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Fostering well-being in Industry 5.0 through managerial behaviours and enabling technologies

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ABSTRACT

Industry 5.0 represents the latest industrial evolution, building on the foundations of Industry 4.0 while shifting the focus towards humanity, sustainability and resilience. In this paradigm, enabling technologies are redefined as tools that support human well-being first and business productivity second. Despite its growing relevance, the management literature remains fragmented on how specific managerial behaviours and technologies effectively support these new objectives. To address this gap, this research adopts a systematic literature review and thematic analysis to identify and systematise well-being-centred managerial behaviours and enabling technologies that facilitate the transition to Industry 5.0. The results reveal a relationship between managerial behaviours and enabling technological that can promote well-being-oriented innovation. A key contribution of this study is the conceptualisation of a new value-creation sequence: human well-being serves as the primary driver of productivity, ultimately leading to sustainable competitiveness. These findings offer important theoretical and managerial implications, providing an integrated framework that treats technology as a consequence of human-centred design. Finally, the study outlines future research paths to promote the development of a worker-centred industrial system.

1. Introduction

Industrial revolutions have historically triggered profound transformations in production systems, labour dynamics, and societal structures (Xu et al., 2018; Sharma and Singh, 2020). Each revolution introduced disruptive technologies, opened new opportunities, and posed significant challenges (Boninsegni et al., 2022). In the current context, we observe a unique overlap between two paradigms: Industry 4.0 (I4.0) and Industry 5.0 (I5.0), signalling a transitional phase rather than a discrete shift (Xu et al., 2021; Mourtzis et al., 2022).

I4.0, launched in 2011, marked the integration of advanced technological enablers into industrial production (Sharma, 2019). Core technologies associated with I4.0 include additive manufacturing, autonomous robots, big data, cloud computing, cybersecurity, the Industrial Internet of Things (IIoT), simulation, and the vertical and horizontal integration of systems (Rüßmann et al., 2015; Bortolini et al., 2018; Büchi et al., 2020; Bruni and Piccarozzi, 2022). Additional contributions have emphasised the roles of Artificial Intelligence (AI) and robotics as integral components (Goel and Gupta, 2020; Peres et al., 2020; Bécue et al., 2021). The central aim of I4.0 was to enhance industrial efficiency and productivity, driving organisational restructuring, skill redefinition, and novel business models (Bigliardi et al., 2020; Sigov et al., 2024).

In contrast, I5.0—proposed by the European Commission—places human-centrality, sustainability, and ethical responsibility at the heart of industrial development (Nahavandi, 2019; Breque et al., 2021). This paradigm redefines the relationship between humans and machines, shifting the focus from automation and efficiency to collaboration and well-being (Pizoń and Gola, 2023). While I4.0 prioritised technological optimisation, I5.0 emphasises the value of human involvement, creativity, and purpose within socio-technical systems (Nahavandi, 2019). Recent literature emphasises that, although I4.0 and I5.0 pursue different focal objectives, they remain closely interconnected.

I4.0 is largely technology-driven and seeks to enhance efficiency and

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productivity through automation, connectivity, and data-intensive processes (Lu, 2017; Xu et al., 2021). In contrast, I5.0 introduces a value-oriented perspective, prioritising a human-centred approach, sustainability and resilience as strategic imperatives (Ghobakhloo et al., 2024a; Fogaça et al., 2025). Rather than replacing the former, I5.0 builds on the technological foundations of I4.0, extending its scope to social and environmental dimensions (Ramos-Gutiérrez and García-Gutiérrez, 2024). This continuity suggests an evolutionary transition in industrial paradigms, in which digital transformation and human value creation coexist as complementary drivers of long-term competitiveness.

Moreover, the concept of I5.0 is closely linked to another previously much-discussed topic in the literature, Society 5.0 (Narvaez Rojas et al., 2021). The Society 5.0 concept, coined in 2016 by the Japanese government, proposes a human-centred society in which problems are solved through technology. It can be defined as a broad and futuristic concept (Deguchi et al., 2020). I5.0 can be placed within this broad context as it focuses attention on businesses and corporate activities as a stepping stone towards achieving a Society 5.0 in the future (Huang et al., 2022). Therefore, I5.0 can be considered both a piece of a larger plan (Society 5.0) and an evolution of the previous 4.0 revolution (Xu et al., 2021).

In this new scenario, the correct sequence for value creation begins with human well-being, proceeds to productivity, and culminates in business competitiveness. In this evolution from I4.0 to I5.0, it is helpful to consider the role of managers in companies. They are the ones who drive organisations towards positivity, value, and well-being. Mahajan et al. (2023) present Value Dominant Logic (VDL) approach rooted on axiology (Lapie, 1902), actor-network theory (Latour et al., 1992), the hygge/well-being concept (Wiking, 2016); The Value-Dominant Logic (VDL) represents a comprehensive managerial framework that emphasises the role of managerial behaviour and decision-making in generating positive value for companies, users, and other stakeholders. This approach underscores the necessity for managers to effectively employ both tangible and intangible organisational resources to promote well-being at individual, corporate, and societal levels. VDL posits that managerial actions can be guided by a value-oriented logic, whereby the creation of internal and external benefits fosters collective welfare. When managed according to VDL principles, organisational resources contribute to sustained well-being and shared value creation. Within this perspective, I5.0 emerges as a complementary paradigm that enhances managerial behaviour beyond the pursuit of mere production efficiency. Firms adopting I5.0 exhibit a heightened sensitivity to the well-being of both the organization and the broader society in which they operate.

Then, according to Piccarozzi et al. (2024, p. 13), I5.0 represents "a revolution that affects everything around organisations, institutions, and societies oriented to sustainability in terms of human-centricity, environmental sustainability and resilience, realised through a strong relation between human creativity and autonomous machines." This vision underscores not only the pursuit of efficiency but also the broader goals of prosperity, societal value, and planetary well-being (Neumann et al., 2021). In this evolving framework, well-being assumes a central role, warranting deeper investigation (Halbreich, 2022; Antonaci et al., 2024). It is a multifaceted construct encompassing physical, psychological, emotional, social, and economic factors (Fletcher, 2016; Nielsen et al., 2017). Well-being can be viewed from individual (worker, consumer, citizen) and collective (organisational, societal, environmental) perspectives (Kadir and Broberg, 2020). From a managerial standpoint, workplace well-being significantly influences employee performance, organisational effectiveness, and societal impact (Krekel et al., 2019; Pagán-Castaño et al., 2020; Khaled and Alena, 2022). Literature has explored various dimensions: physical safety and fatigue (McKee-Ryan et al., 2005; Lerman et al., 2012), psychological stress and emotional load (Daniels and Harris, 2000; Kersemaekers et al., 2018), social and relational aspects (Spiller et al., 2011; Guerci et al., 2022), organisational structure and role clarity (Cartwright and Cooper, 2009; Gillet et al., 2012), and economic or career-related well-being (Diener and Seligman, 2004).

Within I4.0, well-being has attracted increasing scholarly attention, particularly in relation to technological transformation and its impact on human factors (Hanefah, 2018; Orben and Przybylski, 2019). In the I5.0 context, the literature is expanding, investigating well-being in relation to human-machine interaction (Davila-Gonzalez and Martin, 2024), workplace conditions (Antonaci et al., 2024), and mechanisms of well-being enhancement (Calzavara et al., 2024). However, critical questions remain regarding the types of well-being supported by I5.0, the modalities of support, required competencies, and the role of enabling technologies (Khaled and Alena, 2022; Ricci et al., 2025). Despite the increasing scholarly attention to I5.0, existing research remains fragmented in its attempt to establish a direct link between managerial practices, technological enablers, and worker well-being (Antonaci et al., 2024; Kuru, 2023). Most studies to date conceptualise well-being as a secondary or indirect outcome of technological advancement, emphasising dimensions such as productivity, automation, or sustainability (e.g., Ghobakhloo et al., 2024b; Ricci et al., 2025), rather than as a central objective. Other studies have predominantly focused I5.0 enabling technologies or on normative discussions centred on humans and sustainability, without systematically linking these technologies to outcomes in terms of worker well-being (Breque et al., 2021; Nahavandi, 2019).

Furthermore, the notion of well-being is often treated as an abstract construct, without a systematic classification of its multidimensional facets—namely, physical, psychological, organisational, relational, and economic. To address this gap, the present study identifies, categorises, and operationally defines the managerial behaviours and technological enablers that foster well-being-oriented innovation within the I5.0 paradigm.

Against this backdrop, the present study seeks to explore the concept of well-being within the emerging I5.0 paradigm, identifying enabling mechanisms at the intersection of technological evolution and human-centric innovation.

Specifically, two research questions emerge:

RQ1: Which managerial behaviours stimulate the emergence of well-being in I5.0?

RQ2: Which I5.0 enabling technologies support well-being-oriented managerial behaviours?

Building on a systematic literature review (SLR) and thematic analysis, this paper aims to clarify the conceptualisation of well-being in the context of I5.0, focusing specifically on managerial behaviours and enabling technologies that contribute to its enhancement. Hence, this study is grounded in a socio-technical, human-centric management lens that views technological systems and managerial practices as jointly shaping organisational outcomes. By integrating I5.0 principles with management and organization studies, the paper conceptualises worker well-being not as a by-product of technological advancement, but as a central managerial outcome emerging from the alignment among enabling technologies, managerial behaviours, and human values. Based on this conceptual framing, the following section operationalises the study's core constructs—managerial behaviours, enabling technologies, and worker well-being—within the I5.0 framework to support the subsequent systematic literature review and thematic analysis.

2. Methodology

2.1. Conceptual grounding and operational definitions

This section provides the conceptual grounding and operational definitions of the core constructs guiding the study. Specifically, managerial behaviours, enabling technologies, and worker well-being are defined and operationalised to ensure theoretical coherence and analytical consistency throughout the systematic literature review and thematic analysis (Braun and Clarke, 2006; Denyer and Tranfield, 2009). The primary constructs of the study were operationally defined

as follows:

Managerial behaviours were operationally defined as encompassing all actions, decisions, and practices commonly adopted by managers that can influence employees' physical, psychological, or organisational well-being within the I5.0 context. More precisely and in practical terms, they were identified through keywords, coded expressions, and thematic clusters in the selected articles referring to leadership style, human–machine collaboration management (Galván-Vela et al., 2021; Grosse et al., 2023), emotional intelligence (Chin, 2021; Salvadorinho et al., 2025), scheduling and optimization decisions (Abdous et al., 2025; Destouet et al., 2023), stress prevention (Blandino, 2023; Apraiz et al., 2023), and resilience strategies (Hadi et al., 2023; Calzavara et al., 2024). The coding process yielded six behavioural categories: human-centric orientation, emotional intelligence, scheduling optimisation, human–robot collaboration, psychological well-being management, and resilience/sustainability orientation.

Enabling technologies were operationally defined, encompassing digital tools and infrastructure solutions that facilitate the integration of human-centric, well-being-oriented processes in organisations. Their identification was based on explicit mentions of supporting worker safety, inclusion, motivation, and performance. Technologies were coded according to their functions and frequency across the reviewed literature, resulting in the following core categories: collaborative robots (cobots) (Coronado et al., 2022), AI (Cramarenco et al., 2023; Gualtieri et al., 2024), digital and human digital twins (Davila-Gonzalez and Martin, 2024; Cutrona et al., 2024), exoskeletons, sensors (Ashta et al., 2023), simulation modelling, automated guided vehicles (AGVs), pick-and-transport robots (PTRs) (Thylén et al., 2023; Vijayakumar and Sobhani, 2023) and knowledge-based intelligent systems (KBIS), (Pabolu et al., 2025).

Well-being was operationally defined as a multidimensional construct encompassing physical, psychological, organisational, relational, and economic/professional dimensions of workers' experience (Danna and Griffin, 1999). In the analysis, these dimensions served as lenses to classify how managerial behaviours and enabling technologies contribute to human-centric outcomes. Indicators of well-being were inferred from textual evidence referring to stress reduction, job satisfaction, inclusion, safety, motivation, performance improvement, resilience, and human flourishing.

Workers well-being dimensions: physical (pH) as health and safety in the workplace, ergonomics, risk prevention; psychological (PS) for instance satisfaction, motivation, stress, self-fulfilment, perception of control; organisational (ORG) related to organisational climate and culture, leadership, processes, quality of internal communication; economic/professional (EC/PR) as remuneration, job stability, opportunities for growth and professional development; relational (REL) quality of interpersonal relationships, sense of belonging, collaboration, support among colleagues and with superiors (Danna and Griffin, 1999).

These operational definitions guided both the coding and the thematic aggregation stages, ensuring coherence between the conceptual foundations of I5.0 and the empirical evidence emerging from the literature. Following the operationalisation of the key constructs, the subsequent section presents the findings of the SLR and thematic analysis. The results are structured according to the two research questions and articulated into distinct themes, highlighting how the identified managerial behaviours and enabling technologies contribute to fostering worker well-being within the I 5.0 paradigm.

Given this consideration, the methodology is structured in two steps. The first is based on the SLR to select the sample of papers for analysis. The second step involves thematic analysis of the sample papers to identify specific aspects related to the paper's aim and instrumental to the defined research question.

Fig. 1 shows the methodology design.

2.2. Systematic literature review

The SLR methodology enables outlining of the state-of-the-art literature on the topic under analysis. More specifically, the SLR method was selected to provide a comprehensive and structured summary of the existing literature on the subject (Booth et al., 2016) and to highlight gaps in the literature, methodologies not yet applied and areas of study that are still not very detailed about I5.0, managerial behaviours, enabling technologies and their contribution to worker well-being (Snyder, 2019).

SLR was implemented in accordance with the methodological scheme proposed by Mayring (2004) and Denyer and Tranfield (2009).

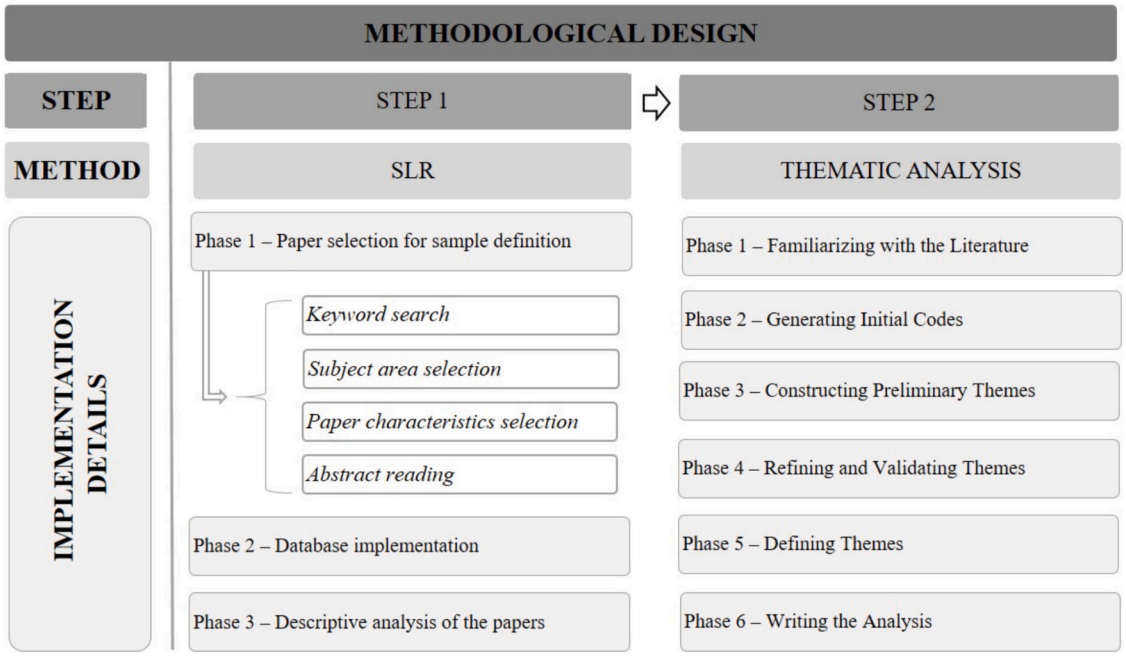

Fig. 1. Methodological design.
Source: authors' elaboration.

The papers were extracted from the Scopus and Web of Science (WoS) databases, considered the most relevant and comprehensive databases internationally in management studies (Newbert, 2007; Merli et al., 2020; Sassanelli et al., 2019). Scopus was selected because it is the largest global repository of peer-reviewed literature (de la Cruz-Lovera et al., 2019. In contrast, the Web of Science (WoS) database was included to ensure broader coverage of relevant publications. Conversely, other databases, such as Google Scholar and ResearchGate, were excluded due to documented inconsistencies and limited reliability in producing systematically relevant results (Haddaway et al., 2015; Alexander et al., 2019).

The selection of papers (SLR - Phase 1) was guided by the keywords deemed relevant to the research. The keywords "Industry 5.0" and "Well-being" and/or "wellbeing" were selected to ensure a specific focus on the topic. The final sample was obtained through a reasoned, replicable process of skimming using filters and selection criteria. Specifically, four selection steps were defined: keyword search; paper selection using thematic filters (subject area); selection based on paper characteristics; selection based on reading the paper abstract. In the final step, duplicate papers in the database were also removed.

In the first analysis step, keywords were searched for in the selected databases. The extraction was done on 1 April 2025 and returned 294 papers in Scopus and 145 papers in WoS.

The following selection step enabled focusing solely on managerial papers, thereby excluding categories such as engineering, the environment, education, and medicine. In this regard, in the Scopus database, the thematic filters "Business, Management and Accounting", "Decision Sciences" and "Social Sciences" were used (108 papers), while in WoS those "Operations Research", "Management Science", "Business" and "Management" (27 papers).

In the third step, English-language articles and reviews from peer-reviewed journals were selected to focus on high-quality papers. The selection returned 47 papers in Scopus and 23 papers in WoS.

Finally, the resulting papers were subjected to an abstract review based on inclusion/exclusion criteria, following the approach of Denyer and Tranfield (2009). Specifically, it was decided to include articles that addressed I5.0 and well-being (or wellbeing) through an analysis of managerial aspects. On the other hand, papers that merely mentioned I5.0 or well-being (or wellbeing) without providing an appropriate discussion of the topic, and that analysed managerial topics not inherently related to business management (e.g., smart cities, purely engineering topics, green transport, urban sustainability), were excluded. The authors independently screened the abstracts to ensure the validity and reliability of the selection process. Any discrepancies in inclusion or exclusion decisions were resolved through joint discussion until consensus was reached (Waffenschmidt et al., 2019). Duplicate papers in the two databases were also eliminated. The final sample under analysis consisted of 31 papers.

Table 1 summarises the results of the various selection steps implemented.

The selected papers were organised in an Excel database (SLR - Phase 2) for subsequent analysis, and fields such as year, journal of publication, field of study, and type of research were highlighted to provide a concise overview of the types of contributions under analysis.

Table 1
– Papers selection step.

Step	Step aim description	n. papers	
		Scopus	WoS
1	Keyword search	294	145
2	Subject area selection	108	27
3	Paper characteristics selection	47	23
4	Abstract reading	22	9
Total sample		31	

Source: authors' elaboration.

Briefly, the main characteristics of the papers (SLR - Phase 3) indicate a growing interest in the topic, with the number of papers in the sample increasing from 2021 to a peak in 2024 (12 papers). The main journals in which the papers are published are Journal of Manufacturing Systems (4 papers, 13% of the sample), Systems (3 papers, 10% of the sample), Computers & Operations Research (2 papers, 6%), International Journal of Production Research (2 papers, 6%), Sustainability (2 papers, 6%). The remaining journals cover topics of various natures, always related to production, industry, and management. From the perspective of applied methodology, 19 papers (61%) are empirical analyses, whereas the remaining 12 papers (39%) present theoretical studies.

The fields of study analysed are: Production (12 papers, 39% of the sample), Manufacturing sector (7 papers, 23%), Organization (6 papers, 19%), Automotive Industry (2 papers, 6%), Construction Sector (2 papers, 6%), Aerospace Sector (1 paper, 3%), Industrial Sector in general (1 paper, 3%). The topics covered are also evident in the analysis of the papers' editorial placement, which addresses both specific and general business aspects.

Following the general analysis from the SLR, the papers were analysed thematically to examine the research in detail and highlight aspects relevant to the identified research questions.

2.3. Thematic analysis of the selected papers

To explore how the transition from I4.0 to I5.0 is being framed in contemporary academic discourse, we conducted a thematic analysis following the approach outlined by Braun and Clarke (2006). Our objective was to capture the main patterns and conceptual shifts that articulate the growing emphasis on human centrality in technological innovation. The thematic analysis was structured in several phases to identify and define managerial behaviours and enabling technologies that support well-being. Below is a description of the 6 various phases.

In phase 1 (Familiarising with the Literature), we began by immersing ourselves in the material. Each article was read multiple times to grasp not only the explicit arguments but also the subtler language used to frame the human-technology relationship. During this phase, we took reflective notes, marking recurring terms, conceptual overlaps, and interesting divergences. Afterwards, in the phase 2 (generating initial codes), we moved to a more structured phase of coding. We worked inductively, identifying recurring ideas, metaphors, and expressions. For instance, when authors spoke of "cognitive load," "inclusive design," or "robots learning from humans," we coded these under emerging labels such as *human adaptability*, *ergonomic intelligence*, or *relational autonomy*. This process was done manually, and later organised using qualitative data software to keep track of overlaps and clusters. Once coding was complete, we stepped back to examine how the codes grouped conceptually (phase 3: constructing preliminary themes). Patterns began to take shape around certain central ideas: the need for emotionally intelligent machines, the redefinition of human-robot collaboration, the strategic value of soft skills, and the risks of stress in digitised environments. These patterns were not imposed, but emerged naturally through constant comparison and iteration.

In the next phase (phase 4 – refining and validating themes), we revisited both the original literature and the coded extracts to ensure that the themes were well-supported, distinct, and internally coherent. Some themes were merged (e.g., *stress prevention* and *psychophysical well-being*), while others were divided for clarity. What became clear was that the literature consistently addressed not just *what* new technologies can do, but *how* they must evolve to support human flourishing. So, we finalised and named the themes presented in the thematic map below (Tables 2 and 3). Each theme was described in detail, with representative examples from the literature (phase 5: defining themes). Finally, in phase 6 (writing the analysis), we wove the themes into a coherent narrative. The report presents I5.0 not as a rejection of technology, but as an evolution towards systems where people and machines can learn,

Table 2
– Managerial behaviour from thematic.

	Paper	Keywords	Theme/managerial behaviour	Conceptualization
DATA SET	1–5–19-20-30-31	Organisational justice; job satisfaction; disengagement; trust; innovation; human centric; societal value; simulation; collaborative workplace	**Human centric**	A fair and trust-based organisational environment boosts employee engagement and drives innovation, aligning industry with human needs. I5.0 redefines success by balancing technological progress with social responsibility and environmental stewardship, integrating economic, social, and environmental dimensions to build resilient, human-centred production. Simulation tools further support this vision by enabling the design of collaborative environments that enhance human potential.
	2–18–23-24-31	Emotional intelligence; soft skills; workforce performance; trust; motivation; psychosocial factors; work satisfaction; ethical integration	**Emotional intelligence**	Emotional intelligence plays a critical role in enhancing workforce adaptability, resilience, and collaboration, establishing itself as a cornerstone of human-centred technological evolution. Ensuring the ethical viability of AI and digital systems requires fostering trust, motivation, and psychological safety, alongside addressing workforce tensions through empathetic, human-centric design strategies. Moreover, continuous skill development and job satisfaction are fundamental drivers of human flourishing within the I5.0 paradigm.
	3–9–14-17-22-27-28-29	Human-robot collaboration; assembly line balancing; task scheduling; digital twins; factory layout; optimization; human operator model; nature inspired; flexible job; scheduling; resilience; ergonomic layout	**Scheduling Optimization**	Integrating human factors into optimised scheduling models is essential for ensuring both operational efficiency and ergonomic sustainability in production environments. Digital Twin technologies, enriched with human behavioural modelling, enhance layout optimisation by respecting human abilities and limitations. Nature-inspired optimisation approaches, combined with digital human modelling, achieve a critical balance between productivity and worker comfort. Flexible and intelligent scheduling systems further reinforce resilience against disruptions while safeguarding worker well-being. Ultimately, ergonomic layout optimisation and human-centred simulation processes are fundamental for developing ethical, inclusive, and high-performing industrial ecosystems.
	4–7–11-12-21–25	Interaction quality; user experience; robot adaptability; automation; smart construction; human machine interaction; passive exoskeletons; order picking; robot; warehouse automation; robots; cobots; automotive industry; human-machine; design guidelines; expert feedback	**Human Robot collaboration**	High-quality human-robot interaction depends on mutual adaptability, trust-building, and user-centred design. Intelligent construction technologies must embed principles of human collaboration to ensure safety, flexibility, and user acceptance. Similarly, wearable robotics must prioritise ergonomics and social sustainability to empower the Operator 5.0 paradigm. In logistics and automotive sectors, human-machine collaboration strategies must focus on safety, adaptability, and ergonomic integration. Updated design guidelines are critical to ensuring that human-robot interaction frameworks support not only operational efficiency but also safety, usability, and emotional well-being.
	6–10–13-26-31	Stress measurement; experimental protocol; physiological indicators; intelligent manufacturing; worker well-being; worker safety; inclusiveness; mental health; safe workstations; human-centred design; ergonomic assessment collaboration	**Psychological well-being**	Objective measurement of stress enables proactive workplace redesign, enhancing psychological resilience and long-term well-being. Managing occupational stress in intelligent manufacturing environments is essential for fostering healthy, sustainable worker engagement. Worker safety, mental health, and inclusiveness constitute core pillars of a resilient I5.0 ecosystem. Designing safe and ergonomically optimised workstations is fundamental to protecting both the psychological and physical health of workers in collaborative settings.
	8–15–16-30	Lean manufacturing; off-site construction; circular economy; resilience; sustainability	**Resilience Sustainability**	Integrating lean practices with circular economy principles fosters the development of resilient and sustainable production systems. Such systems are grounded in human needs, adaptability, and environmental responsibility. Achieving social sustainability in industry further requires a continuous commitment to employee well-being and organisational resilience.

Source: authors' elaboration.

adapt, and thrive together. The themes reflect a broader movement: one that places ethics, empathy, and inclusion at the heart of design, and repositions human dignity as an essential metric of industrial progress.

3. Results

For ease of interpretation, the thematic analysis results were separated according to the two research questions. The first section addressed the research and analysis of managerial behaviour, while the second section allowed for research on enabling technologies that contribute to well-being. The results are structured to reflect the study's dual analytical logic. First, managerial behaviours associated with worker well-being in I5.0 are identified and systematised. Second, enabling technologies are analysed as socio-technical resources that support, amplify, or operationalise such behaviours across different dimensions of well-being. Finally, a joint and comprehensive overview of the two research questions is proposed.

Table 3
– Enabling technologies supporting workers' well-being.

Paper		Enabling technologies	Conceptualization	Well-being dimensions				
				PH	PS	REL	ORG	EC/PR
	2–3–4-5-8-13-21–24-25-26-28-30	**Cobots and human-robot collaboration in general**	Cobots enable improvement in the physical and mental stress of the worker and contribute to safer spaces. They can adapt to different and individual needs, making tasks more ergonomic, flexible and less repetitive, allowing the worker to focus attention on more stimulating and engaging activities.	X	X	X	X	
	2–23–24-25-30	**AI**	AI, through the analysis of data, including from the physical monitoring of workers, can support the well-being issue by reducing stress and managing possible risks. It can support decision-making by lightening the mental load and optimising resources and allocation of workers in various roles according to skills. Well-being is reflected in an improved working environment in terms of safety, inclusion and gratification.	X	X		X	X
	15–16-17	**Digital Twin / HDT - Human Digital Twin**	By leveraging real-time data and workplace simulations, it can improve safety, ergonomics, and efficiency. This may contribute to the growth and satisfaction of workers. HDTs significantly enhance production processes and worker safety, as well as efficiency, resilience, sustainability including quality of interaction.	X		X		X
	8–11	**Exoskeletons**	Wearable robotic devices contribute to the well-being of workers by reducing physical stress, avoiding lesions, and increasing productivity.	X				
	20–29	**Simulation Modelling**	It allows for the design of production systems or even balance assembly lines in a more efficient, safe and ergonomic way, thus reducing physical disorders (for example, musculoskeletal) actively contributing to the physical and mental well-being of workers.	X	X			
	6	**Sensors**	Enable real-time physiological and cognitive monitoring (physiological signals, performance indicators, and human perception of stress) to provide helpful information for understanding the working conditions and the relative well-being of the worker with respect to stress and fatigue.	X	X			
	7	**AGVs**	They guarantee a safer, less tiring working environment, reducing workloads, as well as being more conducive to well-being, allowing the worker to focus on more rewarding tasks.	X			X	X
	12	**PTR**	They lighten the physical workload of workers, improving their safety and minimising errors, thus allowing them to concentrate on tasks with greater added value and therefore greater satisfaction.	X		X		X
	14	**Virtual Simulation**	It allows the creation of digital models of workstations and the simulation of related operations. In these scenarios, it is possible to create ergonomic workstations that help balance human workload with productivity.	X			X	
	22	**Digital Human Modelling Tool (DHM)**	It enables the creation and design of human-focused production systems that improve ergonomics, workload and safety and contribute to levels of well-being.	X	X			
	23	**Large Language Models (LLMs)**	Enable the understanding, monitoring, and thus the improvement of well-being from an organisational and human resources management perspective, based on analyses of textual data, sentiment analysis, and well-being priorities.			X	X	X
DATA SET	27	**KBIS**	Systems that are based on data and analysis allow work to be scheduled by customising it to the needs of the worker, contributing to the reduction of physical stress and improving worker fatigue in production systems.	X			X	
	1–9–10-18-19-31	**No specific technology - general analysis**						

Source: authors' elaboration.

3.1. Managerial behaviour results

From the thematic analysis, in relation to the first research question, we identified 6 managerial behaviours that help us understand the approach useful for supporting well-being in a company according to the I5.0 logic. Table 2 shows the results of the analysis.

3.2. Enabling technologies results

Following the lens of the second research question and the same pattern of analysis described in section 3.1, it was possible to deduce the enabling technologies that can be useful in supporting workers' well-being in the different dimensions. Some technologies emerge clearly and are core in the papers' analysis, while others are deduced from the authors' considerations. Table 3 presents the analysis results, ordering the enabling technologies by frequency.

Furthermore, for the purposes of the analysis, the enabling technologies were combined with the identified managerial behaviours to assess the extent of support for well-being. Again, the enabling technologies were listed according to frequency. Table 4 shows the results.

4. Discussion

This discussion interprets the findings through a socio-technical and human-centric management perspective. Rather than treating managerial behaviours and enabling technologies as separate drivers, the results are theorised as interdependent elements within an I5.0 logic, where value creation is reoriented from productivity maximisation towards multidimensional worker well-being.

4.1. Managerial behaviours stimulating the emergence of well-being in I5.0

The thematic analysis of thirty-one scholarly contributions has revealed the main theoretical and practical directions that define the transition from I4.0 to I5.0, with a specific focus on the harmonious integration of advanced technologies and human centrality (Galván-Vela et al., 2021; Chin, 2021; Gamberini and Pluchino, 2024). The findings indicate a conceptual shift in industrial innovation logics, from a technology-centred efficiency paradigm characteristic of I4.0 towards a socio-technical and human-centric orientation aligned with I5.0.

Table 4
– Enabling technologies in managerial behaviour.

	Paper	Theme/managerial behaviour	Enabling technologies per theme
	5–20–30-31	**Human centric**	AI Cobots Simulation Modelling Cobots
	2–23–24-31	**Emotional intelligence**	AI LLMs Cobots Virtual Simulation Human Digital Twin DHM Tool
	3–14–17-22-27-28-29	**Scheduling optimization**	Simulation Modelling KBIS Cobots
	4–7–11-12-21–25	**Human Robot collaboration**	AI AGVs Exoskletons PTR
	6–13–26-31	**Psychological well-being**	Cobots Sensors Cobots Digital Twin Exoskeletons
DATA SET	8–15–16-30	**Resilience Sustainability**	AI

Source: authors' elaboration.

Rather than positioning advanced technologies primarily as instruments for automation and productivity optimisation, the reviewed literature frames them as enabling resources that support human capabilities, decision-making, and well-being. Within this perspective, technologies such as AI, robotics, and digital systems are not conceived as substitutes for human labour, but as complementary elements that enhance physical, cognitive, and psychological dimensions of work (Chin, 2021). This reorientation underscores the central role of managerial behaviour in shaping how technologies are designed, implemented, and governed to foster sustainable and human-centred organisational outcomes.

Robots, AI systems, and smart factories are designed not merely to optimise production, but to care for the physical, emotional, and cognitive well-being of the people who use them (Chin, 2021; Gamberini and Pluchino, 2024).

Emotional intelligence and soft skills are no longer considered optional; they are essential strategic assets (Chin, 2021). Workers are not seen as mechanical cogs but as complex, emotional, and adaptable beings whose mental health, motivation, and creativity drive sustainable success (Chin, 2021; Narvaez Rojaset al., 2021; Salvadorinho et al., 2025). The collaboration between humans and robots (Human-Robot Collaboration) is being reimagined. Humans should no longer be forced to adapt unnaturally to machines. The automation must be designed to support human capabilities, needs and values, rather than imposing artificial rhythms, logic or behaviours. In this sense, machines must adapt to human cognition, ergonomics, and complexity, rather than the other way around. Instead, robots must learn to communicate, cooperate, and grow alongside their human colleagues, with ergonomics, cognitive load, and user trust guiding every design decision (Lind et al., 2024). In fact, the first and foremost, the theme of human-centricity emerges as a transversal axis, redefining industrial progress not merely in technological terms, but as a synthesis of productivity, sustainability, and individual well-being (Galván-Vela et al., 2021; Grosse et al., 2023; Gamberini and Pluchino, 2024). Within this framework, emotional intelligence and soft skills are critical dimensions for managing change, fostering trust in intelligent systems, and building resilient, collaborative environments (Chin, 2021; Salvadorinho et al., 2025).

The reviewed literature emphasises the need to promote inclusive and empathetic leadership models capable of translating technological innovation into social value. A second core thematic area is that of human-robot collaboration, which plays a strategic role in the design of flexible and adaptive production spaces (Lind et al., 2024). The deployment of Cobots is particularly suitable for variable and complex environments, while traditional robots retain their value in highly standardised tasks. The studies reviewed advocate for new ergonomic, cognitive, and perceptual paradigms that enable safe and synergistic coexistence between humans and machines (Lind et al., 2024). In support of this, there is increasing interest in cognitive ergonomics and preventive design, leveraging digital human models and advanced simulations (Lind et al., 2024). The theme of occupational stress and psychophysical well-being recurs frequently and is treated not only as a risk factor, but also as a crucial metric for guiding the design of socio-technical systems. Stress is acknowledged as a silent enemy in modern production environments. Researchers advocate for workplaces in which stress indicators are continuously monitored—not to push workers harder, but to redesign environments in which people can thrive, remain safe, and feel valued. Finally, the macro-themes of resilience, sustainability, and process optimisation show a methodological convergence towards the use of bio-inspired algorithms and tools such as digital twins, which allow for the proactive identification of design issues by integrating spatial, performance, and ergonomic constraints.

In particular, the concept of sustainability itself is confirmed as expanded beyond environmental metrics. It is confirmed that the central social sustainability concept is creating factories, warehouses, and supply chains in which workers are resilient, included, continuously learning, and emotionally connected to their work (Galván-Vela et al., 2021). Emerging technologies such as digital twins and simulation-based planning are being implemented not only to optimise efficiency but also to simulate human behaviour, predict impacts on well-being, and ensure that new systems are equitable, inclusive, and improve quality of life (Lind et al., 2024). Practices such as optimised scheduling and adaptive layout planning demonstrate how industrial engineering is evolving into a more holistic discipline—one that considers human variability not as a limitation, but as a strategic asset (Lind et al., 2024). The analysed body of the thematic analysis offers a mature and multi-faceted emerging vision of I 5.0 as an ecosystem in which technology and humanity co-evolve.

4.2. Enabling technologies in I5.0 supporting managerial behaviours well-being oriented

Since the beginning of time, human beings have developed and used technology characterised by systems and tools with which problems have been solved or with which it has been possible to improve aspects of their daily lives; therefore, technology has contributed to generating well-being. In that sense, the thematic analysis indicates a set of enabling technologies for well-being, operating in different ways (see Table 3). Some papers propose models, protocols and case studies (Apraiz et al., 2023; Grybauskas and Cárdenas-Rubio, 2024; Galván-Vela et al., 2021) that focus on well-being through technologies from the perspective of I5.0; at the same time, others prompt reflection and propose possible application scenarios and hypotheses (Abdous et al., 2025; Gamberini and Pluchino, 2024) for the contribution of enabling technologies to worker well-being. A close and direct connection between technologies and worker well-being is not always identified, and in some cases, there is no reference to specific tools, or there is a general analysis of the concept of technology and innovation from the perspective of well-being in I5.0 (Galván-Vela et al., 2021; Destouet et al., 2023; Passalacqua et al., 2025). The analysis of enabling technologies within the I5.0 framework suggests that their contribution to worker well-being is neither automatic nor technologically deterministic. Instead, technologies such as collaborative robots, artificial

intelligence, and digital twins function as socio-technical enablers whose impact on well-being depends on how they are embedded within managerial practices and organisational contexts. When aligned with human-centric managerial behaviours, these technologies can reduce physical strain, cognitive overload, and psychological stress, while simultaneously enhancing autonomy, safety, and job satisfaction. Conversely, when deployed without a value-oriented managerial logic, the same technologies risk reproducing efficiency-driven dynamics typical of I4.0, with limited or ambiguous well-being outcomes. In this sense, it is possible to argue that, in companies, regardless of the nature and functions of technologies, fostering well-being requires understanding how management integrates and uses these technologies within business processes.

The analysis enabled extrapolation of the technologies and their ranking by reference frequency across the papers, highlighting that some tools, such as Cobots, AI, and the digital twin, exhibit, albeit to a limited extent, significant diffusion and connection with the aim of well-being.

Cobots are linked to well-being primarily because, through collaboration with workers, they enable them to focus on tasks that require decision-making, creativity, problem-solving, and complex dexterity (Mouhib et al., 2024). They are not revolutionary tools, they were already present before I5.0 (Peshkin and Colgate, 1999), but at the same time they allow human to return close to the production process by interacting with creativity and with a focus on the consumer and their desires with the "human touch" which satisfies consumer and worker at the same time (Kralj and Aralica, 2023; Østergaard, 2019). The optimal allocation of resources to which Cobots can contribute is another enabler of well-being, understood as the appropriate placement of workers who can fully express their skills and competencies in a stimulating and naturally productive environment (Nourmohammadi et al., 2022; Gualtieri et al., 2024).

Again, Cobots can support human mental and physical health and enhance job efficiency, safety, and satisfaction, thereby reducing mental and physical stress (Coronado et al., 2022).

This contributes to both physical (improved workloads) and psychological well-being (improved position in the organization and correct role and satisfaction, worker engagement) although it is emphasised that studies and insights are still needed to fully understand the contribution of these technologies to well-being. (Hadi et al., 2023). However, to concretely contribute to well-being, Cobots need to focus critically on the quality of human-machine collaboration (Coronado et al., 2022) by evaluating a broad overview of factors, metrics, and measures used in the robotics community to monitor qualitative aspects of human performance and well-being. Also emphasised is the need to carefully consider cognitive ergonomics to guide human-computer interaction efficiently and to achieve well-being goals (Leng et al., 2022).

AI turns out to be another technology with a connection to well-being. Its use and integration in work contexts provide solid support for workers' activities, contributing to various aspects of physical and psychological well-being (e.g., Chin, 2021; Coronado et al., 2022; Nourmohammadi et al., 2022). The analysis it offers of data, including data related to workers, also enables management optimisation by correctly allocating human resources to functions and thereby increasing satisfaction and performance (Gualtieri et al., 2024). AI is often mentioned together and in support of other technologies, such as Cobots or in general in support of human-machine collaboration (Gamberini and Pluchino, 2024; Gualtieri et al., 2024; Pacheco and Iwaszczenko, 2024), but also together with Virtual Reality, Machine Learning (ML) and additive manufacturing (Narkhede et al., 2025). At the same time is essential to underlined how research highlights not only factors positively associated with the use of AI on worker well-being, but also critical factors to consider and monitor its development such as levels of automation, system reliability, and AI transparency and their impact on workers' psychosocial, cognitive, and behavioural factors (Passalacqua et al., 2025) and also the need for adequate training of staff in the use of technologies (Pacheco and Iwaszczenko, 2024).

Digital Twin and also the Human Digital Twin (Dacre et al., 2024; Omrany et al., 2024; Cutrona et al., 2024) provide a digital representation of anthropometric and physiological characteristics, but also a representation of a person's inner state helping to facilitate the integration of the human workforce with technologies and enable communication, data aggregation and simulation (Cutrona et al., 2024). These technologies can support specific aspects of management, such as the supply chain, by addressing issues related to the social impacts and performance of all actors in the supply chain and by prioritising human well-being in supply chain operations (Dacre et al., 2024).

Numerous other technologies stand out, often being specific and related to a particular aspect of management, production, or worker training. Sensors, Automated Guided Vehicles (AGVs), Exoskeletons, and Pickup and Transport Robots (PTRs) (Apraiz et al., 2023; Ashta et al., 2023; Thylén et al., 2023; Vijayakumar and Sobhani, 2023) enrich the set of technologies by highlighting tools that are more targeted and focused on a specific purpose (human measurements, transportation support, etc.).

Other technological supports entrust the worker's well-being to the worker's training, knowledge and learn, as LLMs - Large Language Models and Knowledge-based intelligent systems (Grybauskas and Cárdenas-Rubio, 2024; Pabolu et al., 2025), again contributing to the creation of an information dataset applicable to other technologies (AI, ML, etc.) for making predictions, organising work and improving performance. For instance, KBIS (Knowledge-based intelligent systems) are proposed to plan the worker's work taking into account the worker's comfortable work duration time (Pabolu et al., 2025). Other authors highlight that training is a fundamental component in supporting workers' well-being in the context of new technologies (e.g., Salvadorinho et al., 2025).

Interestingly, some technologies can be deduced implicitly from the analysis. This is the case of machine learning (ML). ML enables through algorithms and data analysis to identify patterns and models, make predictions, and support decision-making processes. It can contribute to reduced stress and increased safety by customising activities based on performance and physical worker data analyses. Predictive maintenance helps prevent accidents and breakdowns, supports informed decision-making, and leads to more sustainable working environments (Apraiz et al., 2023; Narkhede et al., 2025). In some cases, (Gamberini and Pluchino, 2024) ML is implicitly inferred/linked to other technologies (i.e. AI, Cobots) helpful in supporting well-being, thus representing an infrastructural aspect that enables the processing of data from different inputs, for example, used in the Sustainable Flexible Scheduling Problem or with the Covariance-Based Structural Equation Method (Destouet et al., 2023; Galván-Vela et al., 2021). Also fundamental is the concept of customising activities, processes, and tasks through the study of data and predictions (Galván-Vela et al., 2021).

Overall, it is clear how many technologies are related to well-being within an integrated, interoperable framework. Consider, for example, the close connection between Cobots, AI (Chin, 2021; Narkhede et al., 2025; Gamberini and Pluchino, 2024). It therefore appears necessary to think not only about a specific tool but about a basic technological architecture that, by integrating various enabling technologies, depending on the sector, scope, characteristics of the enterprise and work organization, enables the achievement of well-being. Narkhede et al. (2025) also mention additional technologies that, when combined, enable the creation of a safer working environment for workers, such as Virtual and Augmented Reality, Additive manufacturing, and industrial robots. So, well-being that can be supported in various ways by the different enabling technologies identified reflects the other dimensions that characterise it. Indeed, some of the technologies focus on physical well-being (i.e. Leng et al., 2022; Apraiz et al., 2023; Ashta et al., 2023; Blandino, 2023; Thylén et al., 2023; Vijayakumar and Sobhani, 2023), some on psychological well-being (i.e. Pabolu et al., 2025; Passalacqua et al., 2025), some on relational well-being (i.e. Gualtieri et al., 2024;

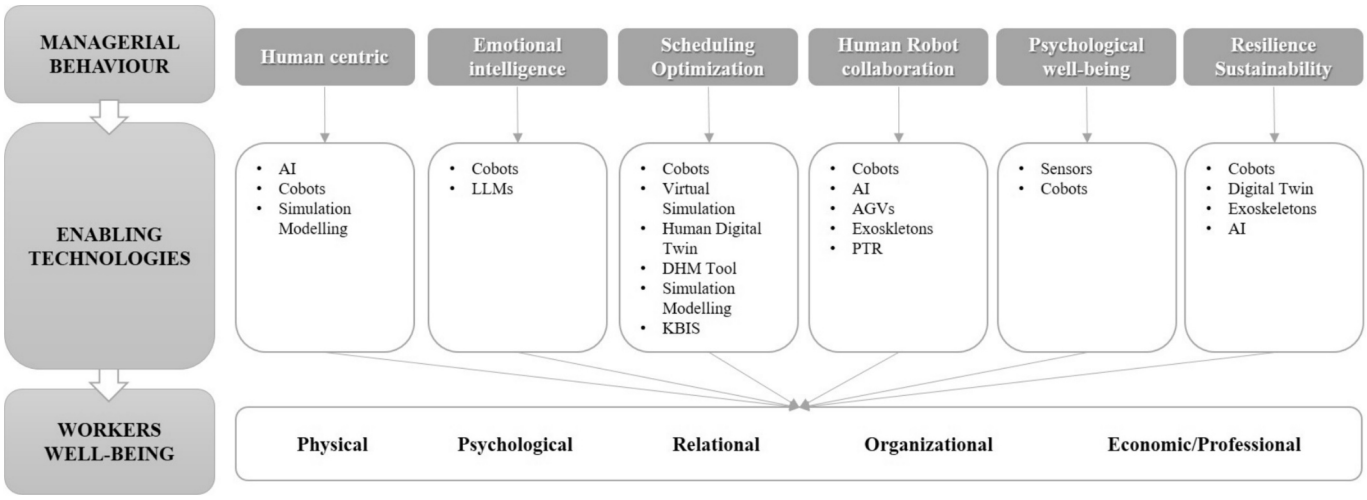

Fig. 2. – Comprehensive view of the analysis
Source: author's elaboration.

Ojstersek et al., 2024) others on organisational well-being (i.e. Nourmohammadi et al., 2022; Mouhib et al., 2024) and finally also on the economic and professional advancement aspect (i.e. Salvadorinho et al., 2025; Grybauskas and Cárdenas-Rubio, 2024). Often, however, these contributions overlap, just look at the case of Cobots, ML and AI that combine positive impacts on different aspects of well-being (i.e. physical, psychological, relational and also organisational well-being).

4.3. *Integrating managerial behaviours and enabling technologies*

Finally, the analysis that intertwines managerial behaviours with the emerging enabling technologies is interesting (see Table 4). As shown by the results, some technologies support the various themes identified, contributing more or less directly to the concept of well-being.

Some managerial behaviours instead denote a link with some specific technologies. For example, the theme of "Emotional Intelligence" posits that LLM technologies directly linked to skills and staff growth are the driving force of well-being (Grybauskas and Cárdenas-Rubio, 2024). Or again, in the theme "Human Robot collaboration" there are not only Cobots that can be considered as the highest level of interaction, but also simpler technologies such as AGVs and PTRs that highlight a simpler and less refined level of collaboration from the point of view of complexity of interaction, but at the same time functional to support the well-being of workers in the firms (Thylén et al., 2023; Vijayakumar and Sobhani, 2023). Therefore, the combined analysis of managerial behaviour and enabling technologies indicates that different managerial perspectives and technological complexities are applicable and achievable across contexts, from large to small, and in more or less technologically advanced contexts. The analysis of the technologies that have emerged, in some cases linked to the previous industrial revolution I4.0, leads us to think that companies that have already followed and internalised this innovative wave can more simply orient themselves to the new I5.0 framework and push towards an innovative, resilient, sustainable upgrade based on the centrality of human/worker. At the same time, given the range of managerial behaviours and the numerous technologies that vary in complexity and cost of application, the possibility that neophytes and SMEs can initiate innovative I5.0 processes cannot be excluded.

In summary, Fig. 2 shows the results in a comprehensive view, highlighting how the various managerial behaviours and combinations of technologies adopted can more or less directly and in different ways contribute to supporting companies in the I5.0 transition to worker well-being.

Fig. 2 constitutes the core analytical framework of this study. It provides a synthetic yet systematic representation of I5.0 by integrating, in a vertical reading (left column), its foundational pillars—managerial behaviour, enabling technologies, and workers' well-being—and, in a horizontal reading, the socio-technical interactions through which these elements jointly shape organisational outcomes.

For analytical clarity, each pillar is decomposed into a finite set of typologies. Specifically, managerial behaviour is articulated into six ideal-typical configurations, each associated with corresponding technological enablers. This categorisation reflects a theoretical abstraction necessary to capture the dominant patterns emerging from the literature review. In empirical organisational settings, these dimensions are inherently interdependent and co-evolving, making the isolation of their individual effects on firm performance analytically challenging.

Consistent with the human-centric orientation underpinning I5.0 as articulated in recent European policy discourse, the framework positions workers' well-being as the ultimate outcome of socio-technical configuration. Accordingly, Fig. 2 identifies five interrelated dimensions of workers' well-being—physical, psychological, relational, organisational, and professional–economic—which collectively characterise the nature and quality of well-being generated within I5.0-oriented organisations. While these dimensions represent broad analytical categories, their salience varies with managerial styles, workers' subjective interpretations of well-being, and the competitive and institutional contexts in which firms operate. Importantly, although enabling technologies may be increasingly standardised and accessible across firms—conditional on capital availability—the human-centric dimension exerts a disproportionate influence on I5.0 outcomes. Empirically and conceptually, the framework suggests that approximately two-thirds of the explanatory power in determining I5.0 effects resides in human and managerial factors rather than in technology per se. By conceptualising I5.0 as a socio-technical system, the framework emphasises that both upstream (managerial decision-making and value orientation) and downstream (perceived and experienced well-being) outcomes are fundamentally shaped by human agency, interpretation, and governance choices. Consequently, the organisational impacts of I5.0 should not be understood as technologically determined, but rather as human-centric, value-laden, and context-dependent.

Overall, the findings suggest that I5.0 can be theoretically understood as a managerial paradigm in which well-being becomes a strategic outcome of socio-technical alignment. This study extends existing I5.0 research by demonstrating that positive well-being outcomes are not inherent to technologies themselves, but emerge from their integration with value-oriented managerial behaviours.

5. Implications

5.1. Theoretical contributions

This article contributes to the literature on I5.0 and the future of work by promoting a socio-technical perspective that explicitly links managerial behaviours and enabling technologies to the multidimensional well-being of workers. Indeed, the paper offers an innovative theoretical contribution to the literature on I5.0 by identifying and integrating managerial behaviours and enabling technologies as joint antecedents of worker well-being in five complementary dimensions: physical (PH), psychological (PS), organisational (ORG), economic/professional (EC/PR) and relational (REL). Systematic and thematic analysis enables the identification of virtuous managerial behaviour oriented towards various human-centred objectives characteristic of the new industrial revolution. At the same time, managerial behaviour can be actively supported by enabling technologies (new, recent, and more innovative) that, at different levels and with varying degrees of complexity and integration, can contribute to discussions of the various dimensions of worker well-being. In this way, the document shifts the focus from technology as an isolated driver of performance to technology as a socio-technical enabler of multidimensional well-being, mediated by managerial action. The proposed analysis contributes to the theory by clarifying the managerial behaviours through which I5.0 can promote the sustainable well-being of workers, emphasising that positive outcomes are not inherent in the technologies themselves but emerge from the alignment between technological design, managerial behaviours and human values. This integration fills a critical gap in the literature and provides a basis for future empirical research at the intersection of I5.0, management studies and workplace well-being. In fact, as highlighted in the introduction, there is no trace in management literature of any contribution linking managerial behaviour to technologies from the perspective of worker well-being. Studies analyse the issues separately, focusing more on productivity impacts than on well-being, and remain oriented more towards I4.0 than I5.0 (Antonaci et al., 2024; Kuru, 2023; ter Haar, 2024).

This systemic view can be useful for stimulating scientific debate and research from different perspectives. From the perspective of management and organisational studies, evidence can help improve the concept of workplace well-being, including by introducing new variables and new ways of thinking about worker well-being, enabled by technology. The study of managerial behaviour can also inform further exploration of leadership as an additional tool for promoting well-being. The joint analysis of I5.0 and enabling technologies in the implementation of managerial behaviour and the establishment of leadership can be instrumental in developing a concrete, human-centred management model that is useful for achieving well-being.

At the theoretical level, the precise combination of technologies with dimensions of well-being and their concrete contributions can support a new vision and definition of enabling technologies. Redefining their contribution not only in technical, operational and production efficiency terms, but also as useful tools (if properly integrated and managed) to support engagement, inclusion and the creation of a stimulating and empathetic working environment. Therefore, the analysis can inform the implementation and updating of existing models in human resource management and human-technology interaction, as well as the development of new theoretical models of leadership and its impact on worker well-being.

5.2. Practical implications

From a practical and managerial perspective, the research has several implications. The first is the confirmed need for companies to focus on managerial behaviours that can create value for all stakeholders, particularly for workers and, consequently, for the society in which the company adopting the I5.0 perspective is integrated (Mahajan et al., 2023). Therefore, the results of this study advise managers to consider well-being as the ultimate goal of adopting I5.0 technologies, alongside the pursuit of sustainability and the strengthening of organisational activities, with a view to a resilient approach to markets. By working in this direction, with managerial behaviours and enabling technologies that support not only management but also workers, it is possible to create fertile ground for promoting well-being and a more people-centred work environment. Underlying this scenario should be a strong corporate culture oriented towards I5.0 principles. The dictates of the new framework must be internalised and strongly desired by management, rather than seen as a trend or a necessary orientation to keep pace with developments. There must be a strong motivational drive, because I5.0 represents a real turning point in the use of technology to serve people and their needs. This can be achieved, on the one hand, by reorganising the company according to business models geared towards well-being and instilling in workers an awareness of their uniqueness and their fundamental role, without which the machine merely performs repetitive tasks but does not evolve and does not create value for the consumer and for the company itself. On the other hand, it is necessary to systematically adopt technologies in the I5.0 perspective to support the various dimensions of well-being. Therefore, it appears essential to study and develop business models that combine and integrate various innovative tools with workers. Practical implications are also reflected in a macroeconomic perspective, in which institutions and policymakers can support the transition by promoting the diffusion of work environments oriented towards well-being. These subjects can concretely support the spread of technologies aligned with the principles of I5.0, through contributions, financial support, and, not least, knowledge and expertise. Therefore, the transition must be guided by the same promoters, who possess a broad and specific set of tools, resources, and skills that enable them to address and overcome the diverse and often complex challenges inherent in a transition between two revolutions. Hence, by also considering practical opportunities for small- and medium-sized firms, a key insight from this study is that I5.0 is not reserved for highly digitised or tech-driven companies. On the contrary, many of the managerial practices and technologies discussed here can be adapted to the context of smaller firms or those in earlier stages of digital transformation. This opens the possibility of more inclusive forms of innovation, in which well-being becomes a concrete objective for businesses of all sizes. This study highlights several important implications for businesses, companies, institutions, and researchers seeking to navigate the transition from I4.0 to I5.0. While technologies remain central, our findings suggest that the fundamental transformation lies in how these tools are embedded in organisational cultures and managerial practices—especially in prioritising human well-being.

6. Conclusion

This study contributes to the ongoing debate on I5.0 by offering a theoretically grounded synthesis of how managerial behaviours and enabling technologies jointly shape well-being within socio-technical systems. Building on a systematic literature review and thematic analysis, the findings clarify that well-being is not an automatic outcome of technological advancement, but rather the result of a deliberate alignment between value-oriented managerial practices and human-centric technological design. By reframing well-being as a central managerial objective rather than a secondary technological effect, the study supports the theoretical maturation of I5.0 within management and organization studies. Our findings suggest that the transition from I4.0 to I5.0 should not be merely a technological leap but a, more profound cultural and strategic shift—one that reframes innovation around human needs, ethical responsibility, and sustainable growth. This identified condition enables us to assign an essential role to managerial behaviour in companies' orientation towards I5.0 and in the centrality of people in processes that generate well-being for workers. Well-being can be characterised in terms of physical, psychological, economic, and

organisational dimensions. In I5.0, managerial behaviours supported by enabling technologies generate forms of well-being, including reduced organisational complexity, increased emotional well-being, reduced physical fatigue, improved mental and psychophysical health, reduced emotional burden and stress from complex and excessively dynamic environments, and reduced frustration and burnout (Coronado et al., 2022). I5.0 thus emerges as a promising framework for enhancing worker well-being, yet its effective implementation depends critically on the workforce's skills and competencies. To ensure that workers can appropriately manage and integrate advanced technologies into their daily activities, the transition towards I 5.0 must be guided by targeted training programs and the development of specific knowledge domains. Such capacity-building efforts enable employees to fully leverage the potential of enabling technologies, thereby fostering well-being-oriented process management and promoting a more human-centric approach to technological innovation (Pacheco and Iwaszczenko, 2024; Campolucci et al., 2024). Hence, education and training could, over time, contribute to explaining in a comprehensible and sustainable way the role of I5.0 in the company, in the working lives of employees, and in the value that the company could generate overall (Carayannis and Morawska, 2023; Mukherjee et al., 2023; Ikenga and van der Sijde, 2024).

With I5.0, humans return to the centre of value creation and business management, and this approach must enhance all their characteristics, especially the most human ones (Golovianko et al., 2025; Pacheco and Iwaszczenko, 2024; Gamberini and Pluchino, 2024). In this context, enabling technologies support and sustain humans by contributing to their well-being and, indirectly, support business productivity. This is how modern competitiveness could be achieved. The correct sequence for value creation and competitiveness begins with human well-being, proceeds to productivity, and culminates in a competitive business edge.

7. Future research directions

If technologies can promote well-being and managerial behaviours can give meaning to the use of technologies within the logic of I5.0, leading companies towards a virtuous competitive advantage grounded in social responsibility and human-centred development strategies, then future research can certainly involve several themes and aspects.

Future research steps may focus primarily on studies that directly analyse workers (micro perspective), the skills they need to achieve proper human-machine integration, and the need to correctly and quantitatively measure the results of technologies in terms of well-being. Another level of analysis is that of companies (meso perspective), to deepen the study of managerial behaviour, the different dimensions and the training processes necessary to implement the transition and achieve the possible results are examined. A final level of study (macro perspective) can be oriented towards society as a whole and to specific sectors.

From a micro perspective, future studies should place well-being at the core of their investigations, bridging the gap between companies' declarations of intent and their actual impact on workers. Enabling technologies should be explored within a value-driven company context, assessing how they can be designed and used to promote human well-being. This calls for continued measurement and evaluation of I5.0 technological enablers in companies, alongside an analysis of the direct and indirect effects of their specific deployment to foster well-being. It is necessary to thoroughly study and implement the integration of psychophysiological and biometric measures in order to assess the impact on workers and various aspects of well-being in concrete terms, rather than just qualitatively.

From a meso perspective, the transition to I5.0 requires a new approach to training within companies. Research should not be limited to calling for “training”, but should aim to codify a reverse training framework that starts from well-being recovery emergencies, is aligned with the company's perspectives and objectives to be pursued according to appropriate managerial behaviours, and, finally, allows the acquisition of the proper knowledge to use appropriate technologies to achieve the I5.0 objectives. Particular attention should be paid to small-medium enterprises (SMEs), where learning processes are often informal, and resources are limited. Action research studies are needed to identify upskilling and reskilling methodologies that are not merely technical, but that promote a change in the mindset of workers, making them active protagonists in the design of technological processes rather than mere users. Furthermore, studies and in-depth analyses are needed to support managers in developing appropriate practices, business models, and leadership styles that enable comprehensive organisational change.

Further research is needed to investigate the direct and indirect impact that an advanced implementation of I5.0 in businesses would have on society (macro perspective) and on communities directly connected to businesses as they begin to think about technologies differently. It will be interesting to measure the impact on local communities and culture when we analyse cases in which businesses shift their focus from a logic in which technology serves efficiency and profit to a more social logic in which technology must be designed and implemented to promote the well-being of company employees. In a certain sense, we can hypothesise a societal improvement that begins with businesses adopting a different value paradigm. If this generates positive effects on company workers, these effects could directly impact the social realities connected to them, generating positive externalities that could, over time, be transferred to other businesses and possibly even to local governance. These mechanisms of impact transfer would enable research to transcend the confines of business management and also extend to local communities, place marketing, and place management. For example, comparative studies across companies of different sizes, sectors, and geographies could help identify limitations, opportunities, and contextual factors that influence the effective implementation of Society 5.0. Research could develop econometric models that include human capital and social well-being as endogenous variables in corporate productivity models. In this sense, the foundations for studying the broader concept of Society 5.0 are laid. For Society 5.0 to go beyond a purely conceptual slogan, it may be helpful to recognise and value the efforts of companies that adopt human-centered approaches and develop products and services that improve well-being at both the organisational and societal levels. International comparative studies will be essential to understand how different institutional and regulatory contexts can accelerate or hinder this systemic transition.

CRediT authorship contribution statement

Michela Piccarozzi: Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Federica Caboni:** Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Roberto Bruni:** Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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