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Middle managers' agency in shaping socially disruptive technologies: Insights into the (re)configuration of human–robot work in Industry 5.0

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ABSTRACT

This paper investigates how middle managers exercise agency in shaping socially disruptive technologies (SDTs), i.e. technologies capable of transforming established work relations, organisational practices, and normative expectations surrounding work. Within manufacturing, collaborative systems are increasingly introduced as flexible automation solutions that reorganize human–robot work configurations. While existing research has mainly focused on task-level transformations following their deployment, limited attention has been paid to the managerial practices that shape how techno–social disruptiveness unfolds within organisations. Drawing on an interpretive qualitative study based on narrative interviews with 26 middle managers across European manufacturing organisations, this study adopts the combined lenses of the social shaping of technology (SST) and configurational boundary work (CBW) to explore how middle managers act as 'mediators of disruptiveness' navigating uncertainty and ethical tensions across four interrelated forms of agency: 'scouting the potential relevance for collaborative applications', 'mobilising alignment within and beyond the organisation', 'steering the initial configuration of human–robot work systems', and 'unlocking workers' embodied knowledge'. Our results extend the CBW literature by highlighting middle managers' agency as a process embedded in multiple temporalities and shaped through the interplay of reflexive and non-reflexive components. The study further problematises the notion of positive compromise in the SST literature and offers an exemplary case account at the organisational level of how SDTs are negotiated and shaped in practice within emerging Industry 5.0 contexts. This perspective gives renewed voice to the role of middle managers, long regarded as '*morally muted*'.

1. Introduction

The manufacturing industry is increasingly adopting what is commonly known as *collaborative robots*,[1] a type of industrial robot designed to operate within a workspace shared with human operators on the factory floor (ISO 10218-1:2025; ISO 10218-2:2025). Their deployment is expected to extend automation into domains that had long resisted full mechanisation, reshaping organisational workflows and processes to enhance efficiency and consistency in production quality (Cohen et al., 2022; Silva et al., 2024; Zhang et al., 2021). At the same time, the relocation of repetitive and physically demanding tasks to these robotic systems is presented as a way to address occupational health and safety concerns, reducing workers' exposure to ergonomically harmful work activities (Adriaensen et al., 2022; Wang et al., 2023).

Recent advances in sensing technologies and artificial intelligence (AI) are expanding the operational capabilities of these robots (Asif et al., 2025), enabling them to operate with increasing situational awareness and operational autonomy (Spencer, 2018; Włoch et al., 2025). Within technologically mediated work environments, such developments will challenge established assumptions, including the distribution of tasks (Asif et al., 2025; Baltrusch et al., 2022), the scope of

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[1] It is important to note that the term 'collaborative robot' (or cobot) has become increasingly ambiguous (see, for example, the argument by Callari, Curzi, and Lohse (2025)) and is considered outdated in the latest ISO standards, where these machines are referred to as collaborative applications. In this paper, we use the term 'collaborative robot/cobot' or simply 'robot' consciously, acknowledging its semantic and substantive limitations, to ensure continuity with current understanding and usage in the field.

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human autonomy and agency (Callari et al., 2024; Formosa, 2021), and the allocation of decision authority and control over production workflows (Callari et al., 2024; Lane, 2025).

These carry implications for how human roles and value are preserved within hybrid production systems and foreground the need for organisational practices that ensure fairness, transparency, and worker wellbeing (Callari, Operto, et al., 2025). Such concerns align with the normative agendas of Industry 5.0 and Society 5.0 (Köktürk et al., 2022; Kolade & Owoseni, 2022; Piccarozzi et al., 2024), which call for a human-centric integration of advanced technologies and highlight the need to organise technological innovation in ways that sustain human dignity, social value, and responsible governance across production systems (Callari et al., 2024).

Emerging research positions robotics and AI-enabled robotic applications among the technologies with the potential to exert a disruptive impact across industries and social systems (Schuelke-Leech, 2018), that is, technologies whose introduction '*can disrupt social relations, institutions, epistemic* paradigms' (Hopster, 2021, p. 1). At the core of the definition is neither actual disruption nor the positive or negative outcomes of disruption itself, but the potential for disruption, meaning that technologies may be conceived as socially disruptive by virtue of their disruptive potential, even when they are never actually implemented and have no impact in any context (Anderson et al., 2026, p. 5). The same authors specify that a technology qualifies as socially disruptive when it '*generates or significantly amplifies substantial challenges to the level of normative orientation and joint action–coordination*' in a given social context (p. 2). In organisational settings, such challenges emerge when established rules, role expectations, and coordination practices cease to provide stable guidance for how work should be organised and governed in novel work configurations, such as in human–robot production systems.

Scholarly attention has examined the broader innovation ecosystem within which socially disruptive technologies (SDTs) develop, highlighting factors such as epistemic communities, financial resources, and supporting infrastructures and institutions (Schuelke-Leech, 2018). Managerial structures constitute a central component of this ecosystem, together with the actors who occupy them. However, despite recognition that management – and middle managers in particular – can shape the development and implementation of these technologies, their role has received limited scholarly attention. This omission appears notable because foregrounding the agency of those confronted with technological disruptiveness brings into focus the ethical concerns that arise when technologies challenge actors' capacities for normative orientation and joint action–coordination (Anderson et al., 2026).

Although recent contributions increasingly acknowledge middle managers as actors of socio-technical co-evolution (Joyce et al., 2023; Leonard & Tyers, 2023), their capacity to reconcile competing organisational and moral objectives remains insufficiently understood (Tarakci et al., 2023). A clearer account of middle managers' agency is therefore essential for exploring '*what makes a technology disruptive*' (Anderson et al., 2026, p. 4) within organisations, an issue that research on SDTs has largely addressed at the level of broad societal transformations rather than through the organisational practices in which disruptiveness can be enacted.

Therefore, this study addresses the following research question:

How does the agency of middle managers unfold throughout the deployment of collaborative applications, which are defined as potentially socially disruptive technologies?

To answer this research question, we place the SDT perspective alongside the social shaping of technology (SST) and boundary work approaches. SST (Russell & Williams, 2002; Williams & Edge, 1996) provides a conceptual basis for examining '*the salient aspects of the context*' (Anderson et al., 2026, p. 4) through which SDTs emerge and take organisational form. By framing technology use and effects as outcomes of context-specific configurations of power and interests, SST directs attention to the indeterminacy of robot deployment, where multiple organisational trajectories remain possible. In doing so, it points to the importance of examining middle managers' agency in mediating the implementation of emerging technologies (Joyce et al., 2023).

At the same time, the development and diffusion of SDTs unfold through networks of expertise that span organisational boundaries (Schuelke-Leech, 2018) and involve actors with divergent interests requiring coordination (Floridi & Strait, 2020). In this respect, boundary work (Langley et al., 2019), and specifically configurational boundary work (CBW), offers an analytical lens to examine how middle managers enact this coordination in practice and how different modes of CBW shape the configuration of human–robot work.

We employ a qualitative and interpretive strategy, conducting narrative interviews with European managers from across the manufacturing sector, where collaborative systems had either been recently introduced or were under active consideration. The European context shapes this research, as it locates our study within corporate organisations whose employment relations, managerial practices, and stakeholder dynamics are shaped by the region's regulatory frameworks, labour protections, and socio-economic structures. Throughout both data collection and analysis, we maintain a stance of situational reflexivity. This is coupled with an abductive reasoning strategy (Timmermans & Tavory, 2022), where surprising insights and tensions in the empirical material serve as prompts for generating novel conceptual connections (Charmaz, 2017).

Our results identify four forms of agency through which middle managers shape SDTs. These forms shed light on the strategic role of middle managers as 'mediators of disruptiveness', facilitating the interpretive work and moral considerations necessary to the emergence of novel human–robot work configurations. Building on this, we offer a threefold contribution. First, we advance a more processual understanding of how middle managers' agency unfolds in boundary work (Langley et al., 2019), showing a process embedded in multiple temporalities and shaped through the interplay of reflexive and non-reflexive components. Second, we problematise the notion of positive compromise in SST (Lloyd & Payne, 2023; Wright, 2000) during the (re)configuration of human–robot work. Finally, we provide an organisational-level exemplary case that enriches understanding of how SDTs (Anderson et al., 2026; Hopster, 2021) unfold in practice. Taken together, the contributions of our study bring to light middle managers' ethical concerns permeating the entire robot deployment process, thereby restoring visibility to a role that has long remained '*morally muted*'.

2. Theoretical underpinnings

2.1. Middle managers' agency through the lens of configurational boundary work

Middle managers occupy a pivotal position as the 'linking pin' (Dopson & Stewart, 1990; Mintzberg, 1989) between the strategic apex and the operating core of the organisation. Embedded in power-laden relationships, they must juggle contradictory demands (Azambuja & Islam, 2018; Gjerde & Alvesson, 2025; Harding et al., 2014; Jaser, 2021; Neumann et al., 2019). A closer examination of what middle managers actually do reveals that they exercise great agency in shaping organisational change (e.g. Heyden et al., 2017; Maurer et al., 2024).

Middle managers operate at the interface of vertical and horizontal flows of information and knowledge (Tarakci et al., 2023). They actively mediate vertical flows by deflecting top management messages to safeguard professional work from excessive surveillance, financial concerns, and productivity targets (Gjerde & Alvesson, 2019). They also influence the direction of organisational change, channelling implementation challenges from the bottom up (Jaser, 2025). Consistent with this, Heyden et al. (2017) argue that when middle managers initiate change, they often mobilise employee support more effectively than senior management, as their proximity to employees fosters fairness and strengthens participation in change. Regarding horizontal flows, middle managers coordinate interdependent activities and people by building shared understandings of strategic objectives, aligning efforts, and managing interactions across teams and divisions (Bouty & Drucker-Godard, 2018; Porck & van Knippenberg, 2023). Leveraging contextual knowledge of power dynamics, they reconnect organisational domains through shared projects that align with stakeholders' interests and foster commitment to desired directions of change (Rouleau & Balogun, 2011). These dynamics carry the potential to alter existing patterns of workplace arrangements and relations with uncertain outcomes (Brey, 2018; Carlsen et al., 2010).

In this paper, we examine middle managers' agentic role of coordination in the context of the integration of robots in manufacturing, specifically through the lens of CBW.

CBW is a particular type of boundary work, which refers to the '*purposeful [...] effort to influence the social, symbolic, material, and temporal boundaries, demarcations, and distinctions affecting groups, occupations, and organizations*' (Langley et al., 2019, p. 705). This definition emphasises the dynamic character of boundaries and their openness to human agency. More specifically, CBW considers '*how people work from outside existing boundaries to design, organize, or rearrange the sets of boundaries influencing others [...] to enable effective collective action of others and at a distance*' (p. 720). This perspective offers a set of sensitising concepts to uncover the different modes through which middle managers facilitate coordination among the multiple actors (such as technologists, suppliers, and users, including both workers and management) involved in large-scale innovation processes, such as, in our study, the integration of collaborative applications in manufacturing.

Within CBW, middle managers can create temporary protected settings or spaces to seed possibilities for change (*arranging boundaries*); establish collaborations between actors with conflicting interests, values and interpretations of technology, while preserving these competing logics (*buffering boundaries*); or merge existing activities or domains into newly redefined ones (*coalescing boundaries*) (Langley et al., 2019). At the same time, this perspective resists an overly agentic portrayal, as CBW, like all forms of boundary work, is always provisional and never finally settled. Even when new practices are established, the boundaries designed to shape others' behaviour remain open to contestation and struggle.

Langley et al. (2019) highlight the need for further research on the role of agency in boundary work. They invite scholars to move beyond the dichotomous understanding that dominates the literature, where reflexive agency, conceived as a future-oriented '*calculative, highly intentional and planned*' (Langley et al., 2019, p. 727) decision process, is positioned in contrast to pre-reflexive agency, understood as the non-reflexive mobilisation of established schemes to flexibly address current unfolding situations (Cardinale, 2017). In their review, Langley et al. (2019) show that the literature on boundary work tends to privilege either the reflexive or the pre-reflexive dimension of agency, arguing that such separation is problematic for two main reasons. First, an exclusive focus on pre-reflexivity leaves unresolved how actors can transform the social structures with which they engage; conversely, an emphasis on calculative decision-making neglects how judgements and choices are made amid ambiguity, uncertainty, and conflict, such as robot integration in manufacturing (Callari, Curzi, & Lohse, 2025).

To address this impasse, Langley et al. (2019) propose reorienting research towards examining the distinct temporal orientations of agency in boundary work, past, present, and future and the varying degrees of reflexivity that underpin them. In this study, we aim to move this research agenda forward.

2.2. Social shaping of technology

SST offers complementary concepts to CBW to study the deployment of collaborative applications in manufacturing, here defined as potentially SDTs. SST reflects a non-deterministic view of technology, moving beyond accounts that focus solely on its effects. Specifically, SST (Russell & Williams, 2002; Williams & Edge, 1996) emphasises that while the material properties of technological artefacts matter, they are socially shaped by institutional and cultural factors, sectoral conditions, and processes of design, development, implementation, and use, each constituting critical sites of innovation and agency.

Technology integration in the workplace constitutes an uncertain and ongoing process of technology–organisation co-evolution (Howcroft & Taylor, 2023; Joyce et al., 2023), involving activities that may unfold sequentially or through setbacks and shifts (Rip & Schot, 2002; Schot & Rip, 1997). These include building a protected space (for articulating scenarios about technological functionalities and organisational uses); broadening the development process (through the progressive involvement of a wider range of actors and the integration of new requirements); stepping out into the wider world (through tentative technology implementation in real-life contexts to learn about its actual use); and recontextualising technology (technologies are progressively embedded within organisational settings).

Crucially, technology–organisation co-evolution unfolds through forms of bounded yet intentional rationality. This process is marked by conflicts and involves the articulation of interests through continual trial and error (Williams & Edge, 1996). In this respect, SST helps unveil how the use and effects of technology emerge from compromises that may be either positive or negative (Wright, 2000), shaped by context-specific configurations of power and interests (Russell & Williams, 2002). As such, the concept of compromise enables researchers to '*attend to the salient aspects of the context*' (Anderson et al., 2026, p. 4), an essential step in the study of SDTs. A negative compromise refers to a conflictual settlement in which labour and capital make mutual concessions to avoid costly confrontation, reflecting a competitive rather than cooperative logic (Wright, 2000). By contrast, a positive compromise denotes '*a non-zero-sum game between workers and capitalists, in which both parties can improve their position through mutual cooperation*' (Wright, 2000, p. 958). Stable forms of labour–management cooperation involve, for example, worker participation in decision-making.

The literature adopting the SST perspective to study the (re)configuration of boundaries in human–robot work (e.g. Da Roit & Iannuzzi, 2023; Lloyd & Payne, 2023; Ohlert et al., 2022; Snell & Gekara, 2023) has predominantly conceptualised compromises in negative terms, with particular attention to workers' agency grounded in associational power. For instance, studies (e.g. Da Roit & Iannuzzi, 2023; Lloyd & Payne, 2023; Ohlert et al., 2022; Snell & Gekara, 2023) document how unions avoid blocking or delaying robot implementation to prevent potential job losses, negotiating compensatory measures – such as reskilling, a fairer share of profits for labour, or strengthened redundancy and employment support – in exchange for the advancement of automation. However, research largely overlooks the agency of management (Joyce et al., 2023; Vereycken et al., 2021). Notably, Leonard and Tyers (2023) call for studies examining the role of middle managers in the digital transformations of Industry 4.0 and 5.0, especially in relation to robotics.

Moreover, although recent studies have begun to address the ethical issues faced by managers during robot deployment, they tend to confine the moral dimension to ex-post evaluations of the innovation journey (Leonard & Tyers, 2023). Our paper brings the ethical dimension to the forefront of the analysis of technological deployment by examining how middle managers engage in moral reasoning, doubts, and situated judgements throughout the process.

2.3. Socially disruptive technologies

SDTs are technologies whose dynamics may '*restructure, reorganize, disrupt current social and institutional norms and standards, operations, production, trends, not limited to a particular market or industry*' (Hopster, 2021, p. 3), even before their effects materialise (Anderson et al., 2026;

Hopster, 2021). Importantly, disruptiveness is '*never intrinsic to the technology itself*' (Hopster, 2021, p. 4); instead, it emerges through the interaction between technological innovation and the social contexts in which it is introduced (Anderson et al., 2026).

Hopster (2021) proposes a set of analytical criteria that identify when technological dynamics may be considered socially disruptive. Among the criteria, four are particularly relevant for analysing the organisational adoption of collaborative applications: the extent of uncertainty, the valence of impacts, the ethical salience of impacts, and the range of impacts. The extent of uncertainty refers to the difficulty of anticipating the social consequences of emerging technologies. SDTs tend to interact with existing socio-technical arrangements in unpredictable ways, generating not only predictive uncertainty but also conceptual and moral ambiguity. The valence of impacts concerns the intensity of positive or negative reactions triggered by the technology when it affects socially valued domains. Technologies that reshape areas considered central to social life, such as work, safety, or professional identity, are more likely to generate strong evaluative responses. The ethical salience of impacts captures the extent to which technological developments raise normative questions, value conflicts, or issues of justice. Finally, the range of impacts refers to the breadth of domains affected by the technology, with broader cross-domain implications indicating higher disruptive potential.

3. Methodology

This study draws on a qualitative, interpretive approach grounded in narrative inquiry (Parks, 2023; Pino Gavidia & Adu, 2022). Narrative inquiry is both the method and process through which participants articulate, share, and interpret their experiences (Mertova & Webster, 2019; Riessman, 2015; Shields, 2006). We adopted narrative inquiry on the understanding that our recruited managers make sense of techno–social change through storied forms (Mertova & Webster, 2019), while also allowing contradictions and ambiguities to surface. In this regard, narratives are interpreted as situated human performances that index broader cultural and institutional logics (Somers, 1994).

3.1. Engaging with the middle manager's narratives

We conducted 26 interviews with managers from across the manufacturing sector (Table 1), where collaborative robots had either been recently introduced or were under active consideration. Participants were recruited initially through purposive sampling and industry events. As the interviews progressed, snowball sampling was used to expand the participant pool by leveraging professional networks and peer referrals. This approach facilitated the inclusion of diverse perspectives in the planning, implementation, or supervision of robot integration.

Interviews were conducted via Microsoft Teams between April and November 2024 and lasted between 1 and 2 h (average: 1.15 h). An evolving interview script was used to structure the conversations with our study participants. Initial open questions focused on organisational change, technology adoption, and task allocation, while follow-up prompts invited reflection on ethical dilemmas, tensions in human–robot work systems, and the future role of workers within these configurations.

3.2. Analytical strategies

This iterative exchange anchored our analysis in lived experience while maintaining awareness of how our disciplinary backgrounds (spanning management and organisation studies, systems ergonomics and occupational psychology, automation, and robotics) formed our interpretive lens. Our analytical orientation was grounded in the principles of abductive reasoning, which guided our iterative engagement between empirical material and theoretical reflection (Tavory, 2016; Tavory & Timmermans, 2014; Timmermans & Tavory, 2022), allowing new directions to emerge in response to unexpected observations. This process was supported by the computer-assisted qualitative data analysis software NVivo (©Lumivero).

The analysis was informed by the principles of constructivist grounded theory (CGT) (Charmaz, 2006, 2017). Within CGT, categories are treated as conceptual constructs that possess properties that specify their analytic scope and explanatory potential (Charmaz & Belgrave, 2018). In our study, the analytical strategy unfolded in three interconnected stages.

First, after transcription, interviews were coded using open, action-oriented codes expressed in the gerund form (Charmaz, 2006; Charmaz & Belgrave, 2018) that foregrounded processes of action, judgement, and sense-making performed by the participating managers. Initial coding remained closely grounded in the empirical material and captured managers' situated practices of emerging human–robot work configurations, and supported an emic understanding of managerial action. This is in line with Charmaz's view (2019) that meaning-making unfolds through close attention to participants' language, situated interpretations, and the discursive repertoires through which they construct concerns, responsibilities, and uncertainties.

Second, subsequent stages of analysis involved focused coding, constant comparison across interviews, and extensive memo writing. Significant or frequent initial codes from the previous stage were used to organise larger segments of data. Focused codes that demonstrated strong explanatory capacity were progressively grouped into categories representing higher-order conceptual patterns observed across the dataset. During this stage, analytic questions guided the interpretation of the properties of the emerging categories (Keane, 2025, 2026), including the examination of the conditions under which specific managerial practices occurred and the consequences they generated within organisational processes. The constant comparative method (Glaser & Strauss, 1967 (1999)) supported the definition of categories through systematic comparison of incidents, codes, and emerging interpretations. Memo writing facilitated the conceptual clarification of categories and the articulation of their internal structure, including their defining properties and the relationships among them.

Third, the emerging categories were further refined and consolidated through abductive interpretation (Timmermans & Tavory, 2022), which involved interrogating the empirical material through dialogue with the study's theoretical underpinnings (section 2), which functioned as dialogical theoretical resources. Theoretical sensitivity (Glaser & Strauss, 1967 (1999)), understood as an attunement to the contextual specificity of meaning and a readiness to reframe existing assumptions (Timmermans & Tavory, 2022), unfolded gradually during this iterative process. In line with Charmaz's emphasis on '*methodological self-consciousness*' (Charmaz, 2019, p. 167), our abductive reasoning entailed ongoing scrutiny of how our interpretations shaped the construction of the resulting four conceptual categories, which capture distinct yet interrelated forms of managerial agency (section 4). The analytic process towards the consolidation of these categories is presented in the appendix (Tables 3–6).

3.3. Epistemological stance

Recognising our dual role as researchers and co-participants in the construction of meaning, a self-reflexive stance was integral to this study. This study pursued rigour as a situated and reflexive practice, aligned with its abductive and narrative orientation. Operating within an interpretative paradigm (Pino Gavidia & Adu, 2022), we approached these interviews as relational sites of meaning construction, where understanding emerges through storied interactions shaped by time, place, and context, and where our presence as researchers both influences and is influenced by these factors. This orientation follows Charmaz's (2019) insistence that researchers recognise how their positionality and moral commitments become active components of the analytic process,

Table 1
Overview of the study participants and the organisations they represent.

PARTICIPANT BACKGROUND			ORGANISATION'S BACKGROUND			
#	Job title	Years of professional experience	Type of organisation, i.e. MNC (Multinational Corporation/Company) or SME (Small and Medium-sized Enterprise)	Manufacturing sector	Robotics implementation stage	Main robot application
1	Ergonomics Manager	>15	MNC	Automotive	Early operational deployment with ongoing experimentation (robotic systems introduced primarily for health and safety improvements and repeatable operations while additional applications continue to be explored)	Assembly assistance, component application
2	Manager of Innovation and Tools	5-10	MNC	Automotive	Selective operational use and experimentation (collaborative robots used mainly for synchronised assistance tasks and simple assembly operations while more advanced collaboration remains conceptual or under study)	Selective operational use and experimentation (collaborative robots used mainly for synchronised assistance tasks and simple assembly operations while more advanced collaboration remains conceptual or under study)
3	Head of Manufacturing	>15	MNC	Pharmaceutical	Early deployment (limited cobot use; mostly traditional industrial robots; emerging autonomous vehicles and lab automation)	Assembly assistance (packaging lines), logistics (autonomous vehicles moving trolleys/samples), inspection and laboratory preparation (pipetting/sample preparation)
4	Factory Automation Manager	<5	MNC	Mechanical and Electrical Engineering	Mixed pilot and operational use (≈60 collaborative robots across several factories but uneven adoption)	Material handling, palletising, pick-and-place, machine tending, tool change operations, quality measurement handling
5	Technical Director	>15	SME	Automotive	Experimental development (collaboration with universities)	Palletising, pick-and-place
6	Principal Manufacturing Engineer	>15	MNC	Mechanical and Electrical Engineering	Pilot experimentation (robotic assembly support and inspection processes explored in test environments before operational deployment)	Assembly assistance, inspection, tooling support
7	Senior Manufacturing Engineer	>15	MNC	Mechanical and Electrical Engineering	Pilot experimentation (robotic technologies tested in limited industrial environments to assess operational integration and performance)	Assembly assistance, inspection
8	Head of Science and Technology	>15	MNC	Food	Experimental development (robotic solutions explored within university laboratories and research centres to evaluate feasibility before industrial deployment)	Assembly support
9	Robotics, Automation & Quality Manager	5-10	SME	Transport	Pilot experimentation (collaborative robotic welding and repair-support systems undergoing testing to evaluate performance and integration into repair workflows)	Welding, inspection, repair assistance
10	Engineering and Technology	<5	MNC	Textile	Mixed pilot and operational use (mobile robots already used operationally for logistics while other robotic systems remain under experimentation and integration)	Logistics, material handling, assembly assistance
11	Manufacturing Development Engineer	5-10	MNC	Transport	Experimental development (robotic solutions explored within engineering and development activities to evaluate feasibility before industrial deployment)	Assembly support, process experimentation
12	Manufacturing Manager	5-10	MNC	Chemical	Early deployment/Mixed pilot and operational use	Logistics robots (AGVs), drilling operations, robotic fixturing, assembly assistance, material delivery systems
13	Manufacturing Research Engineer - IIoT	5-10	MNC	Mechanical and Electrical Engineering	Experimental development (R&D environment exploring integration of robotics and Industrial IoT systems)	Automated manufacturing systems, smart tools, connected robots, data-driven monitoring of manufacturing assets
14	Manufacturing Development Engineer	10-15	MNC	Automotive	Experimental development (robot-enabled assembly and inspection processes developed in research and development environments for	Assembly assistance, inspection, process experimentation

(continued on next page)

Table 1 (*continued*)

PARTICIPANT BACKGROUND			ORGANISATION'S BACKGROUND			
#	Job title	Years of professional experience	Type of organisation, i.e. MNC (Multinational Corporation/Company) or SME (Small and Medium-sized Enterprise)	Manufacturing sector	Robotics implementation stage	Main robot application
					potential future production adoption)	
15	Additive & Joining Repair Manager	>15	MNC	Transport	Pilot experimentation (robotic welding systems being tested and integrated to support repair processes before wider production deployment)	Welding, inspection support, repair operations
16	Automation and Robotics Manager	10-15	MNC	Mechanical and Electrical Engineering	Experimental development (robotic applications developed and evaluated within R&D environments before possible transfer to production lines)	Assembly experimentation, inspection
17	Manufacturing Engineer - Automation	>15	MNC	Transport	Experimental development (robot-assisted assembly processes being designed and validated within manufacturing development units prior to transfer to production)	Assembly assistance, part positioning, inspection support
18	Manufacturing Engineer-Automation & Integrated Systems	>15	MNC	Construction	Experimental development (focus on emerging collaborative systems and interaction design)	Experimental human–robot interaction systems
19	Technology Manager	>15	SME	Mechanical and Electrical Engineering	Pilot experimentation/Early deployment (testing robotic systems mainly for inspection, repair, and welding tasks)	Inspection automation, robotic repair processes, adaptive welding, component handling, automated inspection of turbine blades
20	Robotics Manager	>15	SME	Industrial Robotics Software/ Automation Technology	Experimental development (developing software interfaces enabling human–robot interaction and flexible programming)	Robot programming interfaces, human–robot interaction systems, welding automation, sanding/ polishing processes, textile cutting, pick-and-place automation
21	Production Manager	10-15	SME	Construction	Early operational deployment with ongoing experimentation (some collaborative robotic systems already implemented for specific processes while further applications remain under development and evaluation)	Quality inspection, laboratory processes
22	Manufacturing Manager	10-15	MNC	Transport	Early deployment (collaborative robots used selectively for low-cost automation tasks)	Material handling, assembly assistance (holding/positioning components), simple repetitive handling, low-level assembly operations
23	HO Actuators and End Effectors Manager	>15	MNC	Transport	Pilot experimentation (testing technologies such as exoskeletons and automation for ergonomic improvements)	Assembly assistance, ergonomic support technologies, experimental human-assist robotics
24	Senior Automation Manager	>15	SME	Textile	Mixed pilot and operational use (mobile robots already used operationally for logistics)	Logistics, material handling, assembly assistance
25	Senior Engineer	5-10	SME	Mechanical and Electrical Engineering	Experimental development and early application (collaborative robots explored in development projects and prototype manufacturing to test flexible automation solutions for small-batch production)	Adhesive bonding, adaptive assembly support, prototype manufacturing
26	Technical Services Manager	10-15	MNC	Mechanical and Electrical Engineering	Pilot experimentation (robotic systems trialled in controlled industrial contexts to evaluate productivity, safety, and feasibility)	Assembly support, inspection

especially when participants' accounts express concerns about uncertainty, risk, and the moral implications of technological change. To this end, we treated interpretation as a co-creative process (Charmaz, 2004), engaging participants in ongoing dialogue and reflection on emerging insights, including feedback loops in which we shared interpretations for comment and elaboration (Walsh et al., 2015).

The trustworthiness of our analysis rests not on claims of objectivity but on the transparency of the interpretive process (May & Perry, 2014; Sinkovics et al., 2008), the plausibility of the account, and its resonance with both empirical material and conceptual reflection (Ahmed, 2024). Throughout the study, credibility was anchored in a sustained engagement with participants and their narratives. The interview process was designed to elicit layered, experience-near accounts that captured both the practicalities and the ethical dilemmas of integrating collaborative robots in manufacturing contexts. Iterative feedback and moments of interpretive recalibration, such as returning to prior transcripts in light of new insights, ensured a constant re-alignment between empirical detail and theoretical direction. Dependability was supported by coding iterations, analytic memos, and decision trails. NVivo facilitated both systematic coding and collaborative annotation among researchers. Confirmability was framed as a sensitivity to how our own disciplinary backgrounds shaped what we noticed, prioritised, or problematised. In Charmaz's terms (2019), this involved acknowledging that our interpretations carry moral and epistemic consequences, requiring attention to the research conditions that produced the data and to the possible effects of our representational choices. In this sense, reflexivity was integral, not incidental (Charmaz & Belgrave, 2018; May & Perry, 2014). That is why, consistent with Charmaz's view (2019) that inquiry into socially consequential domains demands attentiveness to power, inequality, and interpretive authority, we remained aware of how our analytical framing might highlight, mute, or reconfigure the tensions raised by managers in relation to technological decisions. Finally, with regard to transferability, the diversity of participants across sectors, roles, and organisations allows others to assess the relevance of these findings to adjacent settings. What matters is not generalisability, but whether the insights provoke new questions, clarify patterns, or illuminate the tensions at stake in other domains of socio-technical change.

4. Results: four forms of agency

The identified four forms of middle managers' agency illuminate the situated and performative nature of (re)configuring human–robot work towards Industry 5.0, as exemplified by the following quotation:

> *'[Given that we're such a risk-averse company] it's that familiarisation, that training, that level of cobot adoption that needs to be addressed, along with the safety aspects. I don't think there's a silver bullet that solves all of this, but we need to slowly gear up the company – perhaps starting at the top level, but also from the bottom upwards – to build people's confidence that these systems will work. We also need to give them opportunities to engage, whether through formal involvement in the project team or through incentives to take on these cobots.'* [**Manufacturing Manager, MNC**, Transport]

4.1. Scouting the potential relevance for collaborative applications

This dimension is characterised by a broad 'scouting' effort in which managers seek to develop a comprehensive understanding of the potential relevance of collaborative applications to the organisation's production context.

> 'We've struggled to automate back-office and small handling operations that involve high variety and low volumes. Collaborative robots are appealing, not necessarily for their collaborative aspect, but for their low-cost ability to integrate robotics at a much lower price point than in the past, thereby enabling a tangible business benefit.' [***Manager of Innovation and Tools***, MNC, Automotive]

This process unfolds amid conditions of technical uncertainty as managerial expectations, shaped by industry narratives about flexibility, ease of programming, and safety, encounter the complexities of implementation within existing production workflows. In this phase, managers engage in experimental trials and feasibility assessments while simultaneously attempting to interpret the value proposition associated with the technology.

> 'I would say collaborative robots are a misnomer and quite misunderstood. Companies that make collaborative robots are very good at marketing, and the attractive features –robots that are safer to be around, easier to program, all the things promoted in the collaborative robot spiel – are, of course, things everyone wants. But when they are actually deployed, the process often isn't collaborative, you still need guarding, or, in many cases, the collaborative robot just isn't the right solution.' [***Engineering and Technology***, MNC, Textile]

> 'There are certain tasks that are specific or make sense just to humans, and it's just retaining those tasks that give a purpose to the human worker. So, sometimes removing those tasks from the humans because it's more effective to be performed by robots is not the right choice.' [***Factory Automation Manager***, MNC, Mechanical and Electrical Engineering]

A central aspect is the development of a business case for robot adoption. Managers seek to clarify what distinguishes these technologies from traditional automation, identifying tasks, examining compatibility with existing workflows and safety requirements, and evaluating alternatives in relation to production dynamics, task variability, and operational demands. This work draws on prior pilot initiatives, internal studies, and strategic priorities, forming the basis for working hypotheses about where collaborative systems could add value. To secure approval from senior leadership, managers must demonstrate measurable value through cost savings, throughput gains, or ergonomic improvements, or show that the robot can operate reliably within complex and variable production environments. However, anticipated productivity gains often remain uncertain, requiring managers to justify investments amid incomplete evidence.

> 'We carried out a pretty extensive study, looking into the last five years of development, from 2015 to 2020, covering all the projects, all the robots, every single plan across the board. It was a massive effort that we undertook [….] we realised that we've been trying to do this for a very long time, and we spent tens of millions attempting to develop a project or system that would finally be installed on a production line. And today, four years later, we have just one. The requirements of our use cases are so demanding that it has been virtually impossible to install any of these collaborative robots in production.' [***Manufacturing Development Engineer***, MNC, Transport]

> 'We're installing robots because of ergonomic conditions […] after 40 years of drilling overhead, you're going to have issues in your shoulders and back […] but the robots are not going to be faster than the human, so in the business case it is very difficult to quantify the benefit.' [***Manufacturing Manager***, MNC, Chemical]

Managers' exploration of collaborative applications also reveals a normative tension concerning the legitimate purpose of automation within the production system. While feasibility studies and pilot projects are framed through economic and operational criteria, the development of the business case also carries implicit judgements concerning the future role and value of human labour within the production system. Critically, collaborative applications prompt a reinterpretation of the conventional notion of automation, shifting its purpose from labour substitution towards labour augmentation, i.e. a potential redeployment to higher-value activities. Managers often articulate these tensions as instances of moral ambivalence, where expectations of productivity and financial accountability coexist with concerns about worker wellbeing, skill continuity, and occupational sustainability. Questions about the extent of automation raise concerns about how production systems should evolve without undermining the continuity of meaningful work. Managers describe an ongoing effort to reconcile technological opportunity with organisational responsibility, particularly when anticipating how automation may reshape employment structures and skill trajectories.

> 'I can bring in a collaborative robot to help [the worker] to do some of the tasks, so [the worker] is not on that particular station from nine to five, [the worker] can possibly be moved to different stations. And then it's presenting these ideas and from a financial point of view, and from a business point of view. Where does the business want to go? Does the business want to primarily focus on cost and

automation, or do they want to also focus on retaining our workforce, our skill set, and upskilling our individuals, taking care of our workforce?' [***Additive & Joining Repair Manager***, MNC, Transport]

'If you automate an entire production line, what happens to the people who were working on that production line? What jobs do you then need? What skills are required to maintain and support that?' [***Manager of Innovation and Tools***, MNC, Automotive]

'It's all about making sure meaningful jobs continue to exist rather than simply replacing everything with automation. I believe there is a balance between improving efficiency and ensuring people feel valued in their job.' [***Ergonomics Manager***, MNC, Automotive]

This feasibility process unfolds through a sustained multidisciplinary effort that challenges established managerial practices, as managers engage in cross-functional collaboration to interpret uncertain technological possibilities and design solutions capable of meeting technical, safety, and operational requirements. In this context, peer learning plays a critical role. Participation in industry working groups, cross-company meetings, and collaborative initiatives, often supported by partnerships with universities and student-led research, creates spaces for collective sense-making and experimentation across internal and external organisational boundaries. Examples are robot trials in limited settings to observe their performance under real production conditions and assess their compatibility with existing workflows before committing to full-scale deployment. Exposure to alternative approaches sharpens internal understanding and contributes to more informed, adaptable deployment strategies.

'We do a lot of work with our university partners and with various companies to develop those systems and deploy them into our facilities. We've also started to think about human factors—how to bring humans and robotic systems to work together.' [***Technical Director***, SME, Automotive]

4.2. Mobilising alignment within and beyond the organisation

Robot integration activates a complex field of negotiation in which middle managers operate as key brokers. At the organisation level, their role is not limited to implementing technical change but extends to mobilising alignment across organisational layers and external actors who may advance competing priorities that require managers to frame new automation proposals in ways that resonate across these perspectives.

'It's kind of some flipping comments about, "Oh, you're producing robots to replace humans". It's not, we're not doing that, we're enhancing your kind of repair capabilities, so I think that'll always be a challenge, it's just because we're careful how we present it internally.' [***Head of Science and Technology***, MNC, Food]

'When you deploy a collaborative robot [...] I then have union representatives and health and safety representatives [...] and despite being able to show that it complies with legislation, I still have a task to make sure they are comfortable with it.' [***Additive & Joining Repair Manager***, MNC, Transport]

In their accounts, middle managers describe this phase as inherently political: how these systems are described – what language is used, which metaphors are evoked, whether deployment is framed as enhancement or replacement – emerges as a critical factor. Interviewees commented that while such narratives can help the conditions for acceptance and engagement, they also risk masking the structural uncertainties that automation introduces into work systems, revealing unresolved dilemmas about how technological change may ultimately reshape employment and skill trajectories.

'We have to be quite careful how we market this technology as well, we're not replacing humans, we're enhancing their job, so I think that'll always be a challenge.' [***Manufacturing Manager***, MNC, Chemical]

This communicative dimension becomes particularly salient in relation to frontline staff and union representatives. Managers consistently acknowledged worker anxiety and fear – emotions they considered legitimate and historically rooted – as well as unease surrounding the transfer of human expertise to machines, with the implications this may have for future roles. These concerns may signal a form of normative contestation over the legitimacy of automation with respect to job security. Rather than dismissing these reactions, some managers commented on how they strive to shift the perception of robotics from a source of dispossession to an opportunity for expanded human agency.

'And I think we've seen in the past a certain nervousness from end users, and from people on the shop floor, when it comes to starting to use these systems. I completely understand why, because it feels as if the technology is displacing them, and as if it is beginning to learn what they can do. And unsurprisingly, there's some nervousness about that because they say, "Well, so you're training, you're using my expertise from many decades of doing welding, you're now training a robot to do that. Well, what does that mean for me moving forward?"' [***Manufacturing Development Engineer***, MNC, Transport]

'I think the challenge we face is bringing people along on this journey with us. I fully appreciate that people on the shop floor are, quite rightly, concerned about the security of their jobs going forward. It's our responsibility to try to bring them on that journey, making sure they are not displaced, do not feel displaced, and also helping them recognise when there are other roles they could be doing instead. While the human is performing a mundane task, we need to give them some understanding of what their position might look like in the future.' [***Manufacturing Engineer – Automation & Integrated Systems***, MNC, Construction]

'A natural reaction for workers is to think, "Hang on a minute, I'm getting replaced by a robot". That's why it's important to engage the whole team. Once they see the benefits, it gets easier.' [***Technical Services Manager***, MNC, Mechanical and Electrical Engineering]

Union representatives emerged as another key stakeholder in the negotiation of these expectations. Managers described the need to demonstrate that technological deployment remains consistent with established norms of worker protection and workplace safety, particularly when introducing systems that alter existing task boundaries.

'[Talking about the union] it's hard to get them involved and willing to discuss things like this, but having controls and safeguards in place around the use of the technology is, I think, the way to secure buy-in from the union. The key concern for the union is not the robots or collaborative equipment, it's protecting people, their members, and ensuring they are not harmed.' [***Automation and Robotics Manager***, MNC, Mechanical and Electrical Engineering]

'We were investigating how to use exoskeletons [...] one of the volunteers tried it [...] some operators walked by and laughed at [them] [...] [they] took it off and never again were we able to bring the exoskeletons back to the shop floor [...] once the operator says "I don't want it", the union will always defend them. That basically killed the possibility of us having the exoskeleton here.' [***Manufacturing Engineer – Automation & Integrated Systems***, MNC, Construction]

This negotiation also extends upwards. Managers are conscious that they must justify investments in collaborative systems to the top leadership, whose expectations typically centre on productivity gains and rapid returns. Interviewees described the pressure of demonstrating efficiency while simultaneously advocating for more gradual deployment trajectories that allow time for experimentation, training, and organisational adjustment. Therefore, aligning leadership expectations with the operational realities of robot deployment becomes a central managerial task. In this process, middle managers believe that they are positioned to buffer these competing timelines, translating strategic pressures into operational pathways while safeguarding workforce engagement.

> 'The problem is our leadership […] now they want more and more and more and quicker and quicker. We're still in that development stage […] we're still developing.' [***Technical Services Manager***, MNC, Mechanical and Electrical Engineering]

> 'We have to be very careful then with our senior leadership, their understanding of what this brings to the business. We've had it recently […] our senior leadership has challenged us […] productivity up, labour costs down […] we have to be able to inform them what can be achieved and what can't.' [***Automation and Robotics Manager***, MNC, Mechanical and Electrical Engineering]

Internally, mobilising alignment requires collaboration across organisational functions as well, bringing together engineering, production, human resources, and, critically, health and safety representatives. The latter emerged as another central stakeholder group, often acting as gatekeepers for responsible implementation. The adoption of collaborative robots was consistently linked to rigorous risk assessments, compliance with evolving standards, and demonstrable safety cases. Indeed, regulatory expectations and industrial practice also become a site where these tensions surface. Managers frequently reported that existing safety frameworks reflect assumptions rooted in traditional automation, whereas collaborative robotic systems operate within more dynamic production environments that require situational judgement during implementation. These accounts highlight how safety governance becomes a terrain of competing interpretations over how safety principles should be applied in collaborative industrial settings.

> 'Standards are written from the point of view of traditional safety applications. In fact, a lot of the regulation is probably geared towards keeping operators away from machinery […] There are light guards on individual benches, and that has been driven by the HSE (Health and Safety Executive) side of it. And, as we're going through our journey, that's where we're able to start to bring our HSE representatives along that journey as well.' [***Additive & Joining Repair Manager***, MNC, Transport]

> 'As we build our test cases […] they help our HSE (Health and Safety Executive) colleagues feel more at ease with the systems and the capabilities […] not to cause injury or damage. We're three to four years in, and we're getting there.' [***Technical Director***, SME, Automotive]

Middle managers' engagement in conferences, inter-organisational forums, and collaborative initiatives with universities and research institutions (section 4.1) were considered part of a broader strategy to gather legitimising resources, reframe internal narratives, and strengthen their position when negotiating the adoption of collaborative applications within the organisation. What is learned outside becomes a means to shape what is possible inside; in this regard, external learning functions as a platform for organisational sense-making and as a tool to build credibility and alignment with internal stakeholders. Some managers also stressed the importance of aligning with the educational system, questioning whether universities are preparing students with skills in robotics, automation, and human factors to ensure a future workforce ready for hybrid collaborative industrial environments.

> 'We need to start to both recruit people with different skills – robotic skills, automation skills, human factor skills – but also to make sure that the university network itself is geared up to start to deliver people with those right skill sets that can then find their route into a company like ourselves.' [***Robotics Manager***, SME, Mechanical and Electrical Engineering]

4.3. Steering initial configurations of human–robot work systems

A core dimension of robot adoption lies in how work is reorganised between human and machine actors. Across the dataset, this (re) configuration reflected an internalised organisational mandate: to streamline operations, enhance productivity, and standardise tasks, while at the same time preserving operational continuity and sustaining the employment and expectations associated with the current workforce. As such, the initial configuration of human–robot work often followed a logic in terms of a deliberate division of labour: robots are expected to absorb the repetitive, physically demanding, or cognitively monotonous tasks, while humans can be repositioned towards activities requiring interpretation, problem-solving, and decision-making. However, worker reskilling that is focused on developing the ability to safely interface with robotic systems is still shaped by day-to-day operational demands.

> 'There are all sorts of clever things that humans could do instead, but if we can use that robot for the mundane things, then again, we get the best of both. I think as a business, that's the way we want to go. We want to try and get the best of both these systems' [***Senior Automation Manager***, SME, Textile]

Here, managers indicate that robot integration proceeds through minimal adjustments to existing workflows. There is little evidence of radical reconfiguration. Instead, integration unfolds as a process of retrofitting, i.e. inserting robotic systems into predefined operational structures and adjusting around them as needed.

> 'I think the low-hanging fruit – the easier tasks to automate, the ones that need doing quickly, and the tasks where people already have the skills to automate – tend to fall more into the world of coexistence. That, I think, is the main driver. Companies are focusing on automating tasks that are not truly collaborative or cooperative, simply because it is more straightforward.' [***Principal Manufacturing Engineer***, MNC, Mechanical and Electrical Engineering]

From a technical and operational standpoint, the human–robot work (re)configurations introduce new challenges. Designing effective human–robot work systems requires more than placing a robot beside a human. It demands clarity about task boundaries, timing, handovers, and responsibilities. Several managers highlighted the difficulty of identifying the optimal points of integration, particularly when collaborative processes blur the distinction between operator and machine. The presence of safety protocols often delays the realisation of the collaborative promise, leading to interim configurations that resemble coexistence[2] or synchronised[3] operation more than true human–robot collaboration.[4] However, these preliminary conservative arrangements were not seen as failures but were framed as transitional steps that were essential for maturing organisational practices, testing assumptions, and incrementally developing internal confidence through continuous

[2] Coexistence: In this work configuration, workers and robots perform distinct tasks for distinct processes in separate locations on the shop floor (Callari, Curzi, & Lohse, 2025, pp. 3-4).

[3] Synchronisation: In this work configuration, one or more workers and one or more robots perform consecutive tasks, sharing the same workspace (Callari, Curzi, & Lohse, 2025, pp. 3-4).

[4] Collaboration: Human–robot collaboration entails humans and robots jointly pursuing shared goals through adaptive, intelligent interaction. While effective in domains like surgery, real-world manufacturing applications remain limited, as most studies occur in controlled lab settings because of unsolved technical and human factors challenges (Callari, Curzi, & Lohse, 2025, p. 4).

adaptation.

‘Collaboration requires much more nuanced thinking about what these systems should actually be doing. For instance, does the robot pick up the component and the human perform the task on it? Or is it the other way around: the human picks up the component, and the robot performs the task? It takes much more consideration of how we would do these things differently.’ [***Manufacturing Manager***, MNC, Transport]

Additionally, although collaborative robots are marketed as a technology that is safe for direct human interaction, this technical potential is filtered through organisational risk cultures, legal obligations, and compliance frameworks. In several cases, middle managers chose to initially deploy these robots within fenced areas or guarded cells, replicating older safety practices developed for traditional industrial robots. This tendency reflects both a general organisational aversion to risk and a broader lack of established protocols that would support dynamic, in-situ human–robot interaction. As such, safety concerns shape spatial layouts and interaction modalities, which often favour separation over proximity. Managers described these decisions as necessary stepping stones in the adoption journey, but they also acknowledged that without clearer regulatory and organisational guidance, the full promise of collaborative applications – i.e. safe, co-present teamwork – remains difficult to realise.

‘With collaborative robotics being recently new within the UK […] the mindset of a lot of people is, they come with the same risks and hazards that industrial-level robots come with, which isn’t the case.’ [***HO Actuators and End Effectors Manager***, MNC, Transport]

‘Sometimes the cobot is placed in a cell because of safety concerns, and it ends up surrounded by a kind of fence.’ [***Production Manager***, SME, Construction]

In steering initial human–robot work configurations, the ethical dimension of collaborative applications becomes embedded within design decisions when defining the spatial and operational boundaries between humans and robots. These decisions involve implicit normative judgements regarding what constitutes acceptable exposure to risk and how far collaboration should extend within the production system.

‘Introducing a robot may bring certain new risks, but at the same time, it removes others, particularly those linked to musculoskeletal strain. The question then becomes which side weighs more heavily: the risks introduced or the risks eliminated. In many cases, the risks we remove are greater than those we introduce.’ [***Robotics, Automation & Quality Manager***, SME, Transport]

4.4. Unlocking workers’ embodied knowledge

What place will humans hold within increasingly automated production systems? Across the dataset, middle managers’ perspectives vary significantly. Some begin with the capabilities of robotic technologies and only later consider the role of workers within these arrangements. Others approach the issue from the opposite direction, treating the configuration of human–robot collaboration from the outset as both a strategic and ethical question concerning how work should be organised, embodied, and sustained on the shop floor.

These more reflective perspectives appear to deepen as organisations develop greater maturity and awareness in managing human–robot configurations. As human–robot practices take shape, managers become better able to recognise the conditions that enable the effective integration of human expertise within hybrid work environments. In such contexts, attention shifts towards understanding how workers’ knowledge, judgement, and practical experience contribute to the functioning of hybrid production systems.

‘I think when you start to think about genuinely trying to embrace cobotic systems, there are some fundamental, almost philosophical, questions that we need to ask ourselves, which are: what is the human doing as part of this? Is the human actually required as part of this? And if the human is required, how do you get the best of both those systems?’ [***Manufacturing Manager***, MNC, Transport]

Across these accounts, an ethical ambivalence seems to arise. Notably, several managers expressed concerns about the broader meaning of work as robots take over familiar tasks. For these managers, decisions should consider workers’ sense of ownership, identity, and long-term engagement. These considerations draw attention to how people experience their contribution and how organisations construct value around human labour. Some managers suggest turning to workforce development as a practical way of addressing these concerns.

Workers’ embedded knowledge becomes a critical organisational resource, particularly where tasks remain variable or context-dependent and require human judgement. Skills and the practices through which they are developed emerge as central throughout the adoption journey. While reskilling workers to ensure safe and effective interaction with collaborative robots remains necessary for implementing human–robot configurations on the shop floor, several managers emphasised the importance of broader upskilling configurations.

‘I think there's always going to be a requirement for having humans do very specific, very niche, very particular tasks.’ [***Ergonomics Manager***, MNC, Automotive]

‘I think we've realised that […] there's always going to be a need for human intervention and human involvement. We're just trying to work out how we'd continue to evolve people, train people, give people tasks that get the best value from this.’ [***Robotics, Automation & Quality Manager***, SME, Textile]

From their perspective, upskilling enables workers to engage with production systems at a more systemic level. Upskilling, in their view, entails cultivating process literacy, i.e. the capacity to understand how the system functions, identify sources of inefficiency or failure, and actively support its optimisation. Some middle managers highlighted that workers may increasingly act as crucial interfaces between shop-floor operations and the performance indicators used to guide managerial decision-making, particularly in complex and highly variable production environments.

‘It’s a case of making sure people are trained. We need the operators to understand the operation itself, and then we need to upskill them to understand how the collaborative robot works, what its limitations are, and what needs to be in place to ensure it performs repeatably and reliably.’ [***Principal Manufacturing Engineer***, MNC, Mechanical and Electrical Engineering]

Several interviewees highlighted the risks of neglecting that interface. Without workers who understand both the robotic system and the surrounding production context, operational breakdowns become harder to resolve, and organisational responsiveness is reduced. Upskilling is therefore an infrastructural requirement for making collaboration work at scale. As one manager noted:

‘The real challenge isn’t just putting a cobot in, it’s everything that needs to come with it. If operators could fix issues themselves without constantly relying on engineers, we’d be far more agile. That’s why we need to think beyond automation and also invest in retaining our workforce, building their skill set, and upskilling individuals so they can support the system and keep things running.’ [***Senior Manufacturing Engineer***, MNC, Mechanical and Electrical Engineering]

At the same time, while upskilling was suggested as a pragmatic organisational response to automation, further reflection during the interviews surfaced broader ethical implications for workers’ roles and responsibilities. Participants indicated that these configurations may introduce ethical tensions related to responsibility, value, and the evolving relationship between workers and automated systems. In particular, some managers acknowledged that collaborative settings may implicitly position workers in comparison with machine performance, raising concerns about how workers may perceive their role within the production system.

> 'But upskilling also means the operator becomes responsible for keeping the system running, and people start wondering what that means for their role, whether the robot is supporting them or whether they are now there to support the robot.' [***Principal Manufacturing Engineer***, MNC, Mechanical and Electrical Engineering]

> 'If the robot is there doing the task with me, the question people start asking is, "Does that mean my pay goes down because the robot is sharing the job?"' [***Manufacturing Manager***, MNC, Transport]

5. Discussion

As collaborative systems are introduced into manufacturing, organisations confront new uncertainties concerning the organisation of work and the future role of human labour. This paper investigates how middle managers exercise agency in the deployment of these technologies, which are potentially SDTs, and in the (re)configuration of human–robot work towards Industry 5.0.

Drawing on an empirical dataset comprising interviews with 26 middle managers working across European manufacturing organisations, and in line with research portraying middle managers as active agents (Heyden et al., 2017; Maurer et al., 2024; Tarakci et al., 2023), our results reveal four forms of agency through which middle managers grapple with uncertainties (scouting), balance competing demands in the (re)configuration of human–robot work on the shop floor (mobilising alignment and steering the initial configuration of human–robot work), and harness workers' embodied knowledge (unlocking). These results show converging patterns with CBW research (Langley et al., 2019), with SST studies on innovation journeys (Rip & Schot, 2002; Schot & Rip, 1997), and emerging scholarship on SDTs (Anderson et al., 2026; Brey, 2018; Hopster, 2021; Schuelke-Leech, 2018). Furthermore, our results offer novel and counterintuitive theoretical insights, as summarised in Table 2 and discussed below.

In the scouting form of agency, managers engage in exploratory sense-making that resonates with Langley et al.'s (2019) notion of arranging boundaries and SST's idea of building a protected space (Rip & Schot, 2002), as they carve temporary cognitive and organisational spaces where novel technological possibilities can be trialled, sheltered from established routines. Here, managers engage in cross-functional collaboration within the organisation and interact with external actors in order to assess the situated workability of proposed solutions (range of impacts in Hopster (2021)).

Moreover, techno–organisational evaluations intertwine with emerging concerns about the meaning of work and the future role of workers in increasingly hybrid environments (Callari, Curzi, & Lohse, 2025; Callari & Puppione, 2025), highlighting the valence and ethical salience of technological impacts (Hopster, 2021). These reflections prompt middle managers to recognise that robot adoption may raise additional questions concerning the aims and meaning of how to conduct the business. Through these considerations, the potential impacts of collaborative applications reach the domain of top management strategy, where organisational purpose and strategic direction receive definition (range of impacts in Hopster (2021)). This dynamic further heightens the extent of uncertainty (Hopster, 2021) surrounding robot implementation.

In mobilising alignment, managers orchestrate negotiations among organisational stakeholders to balance divergent interests and address normative contestation, while drawing on external insights to sustain multiple, coexisting priorities. This reflects CBW's arranging and buffering boundaries (Langley et al., 2019), and SST's broadening of development processes (Rip & Schot, 2002). Normative contestation constitutes a key criterion of SDTs (Hopster, 2021). Robot adoption generates moral disagreement, intense affective disturbance, and strong ethical responses, which Hopster (2021) describes as the extent of uncertainty, valence, and ethical salience of impacts, among workers and their representatives, who hold priorities that do not necessarily align with managerial mandates.

Normative contestation also reveals how the disruptiveness of robots emerges unpredictably through their interaction with context-specific configurations of power and interests, as suggested by SST (Lloyd & Payne, 2023). In this form of agency, middle managers mediate temporary convergence around '*shared normative orientations*' (Anderson et al., 2026, p. 5). This convergence takes the form of what SST conceptualises as a '*negative compromise*' (Wright, 2000): middle managers advance robot deployment in line with top management priorities while ensuring reskilling, job security, and safety-oriented design (Callari & Lohse, 2025). Yet this compromise intensifies the extent of uncertainty (Hopster, 2021) and extends the range of impacts (Hopster, 2021) to the macro-level, as reflected in our empirical results: questions arise regarding the preparedness of the educational system to supply a skilled future workforce, and the capacity of regulatory frameworks to address safety challenges in dynamic collaborative settings.

Steering the initial configuration of human–robot work systems aligns with CBW's arranging boundaries (Langley et al., 2019) and SST's building a protected space and stepping out into a wider world (Rip & Schot, 2002). Here, during the early implementation of task arrangements explored and tested through scouting and mobilising alignment, middle managers confront safety and productivity challenges through cautious implementation as an organisational response to the social disruptiveness of collaborative application. In line with Anderson et al. (2026), our results show that social disruptiveness does not coincide with an already accomplished transformative outcome. Instead, it primarily manifests as a substantial challenge to normative orientation and joint-action coordination in a given context, engendering disorientation: '*not knowing how to continue, being unable to go on as before but also being at a loss as to how to move forward*' (p.6).

Middle managers' accounts and ethical concerns shaping initial deployment highlight the extent to which the challenges to joint action–coordination (Anderson et al., 2026) are already operative, even if the ultimate organisational consequences remain open and unresolved: shared understandings and guiding principles for collective action remain unsettled, and a clear path forward remains undefined, i.e. established '*orders of worth*' (Anderson et al., 2026) no longer provide adequate resources for coordination. Steering initial human–robot configurations is the agentic response through which middle managers navigate amid this uncertainty (Hopster, 2021). In these early-stage deployments, organisations learn in practice, through trial and error, how to rework the conditions under which humans and robots may safely, legitimately, and meaningfully work together in still evolving human–robot work systems (Callari, Curzi, & Lohse, 2025).

Finally, unlocking workers' embodied knowledge corresponds to CBW's coalescing boundaries (Langley et al., 2019) and SST's recontextualising technology (Rip & Schot, 2002), in which middle managers envision new workers' contributions within hybrid settings. Here, workers' spaces of action may increasingly involve integrating task-specific expertise with process-level understanding, combining the technical knowledge embedded in manual operations with the broader competencies needed to govern and adapt production processes, i.e. upskilling (Callari, Curzi, & Lohse, 2025; Callari & Lohse, 2025).

Critically, upskilling configurations represent a type of compromise that SST conceptualises as labour–management cooperation (i.e. '*positive compromise*' (Wright, 2000)), enabling organisations to safeguard operational continuity in highly uncertain hybrid work systems while

Table 2
Overview of this study's theoretical contributions.

Empirical forms of middle managers' agency	**Converging theoretical patterns with CBW and SST, and with SDTs criteria**	**Contribution to CBW** **Processual understanding of agency beyond reflexive–pre-reflexive dichotomy**			**Contribution to SST**		**Contribution to SDTs**
		Reflexive agency within SDTs contexts	**Multiple temporalities of reflexive agency** – extending mainstream literature (e.g. (Cardinale, 2017; Langley et al., 2019)), where reflexivity has been conceptualised only as a future-oriented mode	**Non-reflexive component**	**Ethical dimensions**	**Compromises**	- Collaborative systems in manufacturing, even at their early stage of AI-enabled capabilities, are conceptualised as SDTs - First exemplary case of SDTs at organisational level
Scouting (the potential relevance for collaborative applications)	<u>CBW</u>: ~ Arranging boundaries <u>SST</u>: ~ Building a protective space <u>SDTs</u>: ~ Range of impacts ~ Valence of impacts ~ Ethical salience of impacts ~ Extent of uncertainty	Under conditions of competing interpretations, normative contestation, moral ambiguity, managers exercise agency through continuous monitoring, evaluation of consequences, and ongoing adjustment of action while navigating uncertainty.	Simultaneously oriented towards the present and the future	[N.A.]	Permeate the entire robot deployment process, rather than appearing only at the stage of outcome evaluation, emphasising ethical struggle, moral ambivalence and normative contestation	[N.A.]	
Mobilising alignment (within and beyond the organisation)	<u>CBW</u>: ~ Arranging boundaries ~ Buffering boundaries <u>SST</u>: ~ Broadening the development process ~ Context-specific configurations of power and interests ~ Negative compromise <u>SDTs</u>: ~ Range of impacts ~ Valence of impacts ~ Ethical salience of impacts ~ Extent of uncertainty						
Steering the initial configuration (of human–robot work systems)	<u>CBW</u>: ~ Arranging boundaries <u>SST</u>: ~ Building a protective space ~ Stepping out into a wider world <u>SDTs</u>: ~ Extent of uncertainty		Simultaneously oriented towards the present and the past	Non-reflexive shifts from present and past temporal orientations to future temporal orientations Non-reflexive shifts from reproductive to transformative agency			
Unlocking (workers' embodied knowledge)	<u>CBW</u>: ~ Coalescing boundaries <u>SST</u>: ~ Workers' recontextualization of technology ~ Positive compromise <u>SDTs</u>: ~ Valence of impacts ~ Ethical salience of impacts		Oriented towards the future			Problematising upskilling configurations as a 'positive compromise'	

considering aspects of meaningful work (Callari et al., 2024; Callari & Puppione, 2025; Lysova et al., 2023). However, upskilling represents an ethically ambivalent response that significantly amplifies the valence and ethical salience of impacts of robots (Hopster, 2021), raising doubts about the uneven distribution of benefits and burdens for workers.

These results contribute to the theorisation of reflexivity in CBW (Langley et al., 2019), the problematisation of the positive compromise in SST (Lloyd & Payne, 2023; Wright, 2000), and offer an empirical case of contextual specificity of SDTs (Anderson et al., 2026; Schuelke-Leech, 2018) within human–robot work configuration in Industry 5.0.

5.1. Contribution to CBW

We advance the understanding of the reflexive component of agency (Cardinale, 2017; Emirbayer & Mische, 1998). As highlighted by Langley et al. (2019), a dominant view in management and organisation studies tends to equate reflexivity with calculative, planned decision-making, which would presuppose clear objectives. We challenge this conceptualisation. In our study, the conditions under which collaborative systems may generate value within production systems emerge as a terrain of competing interpretations, both in terms of objectives (e.g. the meaning of work for workers alongside the pursuit of efficiency and revenue imperatives) and the means to achieve them. Crucially, robot integration compels managers to engage in continuous monitoring of how decision-making unfolds, scrutinise emerging consequences, and assess their own actions against alternative purposes that the integration of collaborative applications may serve. Despite this level of uncertainty, the managerial decision-making process is guided by a high degree of conscious reflexivity, understood as the capacity to articulate reasoning while continuously adjusting the course of action (Giddens, 1984). This formulation sheds light on the reflexive component of agency within SDTs contexts, where competing interpretations, normative contestation, and moral ambiguity prevail (extent of uncertainty in Hopster (2021)).

Furthermore, we extend prior theorisation of the temporal orientation of reflexive agency. By temporal orientation, we draw on the definitions provided by Emirbayer and Mische (1998, p. 971). A past-oriented mode of action rests on the '*selective reactivation […] of past patterns of thought and action*' (p. 971). A present-oriented mode concerns the '*capacity […] to make practical and normative judgements […] in response to […] presently evolving situations*' (p. 971). A future-oriented mode refers to the '*imaginative generation […] of possible future trajectories of action*' (p. 971). In our results, alongside forms of reflexive agency oriented towards the future (unlocking workers' embodied knowledge), we identified forms simultaneously oriented towards the present and the past (steering human–robot work configurations), and forms simultaneously oriented towards the present and the future (scouting and mobilising alignment). In drawing attention to these multiple and coexisting temporal orientations of reflexive agency, we supplement the mainstream literature (e.g. Cardinale, 2017; Langley et al., 2019), where reflexivity has been conceptualised only as a future-oriented mode of decision-making.

An additional important insight emerging from our results concerns the way middle managers switch between different temporal orientations of agency as they shape the deployment of robots in manufacturing. As noted by Emirbayer and Mische (1998), examining shifts in the temporal orientation of agency is essential for understanding how actors reconfigure the structures with which they engage. Our study extends this argument by showing that such shifts often unfold through non-reflexive dynamics rather than deliberate reflexive adjustment. This is empirically illustrated in the two forms of agency: steering initial configurations and unlocking workers' embodied knowledge.

During steering initial configurations, managers reflexively pursue provisional, incremental integration rather than embarking on a straightforward path towards broader reconfiguration, enacting a form of agency oriented towards the present and the past that nonetheless produces unintended consequences. As collaborative robots and digitalisation permeate production, they intensify the interdependence of organisational processes, where even minor disruptions can cascade across systems, amplifying uncertainty and threatening operational continuity. A non-reflexive feedback loop develops as unintended effects become unrecognised conditions for further managerial decisions, emphasising the centrality of situated human expertise in future hybrid work systems (unlocking workers' embodied knowledge). Critically, by foregrounding the interplay between reflexive and non-reflexive components of agency, we can explain not only how temporal orientations of agency shift over time, but, more importantly, how reproductive forms of agency can become generative of transformation.

To conclude, the existing literature often conceptualises agency through a dichotomous distinction between reflexive and pre-reflexive modes of action (Langley et al., 2019). Our results instead show that middle managers' agency unfolds as a process embedded in multiple temporalities and shaped through the interplay of reflexive and non-reflexive components.

5.2. Additional contributions to SST and SDTs

Drawing on the SST perspective that examines actors' agency across the entire innovation journey (Rip & Schot, 2002; Russell & Williams, 2002; Williams & Edge, 1996), we show that ethical concerns that accompany these processes are not only present at the final stage of technology integration (Leonard & Tyers, 2023) but also permeate the four forms of middle managers' agency. This perspective gives renewed voice to the middle managers' role, which has long remained '*morally muted*'.

One of the core tenets of SST is that the outcomes of advanced technology deployment emerge through processes of compromise (Russell & Williams, 2002). Through an abductive reasoning process, our results show that positive compromise, conceptualised in SST as '*a non-zero-sum game*' (Wright, 2000, p. 958) in the management-worker relationship, emerges more ambivalently in our middle managers' accounts of upskilling configuration. Specifically, in contrast to the view that worker upskilling is a positive compromise because it sustains worker involvement and prevents substitution (Dornelles et al., 2023; Lloyd & Payne, 2023), our results show that, while it may legitimise embodied knowledge, it can also assign additional responsibility to workers. Such arrangements remain entangled with ethical and political tensions, including issues of human–robot asymmetries of power, uneven distributions of benefits and burdens, and worker wellbeing and organisational justice (Callari et al., 2024; Santoni de Sio et al., 2024), challenging the assumption that they can constitute an automatic improvement in workers' positions.

Finally, our study offers substantive contributions to the emerging field of SDTs by confirming and building on work by Schuelke-Leech (2018) that collaborative systems in manufacturing, even at their early stage of AI-enabled capabilities, can be conceptualised as SDTs. Our results highlight the central role of the context and the agency of actors accomplishing these transformations (Anderson et al., 2026; Hopster, 2021). Critically, we introduce an organisational-level exemplary case that has so far remained overlooked in the SDT literature, which has predominantly examined these phenomena at the level of broad societal transformations (e.g. deepfakes or birth control technologies in Anderson et al. (2026)).

6. Implications

For organisations, the four forms of middle managers' agency identified in this study suggest that the deployment of collaborative applications requires dedicated governance structures. Scouting and mobilising alignment show that middle managers need institutional support from top management to navigate normative contestation. This includes a mandate for middle managers to raise ethical concerns about the future role of workers within hybrid work configurations. Top management should therefore create deliberate spaces where such concerns can be surfaced and explicitly addressed. Upskilling configurations require particular attention. Expanding workers' responsibilities to include system oversight and process governance should be accompanied by an assessment of risks to physical and psychological well-being, as well as by a transparent reconsideration of how these contributions are recognised, compensated, and valued.

Policymakers should promote governance frameworks that require the meaningful participation of workers throughout the design, implementation, and evaluation of collaborative applications. Such involvement can strengthen transparency, improve the alignment between technological solutions and workplace realities, and support collective proactive governance of techno–social change. Policies should therefore encourage structured consultation mechanisms, worker representation in technology-related decision-making, and participatory approaches to technology assessment, ensuring that innovation is developed with those affected by it.

CRediT authorship contribution statement

Ylenia Curzi: Writing – review & editing, Writing – original draft, Visualization, Methodology, Conceptualization. **Tiziana C. Callari:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Niels Lohse:** Writing – review & editing, Supervision, Funding acquisition.

Conflicts of interest

The authors declare no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.techsoc.2026.103442.

Data availability

The authors do not have permission to share data.

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