **M18 (manager): Yes, at times the resentment was quite considerable when someone had to spend a lot of time with the cobot or worked with it without achieving much.** *M18 (Führungskraft): Ja, der Unmut war ab und zu recht groß, wenn sich einer viel mit dem Cobot beschäftigen musste oder beschäftigt hat, ohne große Ergebnisse zu erzielen.* **M21 (manager): The time required for programming is initially an investment. During this period, the employee cannot perform any other production tasks but is 100% focused on the cobot, thinking about programming and so on. However, you have to calculate this over the medium and long term; it will definitely pay off in the end.** *M21 (Führungskraft): Natürlich ist die Zeit, die man zum Programmieren benötigt, erstmal ein Investment. Der Mitarbeiter kann in der Zeit keine andere Produktion durchführen, sondern hängt zu 100 % mit dem Kopf am Gerät, macht sich Gedanken über Programmierung usw. Aber man muss das lang- /mittelfristig, langfristig berechnen und da wird sicherlich ein Plus am Ende dabei rauskommen.* **M23 (employee): Yes, it really is a major step forward […] when someone is involved in a project like this who can fully concentrate on the matter at hand and also has the time to think and reflect.** *M23 (Mitarbeitende): Ja, ist schon ein großer Fortschritt […] wenn jemand in so einem Projekt ist, der sich nur auf die Sache konzentrieren kann und auch überlegen kann und die Zeit hat.*
Financial investment	References from participants regarding the level of financial investment in cobots. (main code) **M27 (manager): As I said before, the acquisition costs are low.** *M27 (Führungskraft): Also wie gesagt, du hast geringe Anschaffungskosten.* **M15 (manager): Well, of course, we do not have an unlimited budget that would allow us, for example, to buy additional feeding stations so that we could insert two components at the same time.** *M15 (Führungskraft): Also, wir haben natürlich kein unermessliches Budget, dass wir zum Beispiel weitere Zuführstationen kaufen könnten, dass wir jetzt zum Beispiel zwei Komponenten gleichzeitig stecken.*

	F4 (employee): They were inexpensive in comparison and do their job. Well, they will return the money; whereas the other (existing industrial robot) does not, but I do not know why. *F4 (Mitarbeitende): Die waren im Vergleich günstig und machen ihren Job. Also, die holen das Geld auch wieder rein, der andere (vorhandener Industrieroboter) nicht, aber an was es liegt.*
Workload and employee utilisation	References from participants on workload and employee utilisation. (main code) **F4 (employee): Nowadays, in the current situation, you are often just glad if you have enough work to do yourself.** *F4 (Mitarbeitende): Heute, in der jetzigen Situation, bist du oft froh, wenn du selber zu tun hast.* **F13 (employee): Well, I think, of course, when things get really busy, so to speak, and we have a lot to do, then we are glad that the thing is running and can handle a large order.** *F13 (Mitarbeitende): Also ich denke, klar, wenn die Hütte brennt, sag ich mal, und wir ordentlich zu tun haben und so, dann sind wir natürlich froh, dass das Ding läuft und einen großen Auftrag schon mal schafft.* **M19 (manager): Because not enough people want to do such work. That is what makes it different from the past. In packaging in the 80s, you could find many more people for such work, and there are fewer and fewer of them.** *M19 (Führungskraft): Weil die Leute werden ja auch nicht mehr, die solche Tätigkeiten machen wollen. Das unterscheidet uns ja auch von früher. Als Verpackungsbetriebe, was weiß ich, in den 80er Jahren, da gab es viel mehr Menschen, die du da gefunden hast für so eine Arbeit und die werden auch weniger.*
Operational restrictions	References from participants regarding operational restrictions related to cobots. (main code) **M15 (manager): There are limitations regarding the products themselves, for example, when it comes to temperature exposure. The cobots are located in normal rooms, but our products are temperature-sensitive, or at least mostly temperature-sensitive.** *M15 (Führungskraft): Wir haben natürlich Restriktionen bei den, bei den Produkten an sich, also was zum Beispiel Temperaturbelastungen angeht. Die Cobots stehen ja im normalen Raum, unsere Produkte sind temperaturempfindlich, das heißt oder zum Großteil temperaturempfindlich.* **M18 (manager): That was just not designed for it at all. You can already see that the modules are not standing properly, etc. They were just intended for manual use.** *M18 (Führungskraft): Das ist ja halt gar nicht dafür konzipiert gewesen, dass merkt man jetzt schon, dass die Module nicht sauber stehen usw. Die sind halt viel für das Händische gedacht gewesen.* **M9 (employee): It only became apparent later that it has to be 100% stable and that it needs to be screwed on. It is not enough for the cobot to just stand on a stable table.**

	M9 (Mitarbeitende): Es ist auch erst später aufgekommen, dass es 100 % stabil stehen muss und dass der angeschraubt gehört, dass er (Cobot) nicht einfach auf einem stabilen Tisch steht, reicht nicht.
Previous automation experience	References from participants on previous experience with automation projects. (main code)
Failed implementation	References from participants on failed aspects of the implementation of automation projects. (code) **F8 (employee): It (the existing industrial robot) simply does not deliver what it is supposed to.** *F8 (Mitarbeitende): Weil er (vorhandener Industrieroboter) einfach das nicht bringt, was er machen soll.* **F4 (employee): The other machine (existing industrial robot) was just useless.** *F4 (Mitarbeitende): Die andere Maschine (vorhandener Industrieroboter) war halt Blödsinn.* **F12 (employee): I think this is more of a negative example (existing industrial robot). It definitely was not worth it at all. I believe it was a bad investment.** *F12 (Mitarbeitende): Das ist eher ein negatives Beispiel, finde ich jetzt (vorhandener Industrieroboter). Das hat sich auf jeden Fall überhaupt nicht gelohnt. Ich glaube, das war eine Fehlinvestition.*
Successful implementation	References from participants on successful aspects of the implementation of automation projects. (code) **F3 (employee): In retrospect, I have to say that all the machines we received have actually made our work easier.** *F3 (Mitarbeitende): Aber im Nachhinein muss ich sagen, alle Maschinen, wo wir gekriegt [bekommen] haben, haben uns eigentlich das Arbeiten erleichtert.* **M20 (manager): The success with the cans line was so great that we started putting out feelers more and more, going to trade fairs, and connecting with other sites.** *M20 (Führungskraft): Der Erfolg an der Dosenanlage war tatsächlich so groß, dass wir da immer mehr die Fühler ausgestreckt haben, auf Messen gefahren sind und uns mit anderen Sites connected haben.* **F6 (employee): No, but it was the same with the other robots when we got them. I always took a positive stance at first and thought, okay, our work would be easier, and it would be more pleasant to work.** *F6 (Mitarbeitende): Nee [nein], aber das war auch mit den anderen Robotern so, als wir die gekriegt [bekommen] haben. Ich habe das immer erst mal positiv aufgenommen und gedacht, okay, unsere Arbeit erleichtert sich dadurch, es wird angenehmer zu arbeiten.*
Workplace dynamics	**The theme encompasses the influence of workplace dynamics on employees' perceptions and attitudes towards cobots. It considers the role of leadership culture, peer influence, and the technology implementation process, with a focus on the levels of involvement and communication during implementation. (theme)**

Leadership culture	References from participants on leadership in the context of cobots. (main code) **M15 (manager): I think some of the employees can be convinced very well with theoretical explanations, but others need to be convinced in practice.** *M15 (Führungskraft): Ich glaube, den einen Teil der Mitarbeiter kann man sehr gut theoretisch abholen mit dem Erklären und andere müssen wir wirklich in der Praxis überzeugen.* **M15 (manager): So, taking a participatory approach, turning those affected into active participants and, in a way, turning the situation around.** *M15 (Führungskraft): Also, so ein partizipatives Vorgehen, Betroffene zu Beteiligten machen, den Spieß so ein bisschen umzudrehen.* **M20 (manager): And that is a classic management task: simply bringing the whole team back together, getting everyone back on track, and formulating a clear vision. We need to increase efficiency, but we are also trying to relieve employees by reducing their workload and repetitive tasks.** *M20 (Führungskraft): Und das ist klassische Führungsaufgabe. Einfach, indem man das ganze Team wieder zusammenbringt, on track bringt und eine klassische, ja Vision auch mitformuliert an der Stelle. Dass wir Effizienzen heben müssen, dass wir aber auch versuchen, Mitarbeiter zu entlasten und dadurch ja Arbeitslast, repetitive Themen einfach runter nehmen.* **F26 (manager): You are no longer the ones inserting the Sarstedt vials; now you are the ones feeding the cobots—you are a bit like the boss of the robot. I think this has made quite a difference in people's minds when they were told: Okay, now I am the boss of the robot, I feed it, and yes, I work with it.** *F26 (Führungskraft): Ihr seid jetzt nicht mehr diejenigen, die Sarstedts stecken, sondern ihr seid diejenigen, die den füttern, so ein bisschen der Chef von dem Roboter. Ich glaube, das hat dann auch relativ viel in den Köpfen bewirkt, dass man gesagt hat: okay, dann bin ich jetzt der Chef vom Roboter und füttere den und ja, arbeite mit dem.* ***M20 (manager): And that was actually how we established a really effective door opener. At the time, I had the employees sit right next to the cobots.*** *M20 (Führungskraft): Und da haben wir damals eigentlich dann einen coolen Türöffner etabliert. Und zwar habe ich dann die Mitarbeitenden damals direkt neben den Cobots auch sich hinsetzen lassen.*
Peer influence	References from participants on the impact of peer influence on their views of cobots. (main code) **F12 (employee): At the beginning, you often heard that it did not work […], especially from people who had worked with it a lot, who were familiar with the technology, and who had to learn it.** *F12 (Mitarbeitende): Man hat dann oft am Anfang gehört, […] es funktioniert nicht, grad von Leuten, die wirklich öfters damit gearbeitet haben, die mit der Technik vertraut waren, die das lernen mussten.*

	M15 (manager): I hope that he (the employee) not only experiences the benefits firsthand when things work well, but is also encouraged by seeing his colleagues use it successfully, motivating him to move in that direction as well. *M15 (Führungskraft): Und meine Hoffnung ist, dass er (Mitarbeiter) es nicht nur in der Praxis dann selber sieht, wenn es läuft, sondern auch schon indirekt über die Kollegen, so ein bisschen in die Richtung geschoben wird, wenn sie Erfolgserlebnisse haben.* **M20 (manager): When employee A once again dutifully pats the robot, so to speak. After it had to be restocked because it had processed everything so far, then, yes, at that moment, it simply had a positive impact.** *M20 (Führungskraft): Wenn dann Mitarbeiter A den Roboter wieder schön brav streichelt im Prinzip. Nachdem er, nachdem er erstmals wieder bestückt werden musste, weil er alles so weit verarbeitet hat, dann, ja dann hat es einfach einen positiven Impact gehabt an der Stelle.*
Technology implementation process	References from participants regarding their involvement in the implementation process. (main code)
High involvement	References from participants on high involvement in the implementation process. (code) **M1 (employee): I was involved from the initial idea through to implementation and wrote most of the programs for it together with a few other colleagues** *M1 (Mitarbeitende): Also von der Idee bis zur Umsetzung war ich soweit die ganze Zeit mit involviert und habe auch die meisten Programme dafür geschrieben zusammen mit ein paar anderen Kollegen.* **M15 (manager): Well, I naturally involve those who are positive about it in the implementation.** *M15 (Führungskraft): Also, dass in Anführungszeichen Lager, das das positiv sieht, die binde ich natürlich gezielt in der Implementierung ein.* **M21 (manager): I think it was the right approach to allow the employees to engage with the concept and then to design the system as a project.** *M21 (Führungskraft): Ich finde, das war der, es war der richtige Weg, dass sich die Mitarbeiter mit dem Konzept beschäftigen durften und in Form eines Projekts die Anlage dann konzipieren durften.*
Low involvement	References from participants on low involvement in the implementation process. (code) **F13 (employee): Well, as I said, we were not really involved in the set-up of the whole thing.** *F13 (Mitarbeitende): Also ich meine, wie gesagt, bei der Etablierung waren wir ja jetzt eh nicht so involviert in das Ganze.* **M16 (manager): For one thing, not everyone had to, was allowed to, or was able to work on it. This naturally leads to the development of insider knowledge.**

	M16 (Führungskraft): Zum einen haben nicht alle daran arbeiten müssen, dürfen, können. Was natürlich dazu führt, dass Insiderwissen aufgebaut wird. **M5 (employee): In the beginning, I did not know what the thing was for.** *M5 (Mitarbeitende): In der ersten Zeit wusste ich ja nicht, wofür das Teil da ist.*
Communication	References from participants on communication during the implementation process. (code) **F8 (employee): Yes, when it was introduced to us, we received a presentation, and I thought to myself: "Wow".** *F8 (Mitarbeitende): Ja, da also wo er uns vorgestellt worden ist, haben wir ja eine Präsentation gekriegt [bekommen] dann habe ich mir gedacht „wow".* **F14 (manager): Well, he always praises it. […] And I do think that this has an effect. So when people see, "Hey, there is praise for this, that is good", it does have a positive impact.** *F14 (Führungskraft): Also, er lobt es ja immer. […] Und ich glaube schon, dass das abfärbt. Also, dass wenn die Leute auch sehen, hey komm, das gibt ein Lob, dass das schon gut ist.* **M18 (manager): We also showed some videos of what it can do now and so on. I think that is never a bad thing. Especially when you have something new, we should talk about it and show it to everyone.** *M18 (Führungskraft): Wir haben mal Videos auch gezeigt, was er jetzt kann und so, das finde ich nie verkehrt. Gerade wenn man was Neues hat, das wir es thematisieren und es allen mal zeigen.*
Attitude towards cobots	**The theme encompasses individuals' overall perception of a technology in terms of its use and advancement, which is influenced by the identified input factors. It includes how people see the role and value of the technology on an individual and organisational level, captures both positive and negative perceptions, and neutral or mixed feelings about the technology. (theme)**
Attitude towards use	References from participants on individual attitudes and opinions about the practical application and everyday use of cobots. (main code)
Positive attitude	References from participants on positive attitudes towards the use of cobots. (code) **M10 (employee): We should work together, and I think [...] we will have a lot of fun with the cobots.** *M10 (Mitarbeitende): Man sollte halt zusammenarbeiten und ich glaube [...] wir mit dem Cobots sehr viel Spaß haben.* **M11 (employee): If you look at costs and benefits, I would always say it is beneficial. Because if we discover even one small thing that no person has to deal with anymore, but the robot can handle, then we have already gained something.** *M11 (Mitarbeitende): Wenn man sagt Kosten, Nutzen, würde ich immer sagen, es nützt. Weil wenn wir nur eine Kleinigkeit entdecken, wo kein Mensch mehr sich damit beschäftigen muss, sondern der Roboter, hat man schon wieder was gewonnen.*

	M17 (employee): So, I enjoy working with machines. But whether it is a robot arm or another machine does not really matter to me. *M17 (Mitarbeitende): Daher, mir macht die Arbeit mit Maschinen Spaß. Ob das jetzt aber ein Roboterarm ist oder eine Anlage, ist für mich relativ egal.*
Neutral attitude	References from participants about neutral attitudes towards the use of cobots. (code) **F12 (employee): I need to see it for myself or work with it myself in order to really be able to judge it.** *F12 (Mitarbeitende): Ich sage, ich muss auch selber mal das sehen oder selber mitarbeiten, dass ich es wirklich selber auch beurteilen kann.* **F22 (employee): Let us wait until the thing is here, and then we will see. And then we have to wait and see how it develops.** *F22 (Mitarbeitende): Jetzt wartet mal ab, bis das Ding da ist und dann sieht man es. Und dann muss man auch erst mal abwarten, wie sich das entwickelt.* **F6 (employee): Well, the cobots themselves are not to blame for the offset.** *F6 (Mitarbeitende): Also die Cobots selber können ja nix für den Offset.*
Negative attitude	References from participants on negative attitudes towards the use of cobots. (code) **M2 (employee): Until everything is running smoothly, I am glad if I do not have anything to do with the cobot.** *M2 (Mitarbeitende): Bis alles richtig läuft, bin ich froh, wenn ich mit dem Cobot nichts zu tun habe.* **F7 (employee): I do help, but [...] I do not necessarily have to be there myself**. *F7 (Mitarbeitende): Ich helfe schon, aber [...] muss nicht unbedingt da dort sein.* **F13 (employee): Yes, in the end, I have to say it is a strange feeling to work with the machines.** *F13 (Mitarbeitende): Ja, im Endeffekt muss ich sagen, es ist ein komisches Gefühl, mit den Maschinen zu arbeiten, sage ich jetzt mal.* **M15 (manager): And there are also employees, but in my view, there are only a few who still say: I am even faster than the cobot. I can do it more reliably and faster.** *M15 (Führungskraft): Und es gibt aber auch Mitarbeiter, aber das sind wenige aus meiner Sicht, die immer noch sagen, ich bin noch schneller wie der Cobot, ich kann das zuverlässiger, schneller.*
Attitude towards advancement	References from participants on individual attitudes and expectations towards the development and adaptation of cobots in practical applications. (main code)
Improvement ideas	References from participants on ideas for improving cobots to perform additional tasks in practice. (code) **F14 (manager): Yes, it would be cool if it (the cobot) could insert two components, one after the other, for example.**

		F14 (Führungskraft): Ja, cool wäre es, wenn er (der Cobot) zwei Komponenten stecken könnte, hintereinander zum Beispiel. **M18 (manager): Things like the piercer and similar ideas. At one time, there were also ideas that you could simply pre-pierce the modules and so on.** *M18 (Führungskraft): So was wie der Piercer und solche Späße. Das waren ja auch mal Ideen, dass man einfach die Module vorstechen kann und so.* **M5 (employee): That it could possibly make slightly faster movements.** *M5 (Mitarbeitende): Dass er eventuell bisschen schnellere Bewegungen macht.*
	Negative attitude	References from participants regarding negative attitudes towards the advancement of cobots in practical applications. (code) **M5 (employee): To create a programme. That is too complicated for me. I do not need it either.** *M5 (Mitarbeitende): Um ein Programm anzulegen. Das ist für mich zu hoch. Brauche ich auch nicht.* **M2 (employee): Theoretically, it is possible to learn how to program the cobots. But everything in me resists even thinking about it.** *M2 (Mitarbeitende): Theoretisch gibt es die Möglichkeit, die Programmierung der Cobots zu lernen. Aber in mir sträubt sich alles, wenn ich nur daran denke.* **M24 (manager): New products are usually somewhat more complex in structure, and sometimes I do not see the potential for them to be processed by the cobot.** *M24 (Führungskraft): Für gewöhnlich sind die neuen Produkte eher etwas komplexer aufgebaut und da sehe ich manchmal kein Potenzial, dass das über den Cobot laufen kann.*
	Positive attitude	References from participants regarding positive attitudes towards the advancement of cobots in practical applications. (code) **F6 (employee): Well, I would not resist learning how to use the cobot at this point.** *F6 (Mitarbeitende): Also ich würde mich jetzt auch nicht wehren, den Cobot zu lernen.* **M1 (employee): It is easy to work with these cobots, to create a new program and see if it works. It is always the same: if it works, then it is fun.** *M1 (Mitarbeitende): Es ist einfach, mit diesen Cobots zu arbeiten, wieder ein neues Programm anzulegen und zu sehen, ob das funktioniert. Das ist immer so das, wenn es funktioniert, dann macht es Spaß.* **M19 (manager): And it was precisely the people with an affinity for technology who wanted to use it straight away, and there were a few who then familiarised themselves with the programming.** *M19 (Führungskraft): Und gerade die technikaffinen Leute wollten den sofort bedienen und es haben sich auch einige gefunden, die den dann, die sich da eingearbeitet haben in die Programmierung.*

Interaction with cobots	**The theme encompasses first-hand experiences of the practical application and everyday use of cobots including the frequency of interactions. This covers both positive and negative experiences, as well as interactions related to the advancement and development of production processes that employ cobots. (theme)**
Experience of use	References from participants about individual experiences with the practical application and use of cobots. (main code)
Negative experiences	References from participants about negative experiences when using cobots. (code) **F6 (employee): As I said, at the moment we have been set back significantly by the offset.** *F6 (Mitarbeitende): Wie gesagt, im Moment sind wir durch das Offset so weit zurückgeworfen worden.* **M2 (employee): Three employees could not get the cobot to work. The cobot inserted 8 or 9 vials, but I had to wait 2 hours before I could insert another vial, which then took 5 minutes.** *M2 (Mitarbeitende): Drei Mitarbeiter haben den Cobot nicht zum Laufen gebracht. 8 oder 9 Flaschen hat der Cobot gesteckt, aber ich musste 2 Stunden warten, bis ich eine Flasche stecken konnte, was dann 5 Minuten gedauert hat.* **M10 (employee): If it does not work or only works halfway, at half power, then it takes away more work time than it is worth.** *M10 (Mitarbeitende): Wenn er nicht funktioniert oder nur halb, auf halb Gas funktioniert, dann bringt es mir nichts, weil er mich mehr von der Arbeit abhält, als dass er halt gut ist.*
Positive experience	References from participants about positive experiences when using cobots. (code) **M1 (employee): Well, the last few orders really went through smoothly from start to finish. So, there are simply no points of criticism: it works.** *M1 (Mitarbeitende): Jetzt, die letzten Aufträge liefen halt wirklich von A bis Z einfach durch. Und damit lässt er halt einfach keinen Kritikpunkt zu, er funktioniert.* **F22 (employee): I have experienced days when it worked very well, when we changed one tray after another.** *F22 (Mitarbeitende): Ich habe Tage erlebt, wo das super gut ging, wo wir ein Tableau nach dem anderen ausgewechselt haben.* **M25 (employee): Well, I would do anything related to counting with the cobot straight away. Simply because I have experienced that it works well.** *M25 (Mitarbeitende): Also, alles was mit zählen zu tun hat, würde ich sofort mit dem Cobot machen. Einfach weil ich halt die Erfahrung gemacht habe, dass es gut funktioniert.* **M18 (manager): Yes, it has become more positive, thanks to successes and results.** *M18 (Führungskraft): Doch, ist positiver geworden, durch Erfolge, durch Ergebnisse.*

Experience with advancement	References from participants on individual experiences about the development and adaptation of cobots in practical applications. (main code)
Negative experience	References from participants regarding negative experiences with advancing cobots in practical applications. (code) **M1 (employee): Sure, of course there were things that did not work right from the start. With the grippers, for example, we went through several rounds, tried different approaches, and had to print new parts.** *M1 (Mitarbeitende): Klar, es gab natürlich Sachen, die nicht von Anfang an funktioniert haben. Greifer, da haben wir mehrere Runden gedreht, haben verschiedene Versuche gemacht, haben neue Teile drucken müssen.* **F4 (employee): Did anyone really feel responsible for it at the beginning? I do not think anyone said at first: You have to take care of it now.** *F4 (Mitarbeitende): Hat sich am Anfang überhaupt irgendjemand richtig zuständig für ihn gefühlt? Glaube ich nicht, dass es am Anfang irgendwie hieß: Du musst jetzt dahinter sein.* **M20 (manager): Of course, you have to leave out a few days of the interim phase, when the error rate was naturally higher.** *M20 (Führungskraft): Natürlich muss man da ein paar Tage Interimsphase außen vorlassen, wo die Fehleranfälligkeit natürlich noch häufiger war.*
Positive experience	References from participants regarding positive experiences with advancing cobots in practical applications. (code) **M1 (employee): Then we also started to do the whole thing professionally. We bought a new vibratory bowl and a table, where we set everything up properly.** *M1 (Mitarbeitende): Dann haben wir auch angefangen, das Ganze in dem Punkt dann professionell zu machen. Haben einen neuen Topf gekauft, haben einen Tisch gekauft, wo wir das Ganze vernünftig aufgebaut haben.* **M17 (employee): So yes, it is a continuous process that never stops, I would say. We then simply rewrote a programme, for example, used less speed, and then checked whether it was better or worse. So yes, there are continuous improvements going on.** *M17 (Mitarbeitende): Also ja, da ist und das ist auch ein fließender Prozess, der nie aufhört, sag ich mal. Wir haben dann einfach mal ein Programm umgeschrieben und weniger Beschleunigung zum Beispiel gefahren und dann geschaut, ist es jetzt sauberer oder weniger sauber? Also ja, es sind kontinuierlich Verbesserungen im Raum.* **M25 (employee): But especially since the upgrade, when it became capable of handling five at once, there has been a remarkable improvement.** *M25 (Mitarbeitende): Aber dann, spätestens seit dem Umbau, seit er fünf gleichzeitig nehmen kann, ist es dann natürlich eine enorme Steigerung gewesen.* **F14 (manager): But the more it was expanded, the more readily it was accepted.**

	F14 (Führungskraft): Aber umso weiter man den eben ausgebaut hat, umso eher ist er dann auch angenommen worden.
Interaction frequency	References from participants on the frequency of interaction with cobots. (main code) **F12 (employee): I just think that someone who has worked entirely or extensively with the cobot naturally has a completely different level of knowledge and a completely different attitude towards it.** *F12 (Mitarbeitende): Ich finde halt, jemand, der sich ausschließlich o-der sehr viel mit dem Cobot beschäftigt hat, hat natürlich ein ganz anderes Wissen, eine ganz andere Einstellung dazu.* **M17 (employee): I would not have a problem if I did that more often or mainly that.** *M17 (Mitarbeitende): Ich hätte da auch kein Problem, wenn ich das öfters machen würde oder hauptsächlich das.* **M23 (employee): Usually, you come up with even more ideas when you deal with the subject matter.** *M23 (Mitarbeitende): Dann fallen einem meistens noch mehr Sachen ein, wenn man mit der Materie zu tun hat.* **F14 (manager): It was the same with the cobot at the beginning; you had this thing standing here and it was not used very often.** *F14 (Führungskraft): Und beim Cobot war es am Anfang schon auch so, da hatte man dieses Ding hier stehen und es ist nicht oft genutzt worden.*
Impact on work-place dynamics	**The theme illustrates the diverse alterations and transitions brought about by the implementation of cobot technology. This theme emphasises how cobots reshape the workplace environ-ment, impacting relationships, working practices, and the overall organisational culture. (theme)**
Alterations in social interaction	References from participants on alterations in social interaction due to the direct interaction with the cobot in work processes. (main code) **M10 (employee): Well, if I were in a room with the cobot, it would get boring at some point. So, I would prefer to sit with someone, because then you can talk to each other.** *M10 (Mitarbeitende): Also wenn ich jetzt in einem Raum mit dem Cobot wäre, wäre es ja irgendwann schon langweilig. Also da würde ich schon gerne mit jemandem zusammensitzen, weil du halt mit je-mandem reden kannst.* **F12 (employee): Because togetherness has always been important to me. For me, it is part of my job and my work. No matter what I do, social interaction is important to me.** *F12 (Mitarbeitende): Weil das für mich schon immer wichtig war, die-ses Miteinander. Das gehört für mich zu meiner Tätigkeit, zu meiner Arbeit dazu. Egal, was ich mache, für mich ist der Kontakt schon wich-tig.* **F13 (employee): I do think it is getting a bit lonelier. Maybe you work a bit more for yourself, alone.**

	F13 (Mitarbeitende): Ich glaube schon, dass es ein bisschen einsamer wird, also ein bisserl [bisschen]. Man arbeitet vielleicht ein bisschen mehr für sich selbst, alleine. **F22 (employee): Yes, of course, there is no feedback if something is not working. Or you do not have that collegial interaction that is completely gone.** *F22 (Mitarbeitende): Ja, da kommt natürlich kein Feedback, sage ich mal, wenn irgendwas nicht funktioniert. Oder du hast nicht diesen kollegialen Umgang, der fällt ja komplett weg.*
Changes in communication and cooperation	References from participants on changes in communication and cooperation within the workgroup due to the introduction of cobots. (main code) **M10 (employee): Well, you work a bit more closely with the production workers because there needs to be an alignment.** *M10 (Mitarbeitende): Also man arbeitet halt schon ein bisschen enger mit dem Bearbeiter zusammen, weil es ja irgendwo eine Absprache braucht.* **M17 (employee): Of course, there was more dynamic interaction between the groups.** *M17 (Mitarbeitende): Also da war dann natürlich mehr Dynamik drin zwischen den Gruppen.* **M24 (manager): And yes, the cooperation among each other. I am not sure whether it really had a major impact.** *M24 (Führungskraft): Und ja, die Zusammenarbeit untereinander. Ich weiß nicht, ob er jetzt wirklich einen großen Einfluss hat.* **F26 (manager): In terms of how it feels, I would say that there used to be the group of production technicians and the group of production workers, which were two small, distinct groups. I do not think that has completely gone, but it has definitely softened.** *F26 (Führungskraft): Gefühlsmäßig hätte ich jetzt gesagt, man hat ja quasi die Gruppe der Maschinisten und die Verpacker gehabt und das waren zwei so Grüppchen. Und das glaube ich hat sich dadurch nicht komplett aufgelöst, aber ja schon aufgeweicht.*
Changes in perception of work	References from participants on changes in the perception of work/the value of work due to the implementation of cobots. (main code) **M1 (employee): But, as I said, I really enjoy working with them. It is just incredibly satisfying for me, and yes, it is fun.** *M1 (Mitarbeitende): Aber ich, wie gesagt, ich arbeite sehr gern mit ihnen. Weil es einfach für mich unglaublich befriedigend ist. Und ja, es macht Spaß.* **M19 (manager): Because we did not say that you are doing a job that a machine could just do without a second thought. Instead, we argued that it is really a shame for someone like you to sit at a table for eight hours just putting vials in. A machine can do that, too. You can do something more valuable in this time.** *M19 (Führungskraft): Weil wir haben ja jetzt nicht gesagt, ihr macht eine Arbeit, die mir nichts dir nichts von einer Maschine erledigt werden kann. Sondern wir sind ja da mit dem Argument gekommen und*

		haben gesagt, es ist einfach zu schade, dass jemand wie du acht Stunden an einem Tisch sitzt und Flascherl [Fläschchen] da reinsteckt. Das kann auch eine Maschine. Du kannst in der Zeit was Wertvolleres machen. **M20 (manager): There were also other areas of application (for the cobots), because the job was very repetitive and anything but rewarding.** *M20 (Führungskraft): Das waren auch andere, weitere Anwendungen (für die Cobots), weil der Job war sehr repetitiv und alles andere wie wertschätzend.*
	Transformation in organisational processes	References from participants about the transformation of organisational processes due to the implementation of cobots. (main code) **F6 (employee): But I also see it as a process we have to get used to—for example, that one or two people cannot go to the production belt because there is now a cobot working (that needs to be supervised). You simply have to establish a procedure so that everyone can deal with it. There are simple rules, and that is all.** *F6 (Mitarbeitende): Aber ich sehe das auch so, dass das ein Prozess ist, an den wir uns gewöhnen müssen, dass der eine oder andere halt zum Beispiel nicht mit ans Band kann, weil da jetzt ein Cobot steckt (der betreut werden muss). Da muss man ja nur eine Vorgehensweise einfach etablieren, damit jeder damit zurechtkommt, damit es da einfach Regeln dafür gibt und fertig.* **F15 (manager): And if I am not doing the work at my own workstation, but at another general workstation at the cobot, I simply have to change the processes.** *F15 (Führungskraft): Und wenn ich die Tätigkeit nun nicht an meinem Arbeitsplatz mache, sondern an einem anderen allgemeinen Arbeitsplatz am Cobot. Muss ich einfach Abläufe ändern.* **M19 (manager): But simply the fact that you have something like this and have integrated it into the work process—I think that is a very important signal.** *M19 (Führungskraft): Sondern einfach, dass man, das man sowas hat, dass man so was in den Prozess integriert hat. Das ist ein ganz wichtiges Signal, finde ich.*
Acceptance of cobots		**This theme captures the acceptance of cobots based on individuals' attitudes and experiences with the technology. It is grouped into active and passive forms of acceptance and resistance, providing an understanding of individual views and behaviour towards cobots. (theme)**
	Active acceptance	References from participants associated with active acceptance of cobots. (main code) **F6 (employee): With the cobots. As I said, I fully support it. I think it is good.** *F6 (Mitarbeitende): Mit den Cobots. Weil, wie gesagt, ich stehe da voll dahinter. Ich finde es gut.* **M9 (employee): I am happy every time I go to the cobot and think, yes, I can set up something new again or fix an error.**

	M9 (Mitarbeitende): Ich freu mich jedes Mal, wenn ich zum Cobot hinkomme und sage, ja, ich kann mal wieder was Neues einstellen oder Fehler beheben. **F4 (employee): So, nothing has changed. I am still genuinely excited—about what it does, what it can do, and especially about what it might be able to do in the future.** *F4 (Mitarbeitende): Also nach wie vor. Eigentlich bin ich begeistert. Was, was er macht, was er kann und bestimmt, was er noch könnte.*
Passive acceptance	References from participants associated with passive acceptance of cobots. (main code) **F13 (employee): Well, I could imagine it (using a cobot). It is not that I would say, yeah, I really want to do it, but I could definitely imagine it.** *F13 (Mitarbeitende): Also ich könnte es mir vorstellen (einen Cobot zu verwenden), es ist zwar nicht so, dass ich sagen würde, yeah, ich will es unbedingt machen, aber ich könnte es mir auf jeden Fall vorstellen.* **M18 (manager): Then acceptance is simply higher if I do not have to go there every time only to find that the thing is whistling and not working.** *M18 (Führungskraft): Dann ist die Akzeptanz einfach höher, wenn ich nicht ständig hingehe und das Teil pfeift und nicht funktioniert.* **M19 (manager): I believe that the more you deal with it or the more you have to do with it yourself, the more you accept it.** *M19 (Führungskraft): Ich glaube, je mehr man sich damit befasst oder je mehr man selber damit auch zu tun hat, desto mehr akzeptiert, akzeptiert man den auch.*
Passive resistance	References from participants associated with passive resistance of cobots. (main code) **M5 (employee): For me, it would not be enjoyable to operate the cobot every day, [...] it simply does not appeal to me.** *M5 (Mitarbeitende): Also für mich wäre es nicht schön, jeden Tag den Cobot bedienen, [...] spricht mich nicht an.* **F12 (employee): So, for me personally, for my work, for my everyday work, I honestly do not need it right now.** *F12 (Mitarbeitende): Also für mich persönlich, für meine Arbeit, für meinen Arbeitsalltag, bräuchte ich ihn jetzt ehrlich gesagt nicht.* **F13 (employee): And that is why, at the moment, I would prefer to do it manually, simply because I feel better or safer doing it that way.** *F13 (Mitarbeitende): Und deswegen würde ich im Moment sagen, ich würde es lieber mit der Hand machen. Ja, aber einfach nur, weil ich mich dabei besser fühle oder sicherer fühle.*
Active resistance	References from participants associated with active resistance of cobots. (main code) **M2 (employee): I get really annoyed just having to walk past it.** *M2 (Mitarbeitende): Ich bekomme einen Hass, wenn ich nur daran vorbeigehen muss.*

	M11 (employee): Well, it just had the effect that there was total rejection. Really, absolutely total. *M11 (Mitarbeitende): Naja, das hat sich eben so ausgewirkt, das eine komplette Ablehnung da war. Also wirklich komplett.* **F14 (manager): I can only think of one person who really does not like it.** *F14 (Führungskraft): Ich erinnere mich da nur an eine Person, die das überhaupt nicht mag.*
System performance	**This theme encompasses the impact of the introduction of cobots on the performance of the organisational system. It examines factors such as human effort, production time, product quality, and future work orientation, all of which ultimately affect the overall productivity and efficiency of the organisation. (theme)**
Reduction of human effort	References from participants on the reduction of human effort in cobot-assisted production. (main code) **M2 (employee): The only thing I see is that you do not have to fill the modules yourself. Otherwise, I do not see any improvement through the cobot.** *M2 (Mitarbeitende): Das einzige, das ich sehe ist, dass man die Module nicht selber stecken muss, ansonsten sehe ich durch die Cobot keine Verbesserung.* **M11 (employee): So you save yourself one person who would otherwise spend the whole day on the insertion process. Of course, that person can then work on something else and therefore also contributes to output. So, from that perspective, productivity has definitely increased.** *M11 (Mitarbeitende): Somit sparst du dir einen Mann, der den ganzen Tag steckt. Also der natürlich dann was Anderes bearbeitet und somit auch noch Ausstoß hat. Also von daher, die Produktivität ist auf jeden Fall gestiegen.* **M23 (employee): The employee is only there to fix errors and either bring pallets over, take the full ones away, and put the empty ones back in. That just means less work and fewer employees are needed.** *M23 (Mitarbeitende): Da ist der Mitarbeiter nur da, dass er Fehler behebt und entweder Paletten* *hinfährt und volle weg tut und die Leere wieder rein tut. Das sind halt weniger arbeitsaufwände und weniger Mitarbeiter.*
Reduction of production time	References from participants on the reduction of production time through the use of cobots. (main code) **F6 (employee): Then I only need half the time for the order.** *F6 (Mitarbeitende): Dann brauche ich ja nur noch die Hälfte an Zeit für den Auftrag.* **M1 (employee): Well, the cobots became more efficient because they simply got faster. As I said before, first we went from just one pick to handling four Sarstedt vials at the same time, and then, with the second cobot, we were able to increase throughput simply by increasing the number of pieces.** *M1 (Mitarbeitende): Also sie (die Cobots) wurde effizienter, weil sie*

	einfach schneller geworden sind. Aber wie gesagt, erst von diesem einen Pick, als wir auf vier Sarstedts gleichzeitig gekommen sind und dann noch mit dem zweiten Cobot. Wir haben einfach durch die Stückzahlen den Durchsatz erhöhen können. **M5 (employee): In other words, more orders per week. Because the cobot [...] can handle such a large workload when there are a lot of orders.** *M5 (Mitarbeitende): Also sprich mehr Aufträge in der Woche. Dadurch, dass der Cobot [...] so eine Menge abnimmt bei einer großen Auftragslage.*
Impact on product quality	References from participants on product quality in cobot-assisted production. (main code) **M1 (employee): And the cobot does not have any concentration problems either, because it just puts its stuff in. It always fills up this module, and it does not forget a Sarstedt vial. It simply cannot do that. That is a big advantage.** *M1 (Mitarbeitende): Und der Cobot hat auch keine Konzentrationsprobleme, denn der steckt sein Zeug halt rein. Der steckt auch immer dieses Modul voll, der vergisst kein Sarstedt, das kann der nicht. Das ist halt schon ein großer Pluspunkt.* **M25 (employee): I would say that you simply have an extra safeguard. I would say that it is very pleasant to work with in that case.** *M25 (Mitarbeitende): Ich würde sagen, dass man einfach noch mal eine extra Absicherung hat. Ich würde schon sagen, dass das ein sehr angenehmes Arbeiten in dem Fall ist.* **M19 (manager): But the cobot cannot see what it is doing. Just to give one example: our employees are used to paying a lot of attention to the appearance of the product.** *M19 (Führungskraft): Aber der Cobot sieht ja nicht, was er macht. Das heißt, dazu nur ein Beispiel. Unsere Mitarbeiter sind es halt gewohnt, sehr auch auf die Optik zu achten.*
Future orientation of work	References from participants on the future orientation of work due to cobots. (main code) **F13 (employee): Because I believe that it is really important for the future to just stay open. Even when it comes to cobots—or anything else—things are always changing.** *F13 (Mitarbeitende): Doch weil ich auch glaube, dass es verdammt wichtig ist für die Zukunft, einfach offen zu sein. Auch für, ja egal ob es jetzt die Cobots sind oder es verändert sich immer was.* **F14 (manager): Because it is also a kind of showcase that you are using something like this and not just doing everything manually.** *F14 (Führungskraft): Weil das ist ja schon auch ein Aushängeschild, dass man sowas benutzt und nicht alles nur mit Handarbeit macht.* **M25 (employee): For me, that has always been a step into the future, and basically, I think it is a good thing.** *M25 (Mitarbeitende): Also das ist für mich immer ein Schritt in die Zukunft gewesen und das finde ich grundsätzlich schon mal gut.*

Cobot	The manufacturer's brand name of the cobot was replaced with the generic term "cobot".
()	Explanations from the researcher (drawn from member checking and subsequent clarification questions with participants).
[]	Translation of colloquial phrases (as indicated in the German transcript).
[...]	Words were omitted (to enhance clarity).

Appendix F: Matrix coding queries

Appendix F.1: Matrix coding query of participants' previous experience with robots

	Σ Statements (observations and interviews)	
	Previous experience with robots (Participant group: Employees)	
Themes / *main codes* / (sub) codes	**No**	**Yes**
Subjective usefulness	**77**	**95**
Goal achievement with cobots	*19*	*19*
Relevance of cobots	*23*	*22*
Physical relief	*30*	*27*
Personal development	*4*	*14*
Flexibility of cobots	*1*	*13*
Subjective user-friendliness	**65**	**58**
Ease of use	*12*	*4*
Ease of advancement	*1*	*11*
Learner friendliness	*49*	*40*
Support and assistance	21	17
Training setup	28	23
New demands on employees	*3*	*3*
Emotional factors	**131**	**93**
Cobots perceived as opportunity	*32*	*40*
Curiosity about cobots	10	15
Positive expectations	5	5
Reduction of fear	8	6
Satisfaction	9	14
Cobots perceived as threat	*78*	*17*
Fears associated with cobots	45	12
Damage concerns	7	0
Doubts about value	6	5
General anxiety	9	2
Job loss fears	23	5
Frustration	20	2
Scepticism	13	3
Emotional response to cobots	*14*	*22*
Humanisation	10	18
Objectification	4	4
Trust in cobots	*7*	*14*
Number of participants	**9**	**8**

Notes:
Main differences in the proportion of statements per category (analysed for **themes** and *main codes*):
(Category shares were normalised per participant and then divided by the sum of all normalised shares)
■ ≥ 15% deviation above equal (50:50) distribution of the normalised category shares (blue)
■ ≥ 15% deviation below equal (50:50) distribution of the normalised category shares (yellow)

Table F-1: Matrix coding query of participants' previous experience with robots

Appendix F.2: Matrix coding query of participants' position

	Σ Statements (observations and interviews)		
	Position (Participant group: Managers and employees)		
Themes / *main codes* / (sub) codes	**Manager**	**Production Technician**	**Production worker**
Subjective usefulness	**67**	**61**	**111**
Goal achievement with cobots	*16*	*12*	*26*
Relevance of cobots	*14*	*16*	*29*
Physical relief	*4*	*10*	*47*
Personal development	*26*	*10*	*8*
Flexibility of cobots	*7*	*13*	*1*
Subjective user-friendliness	**31**	**51**	**72**
Ease of use	*7*	*4*	*12*
Ease of advancement	*6*	*11*	*1*
Learner friendliness	*15*	*33*	*56*
Support and assistance	4	15	23
Training setup	11	18	33
New demands on employees	*3*	*3*	*3*
Emotional factors	**85**	**73**	**151**
Cobots perceived as opportunity	*23*	*32*	*40*
Curiosity about cobots	12	12	13
Positive expectations	3	4	6
Reduction of fear	6	4	10
Satisfaction	2	12	11
Cobots perceived as threat	*37*	*12*	*83*
Fears associated with cobots	23	10	47
Damage concerns	1	0	7
Doubts about value	6	4	7
General anxiety	7	2	9
Job loss fears	9	4	24
Frustration	3	2	20
Scepticism	11	0	16
Emotional response to cobots	*14*	*17*	*19*
Humanisation	10	15	13
Objectification	4	2	6
Trust in cobots	*11*	*12*	*9*
Number of participants	**10**	**6**	**11**

Notes:
Main differences in the proportion of statements per category (analysed for **themes** and *main codes*): (Category shares were normalised per participant and then divided by the sum of all normalised shares)
[blue] ≥ 10% deviation above equal (33:33:33) distribution of the normalised category shares
[yellow] ≥ 10% deviation below equal (33:33:33) distribution of the normalised category shares

Table F-2: Matrix coding query of participants' position

Appendix F.3: Matrix coding query of participants' age

	Σ Statements (observations and interviews)		
	Age of participants (Participant group: Managers and employees)		
Themes / *main codes* / (sub) codes	**Up to 35 years old**	**36 to 50 years old**	**Over 50 years old**
Subjective usefulness	**77**	**106**	**56**
Goal achievement with cobots	*22*	*22*	*10*
Relevance of cobots	*13*	*29*	*17*
Physical relief	*12*	*26*	*23*
Personal development	*15*	*25*	*4*
Flexibility of cobots	*15*	*4*	*2*
Subjective user-friendliness	**50**	**56**	**48**
Ease of use	*3*	*10*	*10*
Ease of advancement	*8*	*4*	*6*
Learner friendliness	*34*	*40*	*30*
Support and assistance	13	15	14
Training setup	21	25	16
New demands on employees	*5*	*2*	*2*
Emotional factors	**84**	**133**	**92**
Cobots perceived as opportunity	*27*	*33*	*35*
Curiosity about cobots	4	16	17
Positive expectations	5	7	1
Reduction of fear	4	7	9
Satisfaction	14	3	8
Cobots perceived as threat	*29*	*63*	*40*
Fears associated with cobots	20	33	27
Damage concerns	0	2	6
Doubts about value	7	9	1
General anxiety	7	7	4
Job loss fears	6	15	16
Frustration	3	14	8
Scepticism	6	16	5
Emotional response to cobots	*11*	*27*	*12*
Humanisation	9	21	8
Objectification	2	6	4
Trust in cobots	*17*	*10*	*5*
Number of participants	**8**	**12**	**7**

Notes:
Main differences in the proportion of statements per category (analysed for **themes** and *main codes*): (Category shares were normalised per participant and then divided by the sum of all normalised shares)

- ≥ 10% deviation above equal (33:33:33) distribution of the normalised category shares (blue)
- ≥ 10% deviation below equal (33:33:33) distribution of the normalised category shares (yellow)

Table F-3: Matrix coding query of participants' age

Appendix F.4: Matrix coding query of participants' gender

	Σ Statements (observations and interviews)	
	Gender (Participant group: Managers and employees)	
Themes / *main codes* / (sub) codes	Female	Male
Subjective usefulness	**94**	**145**
Goal achievement with cobots	21	33
Relevance of cobots	21	38
Physical relief	*36*	*25*
Personal development	13	31
Flexibility of cobots	*3*	*18*
Subjective user-friendliness	**67**	**87**
Ease of use	9	14
Ease of advancement	*2*	*16*
Learner friendliness	51	53
Support and assistance	19	23
Training setup	32	30
New demands on employees	*5*	*4*
Emotional factors	**133**	**176**
Cobots perceived as opportunity	*38*	*57*
Curiosity about cobots	12	25
Positive expectations	5	8
Reduction of fear	12	8
Satisfaction	9	16
Cobots perceived as threat	*69*	*63*
Fears associated with cobots	51	29
Damage concerns	7	1
Doubts about value	8	9
General anxiety	11	7
Job loss fears	25	12
Frustration	8	17
Scepticism	10	17
Emotional response to cobots	*19*	*31*
Humanisation	15	23
Objectification	4	8
Trust in cobots	*7*	*25*
Number of participants	**10**	**17**

Notes:
Main differences in the proportion of statements per category (analysed for **themes** and *main codes*):
(Category shares were normalised per participant and then divided by the sum of all normalised shares)
[blue] ≥ 15% deviation above equal (50:50) distribution of the normalised category shares
[yellow] ≥ 15% deviation below equal (50:50) distribution of the normalised category shares

Table F-4: Matrix coding query of participants' gender

Appendix F.5: Matrix coding query of participants' interaction frequency with collaborative robots

	Σ Statements (observations and interviews)		
	Interaction frequency (Participant group: Employees)		
Themes / *main codes* / (sub) codes	**Low**	**Medium**	**High**
Interaction with cobots	**29**	**45**	**79**
Experience of use	*26*	*28*	*37*
Negative experiences	13	16	17
Positive experience	13	12	20
Experience with advancement	*3*	*17*	*42*
Negative experience	2	5	6
Positive experience	1	12	36
Number of employees	**7**	**5**	**5**

Definition of interaction frequency:
High: regular interaction (min. 1x per week)
Medium: regular interaction (min. 1x per month)
Low: occasional interaction (min. 1x per year)

Notes:
Main differences in the proportion of statements per category (analysed for **themes** and *main codes*):
(Category shares were normalised per participant and then divided by the sum of all normalised shares)
≥ 10% deviation above equal (33:33:33) distribution of the normalised category shares
≥ 10% deviation below equal (33:33:33) distribution of the normalised category shares

Table F-5: Matrix coding query of participants' interaction frequency with collaborative robots