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Strategic competency development for Industry 5.0 leaders: perspectives from the manufacturing sector

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A B S T R A C T

This paper aims to identify and define key leadership competencies required for Industry 5.0 in the manufacturing sector, emphasising the integration of advanced technologies with human-centric and sustainability values across different organisational levels.

A two-round Delphi study was conducted with 30 manufacturing experts from multiple priority sub-sectors in Indonesia. Quantitative consensus was assessed using median ≥ 4.0 and IQR ≤ 1.0, complemented by Kendall's W to measure agreement strength.

The study generated a comprehensive Industry 5.0 Leadership Competency Framework consisting of five core dimensions: technical mastery, strategic leadership, people management, business acumen, and sustainability, supported by 24 validated competencies prioritised across senior, middle, and entry-level leadership roles.

This study advances leadership theory by proposing a multilevel (macro-meso-micro) human-centric leadership model that integrates sustainability and ethical technological implementation, addressing a missing linkage in current Industry 5.0 literature.

The framework guides manufacturing organisations in designing tiered leadership development pathways, performance evaluation instruments, and succession strategies aligned with Industry 5.0 transformation and sustainable operational excellence.

K E Y   W O R D S

Industry 5.0, manufacturing leadership, competency framework, Delphi study, sustainable transformation

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Introduction

Industry 5.0 represents a major step forward in the development of interventions compared to Industry 4.0, which focuses on the sustainability of economic progress alongside novelty, toughness, and humanistic solutions. Compared to Industry 4.0, which was mainly concerned with the digital evolution and automation, Industry 5.0 is a more proportional approach to human potential and smarter technologies (Ghobakhloo et al., 2023). The change would require a drastic modification in manufacturing processes, especially in how organisations are

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leading towards leadership development and competency development. According to Suciu et al. (2023), core competencies should be carefully considered in this transition to achieve sustainable and resilient development in the manufacturing conditions. In the digital age, the role of leadership competencies has become even more significant, especially in the context of the continuously growing complexity of available technologies, technological environments, and ecosystems, which require a high-level mix of technical, strategic, and people-oriented skills (Kwiotkowska et al., 2021).

Modern challenges in manufacturing leadership are connected to the need to unite technological progress with a focus on people and sustainability. Shet et al. (2021) listed 14 key managerial competencies for qualified leaders who demonstrate effective leadership skills in this dynamic environment. Kipper et al. (2021) identified competencies such as strategic vision, self-organisation, proactivity, and interdisciplinary thinking as essential leadership requirements in a digitalised manufacturing environment. The post-COVID-19 environment has exacerbated these difficulties, as much more attention has been paid to relationship development and employee wellbeing (Majczyk et al., 2022). Also, manufacturing leaders must address competency gaps in strategic perspective and digital transformation, and ensure operational excellence (Kwiotkowska et al., 2022).

Past studies have outlined competence requirements for manufacturing practices across different areas, but fail to integrate humanistic and sustainability issues, which are the focus of Industry 5.0. Gudanowska et al. (2018) suggested that competencies in the production industry are defined locally, whereas Grzybowska and Lupicka (2017) indicated the requirements of Industry 4.0 without envisioning the anthropomorphic gears of Industry 5.0. Likewise, Singh et al. (2014) focused on listing competencies that influence industrial competitiveness and omitted the sustainability aspects of manufacturing strategy that determine it. Although Schinner (2022) examined competency management in manufacturing and Dahl et al. (2023) examined future competency learning methods, the two papers do not include the integrative thinking needed to support a sense of participation in a human-AI setting. Wickramaratne et al. (2014) examined entrepreneurial competencies, but did not consider the ability to build resilience, a new requirement in the work environments of Industry 5.0.

The lack of a complex, definite competency model for Industry 5.0 manufacturing leadership is a major challenge for organisational development. It has been found that manufacturing leaders may lack the integrated abilities required for effective navigation in the world of technological development and humanised approaches (Ghobakhloo et al., 2023). The research by Kwiotkowska et al. (2022) found that more than 60 per cent of manufacturing industry companies reported a significant lack of competencies in strategic perspectives and digital transformation skills. This inconsistency is especially pronounced in sustainability leadership and stakeholder involvement, where traditional manufacturing leadership is not sufficient. Almost every seventh manufacturing organisation is facing ineffective leadership in digital transformation, and the main reason is insufficient competency development frameworks (Kwiotkowska et al., 2021).

The combination of technological progress and humanistic leadership tendencies offers special prospects of institutional reconstruction and new invention. A report shows that the new manufacturing leaders should attain skills beyond the technical experience and understanding, including emotional intelligence and advanced thinking (Bianco et al., 2023). Companies that use integrated leadership development models in their operations achieve higher performance and become more innovative. Current studies indicate that adaptive leadership characteristics are crucial for swift responses to technological change and market conditions (Kaur & Anand, 2022). This research gap underlines the requirements for a framework that combines technological expertise and humanistic proficiency, alongside sustainability principles that drive transformations beyond the Industry 4.0 era. Such a structure would accommodate the needs of the present and the demands of future manufacturing leadership under Industry 5.0, allowing organisations to achieve sustainable change without losing operational excellence.

1. Literature review

1.1. Evolution from Industry 4.0 to Industry 5.0

The adoption of Industry 5.0 brings a major change from Industry 4.0, focusing on human-centric practices. Industry 5.0 is a radical shift in the Industry

4.0 paradigm, which is largely focused on technology-based solutions towards a more balanced integration of human capability with high-tech technologies. Whereas Industry 4.0 was all about digitalisation, automation, and cyber-physical systems, Industry 5.0 centres on three major pillars: sustainability, resilience, and human-centricity (Ghobakhloo et al., 2023; Lagorio et al., 2022). This development is an admission that the use of technology is no longer a comprehensive solution to difficult industrial problems; hence, an additional element should be incorporated in the change, i.e., viewing human resources in terms of creativity, ethical practices, and respect for the environment, to effectively effect the change. Industry 5.0 is characterised by distinctive features of collaborative human-machine activities, regenerative production systems, circular-economy practises, and value-driven technological implementations that place particular stress on human wellbeing and the environment (Oeij et al., 2024; Poszytek et al., 2023; Giedraiti & Stašys, 2019). As a result, manufacturing grounds need to find a balance between high-tech and high-touch, or create an environment or a setting where technology does not substitute for human capabilities but rather supplements them (Pinto et al., 2024; Tschiedel et al., 2025; Sahban, 2019). There is also a need for new leadership practices that incorporate technical knowledge and awareness alongside emotional intelligence and moral decision-making (Kipper et al., 2021; Shet et al., 2021). Moreover, it is necessary to implement sustainability measures in their manufacturing, in addition to implementing performance measures, to stress the responsible use of resources and reduce environmental burdens (Suciu et al., 2023). These changes require rethinking competency frameworks alongside human-oriented, sustainable manufacturing conditions, as the future of the industry would presuppose in Industry 5.0.

The development of Industry 4.0 to 5.0, as presented in Fig. 1, shifts industrial systems to a human-centred, sustainable, and resilient model. Whereas Industry 4.0 was mainly concerned with the digitalisation and the efficiency of industries with the help of such inventions as the Internet-of-Things (IoT),

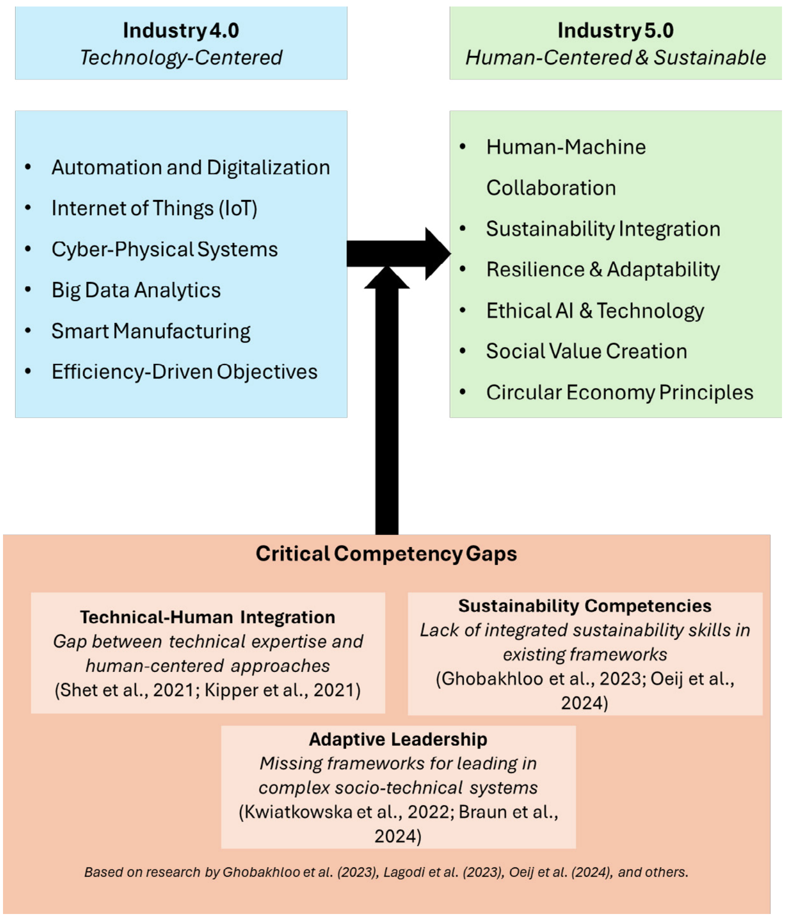

Fig. 1. Evolution from Industry 4.0 to Industry 5.0 and competency gaps

Cyber-Physical Systems, and Big Data Analytics, Industry 5.0 would continue these concerns, but with a new area of focus, which would be the collaboration between the human and the machine, integration with sustainability, and adaptation simplicity and robustness (Ghobakhloo et al., 2023; Oeij et al., 2024). Moreover, Fig. 1 shows the essential competency gap caused by this transition. To begin with, technical-human integration skills are needed to fill the gap between humanistic strategies and technical knowledge (Kipper et al., 2021; Shet et al., 2021). Second, sustainability competencies should be integrated into the line of operations to incorporate responsible and ethical production (Ghobakhloo et al., 2023; Oeij et al., 2024). Third, the skills of adaptive leadership become increasingly relevant while navigating through the social-technical interactions that complicate Industry 5.0 media (Braun & Clarke, 2006; Kwiatkowska et al., 2022). It is essential to address these competency gaps to take a step towards creating future manufacturing ecosystems where advanced technologies enable human creativity and foster environmental protection.

1.2. Gaps in existing competency frameworks

Though substantial progress has been made in determining the competencies needed for Industry 4.0, the move to Industry 5.0 identifies gaps beyond the scope of current frameworks. As Table 1 shows, most earlier frameworks have focused on digitalisation, automation, and technical expertise and have failed to incorporate a human angle, sustainability, and resilience (Ghobakhloo et al., 2023; Lagorio et al., 2022; Poszytek et al., 2023). The transition from Industry 4.0 to Industry 5.0 requires a reorientation of competency frameworks to incorporate human-machine collaboration, ethical decision-making, sustainability integration, and adaptability in complex socio-technical systems. Technical competencies identified for Industry 4.0 - such as operating emerging technologies and digital adaptability - lack the necessary connection to human skills, such as emotional intelligence, workplace wellbeing, and ethical technology use (Grzybowska & Łupicka, 2017; Oh et al., 2024; Singh et al., 2014).

Similarly, while the importance of soft skills and leadership has been acknowledged in earlier research, existing models often fall short in designing competencies for human-AI collaboration, systematic integration of sustainability principles, and development of circular economy capabilities (Pinto et al., 2024; Shet et al., 2021; Ward et al., 2025). Current training and development methodologies remain predominantly conventional, relying on formal learning approaches without sufficient emphasis on adaptive, personalised learning and continuous competency development pathways (Braun & Clarke, 2006; Kutty Mammi & Ithnin, 2012; Peláez-Sánchez et al., 2024). In addition, implementation and measurement strategies remain highly qualification-oriented, where dynamic evaluation systems and situational adjustments are much needed in an Industry 5.0 surrounding (Dahl et al., 2023; Kipper et al., 2021; Kwiotkowska et al., 2022). In a broader sense, numerous frameworks are confined to a particular part, lacking an integrated approach to managing socio-technical systems productively (Bianco et al., 2023; Schinner, 2022; Suciu et al., 2023). Moreover, organisational readiness strategies are usually related to reactive or one-dimensional interventions, rather than proactive, changeable transformation patterns corresponding to the competency maturity demands of Industry 5.0 (Gudanowska et al., 2018; Kaur & Anand, 2022; Majczyk et al., 2022).

On the whole, an integrated competency framework is greatly needed to close a significant gap between industrial demands and the disjointed current methods. This kind of framework would have to integrate technical, human-centric, sustainability, and strategic aspects into a single model that can be used to drive leadership and the workforce, in the future, in the age of Industry 5.0. Until these gaps are closed, manufacturing organisations face significant difficulties in continuing with innovation, operational excellence, and resilience in a world that is increasingly complex and dynamic.

2. Research methods

2.1. Research design

The research used a modified Delphi technique to build expert consensus regarding leadership competencies needed for Industry 5.0 in the Indonesian manufacturing sector. Delphi is particularly effective when the aim is to synthesise specialised knowledge in emerging topics with limited empirical grounding (Hasson et al., 2000). A total of 30 experts from diverse sub-sectors participated in two iterative rounds of rating and refinement. The authors' institution granted ethical approval, and informed consent

Tab. 1. Identified gaps in existing competency frameworks for Industry 5.0 transition

KNOWLEDGE DIMENSION	WHAT EXISTS	GAPS IDENTIFIED	KEY REFERENCES
Industry evolution from 4.0 to 5.0	Focus on digitalisation and automation	Lack of integration of human-centric approaches	Ghobakhloo et al. (2023)
	Competency frameworks for Industry 4.0	Unclear mapping of transition from 4.0 to 5.0	Lagorio et al. (2022)
	Emphasis on technology	Sustainability principles not fully embedded	Poszytek et al. (2023)
Technical competencies	Identification of specific technical skills	Integration with human skills	Grzybowska and Łupicka (2017)
	Expertise in operating technology	Human-machine collaboration	Singh et al. (2014)
	Technical adaptability	Ethical awareness in technology use	Oh et al. (2024)
Human-centric approaches	Importance of soft skills	Design of human-AI collaboration	Shet et al. (2021)
	Interpersonal competencies	Workplace wellbeing competencies	Pinto et al. (2024)
	Basic leadership skills	Ethical decision-making skills	Ward et al. (2025)
Sustainability and resilience	Some sustainability aspects identified	Systematic integration of sustainability in competencies	Tschiedel et al. (2025)
	Focus on resource efficiency	Environmental risk management	Oeij et al. (2024)
	Basic operational resilience	Circular economy competencies	Wickramaratne et al. (2014)
Development methodology	Conventional training models	Adaptive development methodology	Pelaez-Sanchez et al. (2024)
	Formal learning approaches	Personalised learning pathways	Kutty Mammi and Ithnin, 2012
	Competency-based systems	Integration of continuous learning	Braun and Clarke (2006)
Implementation and measurement	Descriptive competency frameworks	Measurable success metrics	Kipper et al. (2021)
	Qualification-based assessment	Dynamic evaluation systems	Kwiotkowska et al. (2022)
	Generic implementation models	Contextual adaptation mechanisms	Dahl et al. (2023)
Multidisciplinary perspective	Focus on single domains	Integrated multidisciplinary frameworks	Suciu et al. (2023)
	Sectoral and siloed approaches	Knowledge synthesis across domains	Schinner (2022)
	Limited cross-disciplinary integration	Socio-technical systems perspective	Bianco et al. (2023)
Organisational readiness strategy	General implementation guidelines	Organisational transformation strategies	Majczyk et al. (2022)
	Focus on individual competencies	Competency maturity models	Kaur and Anand (2022)
	Reactive approach	Proactive and adaptive approaches	Gudanowska et al. (2018)

was obtained from all participants with confidentiality safeguards in place.

Purposeful sampling was used as the data collection method to select participants who had the qualities described and relevant backgrounds to provide diverse and exhaustive views on the research question (Saunders, 2017). The 30 Indonesian manufacturing experts covered a variety of sub-sectors, allowing the study to gain a broad picture of competencies in the industry as opposed to a specific niche. Special consideration was given to the inclusion of experts from manufacturing industries, which are considered the cornerstone of the Indonesian manufacturing ecosystem, such as textile, automotive, electronics, food and beverage, and chemical industries. Details of the companies are given in Table 2.

Table 2 provides an overview of the companies represented in the study, highlighting the diversity of sectors, industrial focus, and production scales in the Indonesian context. The sample includes both private and public/government organisations, reflecting Indonesia's manufacturing landscape where state-

Tab. 2. Manufacturing company information in the Indonesian context

	Frequency	Percentage
Sector		
Private	21	70.00
Public/government	9	30.00
Industrial type		
Heavy manufacturing	18	60.00
Consumer goods	12	40.00
Industrial sector		
Textiles and apparel	6	20.00
Food and beverage	5	16.67
Automotive and transportation	5	16.67
Electronics and components	4	13.33
Chemicals and pharmaceuticals	3	10.00
Metals and machinery	3	10.00
Furniture and wood products	2	6.67
Mining and processing	2	6.67
Production scale		
Large (>1000 employees)	12	40.00
Medium (500-1000 employees)	12	40.00
Small (<500 employees)	6	20.00
Geographic location		
Java	18	60.00
Sumatra	6	20.00
Sulawesi	3	10.00
Kalimantan	2	6.67
Eastern Indonesia	1	3.33

owned enterprises coexist with private companies. The represented sectors span heavy manufacturing and consumer goods, with particular emphasis on priority sectors identified in Indonesia's Making Indonesia 4.0 roadmap, including food and beverage, textiles, automotive, electronics, and chemicals. The range of company sizes - from large-scale operations with over 1,000 employees to smaller enterprises - ensures a comprehensive understanding of leadership competencies across varied manufacturing contexts within Indonesia's industrial ecosystem.

Table 3 summarises key demographic characteristics of the study's participants, including gender, age, educational background, years of experience, and job positions. Participants represent a balanced mix of genders and a broad age range, with most holding advanced degrees in fields such as engineering, business, and technical sciences. The range of experience levels and seniority - from plant managers to senior executives - provides well-rounded insights into the competencies needed for effective leadership in Industry 5.0 within the manufacturing sector.

2.2. Data collection

The Delphi study was conducted in two distinct rounds, each designed to systematically refine and validate leadership competencies required for Industry 5.0 in manufacturing contexts.

2.2.1. Round 1: competency identification and initial rating

The first round focused on identifying and generating a comprehensive list of potential leadership competencies. A questionnaire was developed based on a literature review and theoretical frameworks, including Industry 5.0 principles, Leadership Pipeline theory, and Situational Leadership theory. The questionnaire was structured into five thematic sections,

Tab. 3. Manufacturing company information in the Indonesian context

	FREQUENCY	PERCENTAGE
Gender		
Male	18	60
Female	12	40
Age range		
30-39 years	6	20
40-49 years	12	40
50-59 years	9	30
60+ years	3	10
Education level		
PhD	6	20
Master's	15	50
Bachelor's	9	30
Education background		
Engineering	12	40
Business/management	9	30
Technical sciences	6	20
Other	3	10
Years of manufacturing experience		
10-15	9	30
16-20	12	40
21-25	6	20
>25	3	10
Position		
Senior executive/director	6	20
Operations director	6	20
R&D/technical head	6	20
Quality/safety head	3	10
Government official	3	10
Association head	3	10
Plant manager	3	10

Tab. 4. Delphi questionnaire's thematic sections

SECTION	FOCUS AREAS
I. Respondent background	Professional experience Current roles and responsibilities Exposure to digital transformation and Industry 5.0
II. Understanding of Industry 5.0	Definition and conceptualisation of Industry 5.0 Differences between Industry 4.0 and 5.0 Perceived impact on the manufacturing sector
III. Leadership competencies for Industry 5.0	Identification of critical competencies Differences from previous industrial eras Practical application in daily operations Relevance across leadership levels (entry, middle, and senior)
IV. Challenges and opportunities	Barriers to competency development Organisational strategies for overcoming challenges Emerging opportunities from Industry 5.0 transformation
V. Future vision	Projected evolution of the manufacturing sector Workforce development preparation strategies Long-term competency needs

as shown in Table 4. Participants were asked to identify key competencies they believed essential for effective leadership in Industry 5.0 manufacturing environments and to provide rationales for their selections. Additionally, participants rated the importance of each competency on a 5-point Likert scale (1 = not important, 5 = extremely important) and specified the leadership level (entry, middle, and senior) at which each competency was most critical. The objective of this round was to canvass as many views as possible and advance to the process of consensus-building in the next round.

2.2.2. Round 2: consensus building and final validation

A summary of the results of the first round was anonymised and given to participants in the second round (aggregate ratings and results of qualitative analysis of themes). The prioritisation of the competencies was based on the mean importance ratings given by the participants, and to contextualise it, the individual participants' rationalisations were also provided. Then, participants were invited to see these outcomes and reconsider their ratings based on the group's response. For each competency, participants could retain or modify their previous ratings and were expected to provide a rationale if their ratings differed substantially from the median value. Also, the participants rated the suitable level of leadership for each competency and its applicability across various manufacturing situations. This feedback process enabled quantitative consensus and qualitative development of the findings (Table 4).

2.3. Data analysis

The data analysis strategy was designed to give a quantitative and qualitative understanding of the Delphi findings. Quantitative ratings were subjected to statistical analysis, whereas qualitative responses were analysed using the thematic method.

2.3.1. Quantitative analysis

The Likert scale ratings were statistically analysed to determine the importance of each identified competency. Measures of central tendency (mean and median), measures of dispersion (standard deviation and interquartile range), frequency distributions, and percentage agreement were calculated. Consensus was defined as median ≥ 4.0 (indicating high perceived importance) and IQR ≤ 1.0 (indicating high agreement), with IQR ≤ 0.5 reflecting strong consensus among participants. To evaluate the stability of responses across Delphi rounds, agreement levels between Round 1 and Round 2 were further assessed using Kendall's coefficient of concordance (W) and its significance values (Schmidt, 1997), enabling a more robust measure of inter-expert reliability.

2.3.2. Qualitative analysis

A thematic analysis of the qualitative data collected through open-ended replies was conducted, followed by a six-phase method suggested by Braun and Clarke (2006). Data familiarisation was the first step, which involved reading and re-reading all the responses and taking preliminary notes. Next was the first coding stage, which involved systematically identifying the pertinent features in the responses and coding them. The following step was to code these codes into possible themes in the data. After themes were identified, they were re-examined based on their internal consistency and coherence across the entire dataset. Then, themes were refined and clearly defined, and each theme was assigned a specific name. The report, which contained illustrative examples and provided links between the findings and the research questions, was prepared at the end of the analysis. Interrater reliability was used to enhance the analysis by having two analysts work independently and code a portion of the data. The kappa coefficient devised by Cohen was used to analyse the agreement between the coders, and values greater than 0.75 were considered excellent (Fleiss et al., 2003). Coding inconsistencies were determined and eliminated by agreement.

2.3.3. Integration and framework development

The last step of the analysis entailed synthesising the quantitative consensus ratings with the qualitative thematic outputs to develop a combined competency framework. The integration enabled a multidimensional perception of each competency, including its relative significance, the level of leadership at which it can be applied, its contextual uses, and the relationship with other competencies. This framework clustered the competencies in a rational and logical way depending on the statistical relations as well as the thematic prerequisites to produce an apparent, organised model that reflects not only the consensual priorities of the expert panel but also the context-based nuances identified through qualitative analysis.

3. Research results

The first round of the Delphi study yielded a comprehensive set of leadership competencies considered essential for Industry 5.0 in manufacturing contexts. Table 5 presents the initially identified competencies, their mean importance ratings, and standard deviations. The table also shows the leadership level at which experts believed each competency was most critical.

The qualitative analysis of Round 1 responses revealed several key themes regarding the nature and application of these competencies in manufacturing contexts. Participants emphasised the fundamental shift from technology-centred to human-centred approaches in Industry 5.0, identifying human-machine collaboration as the highest-rated competency (M = 4.82, SD = 0.38). One senior executive commented:

"The essence of Industry 5.0 lies in the harmonious collaboration between humans and technology. Leaders must orchestrate this interaction to maximise both technological capabilities and human creativity".

Sustainability leadership (M = 4.73, SD = 0.45) emerged as another critical competency, reflecting Industry 5.0's emphasis on environmental responsibility. Participants noted that this represented a significant departure from previous industrial paradigms, which focused primarily on efficiency and productivity without necessarily considering environmental impact (Table 6):

"Previous manufacturing approaches treated sustainability as an afterthought or compliance issue. In Industry 5.0, it must be embedded in every decision and process, requiring leaders who can balance economic, social, and environmental objectives".

The results summarised in Table 6 reflect the particular characteristics of the Indonesian manufacturing context. Two additional competencies - cross-cultural management and local resource optimisation - emerged as especially critical, receiving strong consensus ratings from the expert panel. These competencies were not originally emphasised in broader international frameworks but were seen as essential for addressing the cultural diversity and resource variability that characterise Indonesia's industrial landscape. Furthermore, competencies such as supply chain resilience and SME integration capability were highlighted as particularly relevant for Indonesia's manufacturing ecosystem, where supply chain

Tab. 5. Industry 5.0 leadership competencies: Round 1 results

COMPETENCY	MEAN RATING	SD	PRIMARY LEADERSHIP LEVEL
Human-machine collaboration	4.82	0.38	Middle
Digital transformation management	4.76	0.43	Senior
Sustainability leadership	4.73	0.45	Senior
Adaptive decision-making	4.70	0.47	All levels
Systems thinking	4.67	0.48	Middle/senior
Ethical technology deployment	4.63	0.49	Senior
Data-driven leadership	4.60	0.50	Middle/senior
Resilience building	4.57	0.50	All levels
Cross-functional integration	4.53	0.51	Middle
Human-centred design thinking	4.50	0.57	Middle
Technological foresight	4.47	0.57	Senior
Workforce upskilling management	4.43	0.63	Middle
Collaborative innovation	4.40	0.67	All levels
Complexity management	4.37	0.72	Senior
Agile change leadership	4.33	0.76	Middle/senior
Social value creation	4.30	0.79	Senior
Circular economy implementation	4.27	0.83	Senior
Multi-stakeholder engagement	4.23	0.86	Senior
Digital wellbeing facilitation	4.17	0.91	Middle
Cultural intelligence	4.13	0.94	All levels

Tab. 6. Industry 5.0 leadership competencies in Indonesian manufacturing: Round 2 results and consensus indicators

Competency	Round 1 Mean	Round 2 Mean	Change	IQR	Consensus Level*
Human-machine collaboration	4.82	4.9	0.08	0	Strong
Digital transformation management	4.76	4.87	0.11	0	Strong
Sustainability leadership	4.73	4.83	0.1	0	Strong
Adaptive decision-making	4.7	4.8	0.1	0.5	Strong
Cross-cultural management	4.65	4.77	0.12	0.5	Strong
Systems thinking	4.67	4.73	0.06	0.5	Strong
Local resource optimisation	4.61	4.73	0.12	0.5	Strong
Ethical technology deployment	4.63	4.7	0.07	0.5	Strong
Data-driven leadership	4.6	4.67	0.07	1	Moderate
Resilience building	4.57	4.67	0.1	1	Moderate
Human-centred design thinking	4.5	4.63	0.13	1	Moderate
Cross-functional integration	4.53	4.6	0.07	1	Moderate
Technological foresight	4.47	4.57	0.1	1	Moderate
Supply chain resilience	4.43	4.57	0.14	1	Moderate
Workforce upskilling management	4.43	4.53	0.1	1	Moderate
Collaborative innovation	4.4	4.53	0.13	1	Moderate
Agile change leadership	4.33	4.47	0.14	1	Moderate
Complexity management	4.37	4.43	0.06	1.5	Moderate
Social value creation	4.3	4.4	0.1	1.5	Moderate
SME integration capability	4.27	4.37	0.1	1.5	Moderate
Circular economy implementation	4.27	4.33	0.06	1.5	Moderate
Multi-stakeholder engagement	4.23	4.3	0.07	1.5	Moderate
Digital wellbeing facilitation	4.17	4.23	0.06	2	Weak
Cultural intelligence	4.13	4.2	0.07	2	Weak

*Consensus levels: strong (IQR ≤ 0.5), moderate (IQR 0.6-1.5), weak (IQR > 1.5)

vulnerabilities and the importance of small and medium-sized enterprises (SMEs) present unique leadership challenges. These findings underscore the need for localised adaptation of Industry 5.0 leadership frameworks to ensure contextual relevance and operational effectiveness within different national manufacturing environments.

4. Discussion of the results

The transition to Industry 5.0 requires leadership competencies that simultaneously address technological advancement, sustainability integration, and human-centric innovation. As demonstrated in the preceding analysis, Indonesian manufacturing confronts distinctive contextual challenges, including resource variability, workforce diversity, and uneven levels of digital maturity. Accordingly, a structured, multilevel competency framework is essential to support sustainable, resilient transformation across the sector. As one senior leader noted, "The future of Indonesian manufacturing is not just about machines - it is about how well we can orchestrate people, policies, and technologies into a sustainable system".

To strengthen conceptual coherence and enable a better grounding for multilevel analysis, the validated competencies were organised into five overarching dimensions, as summarised in Table 7.

To address this need, the proposed framework adopts a macro-meso-micro structure. At the macro level, the competencies of the leadership will align with the goals of manufacturing ecosystems of the nations, this would be policy alignment, national transformation, and sustainability integration. With the meso level, a concentration on organisational capabilities, that is, on human-technology integration, sustainability practices, and systems-driven innovation is made. Lastly, at the micro level, the framework defines the technical, adaptive and con-

Tab. 7. Mapping of validated competencies into five core dimensions

Dimension	Key validated competencies (examples)
Technical mastery	Human-machine collaboration; digital transformation management; technological foresight
Strategic leadership	Sustainability leadership; systems thinking; complexity management; circular economy implementation
People management	Cross-cultural management; collaborative innovation; cultural intelligence; workforce upskilling management
Business acumen	Data-driven leadership; supply chain resilience; local resource optimisation
Sustainability	Ethical technology deployment; social value creation; multi-stakeholder engagement; digital wellbeing facilitation

textual competencies necessary at various levels of leadership in the firms. The avalanche model of strategic cascade extends coherence in strategic ambitions all the way to individual behaviours and reduces the risk of fragmentation, as alerted by analysts who regard it as a possible hindrance to sustainable change (Ghobakhloo et al., 2023).

4.1. Meso-level: organisational competency clusters

At the organisational (meso) level, leadership development work must revolve around three related and independent groups of competencies: human-technology integration, sustainability, and systems and innovation. The Delphi participants repeatedly made it clear that Industry 5.0 leadership requires combined, multidimensional skills rather than a separate technical competency. As a plant manager aptly remarked, “We can no longer separate machine learning from people learning - they must grow together, sustainably and ethically”. Echoing this sentiment, another participant further stressed, “Industry 5.0 requires us to think like ecosystem builders, not just factory managers”. Yet another participant from the food and beverage sector noted, “Our leadership challenge is not just technical upgrades; it’s building organisations that can think, adapt, and evolve with both people and technology in mind”. These reflections highlight the urgency of developing leadership capabilities that transcend traditional boundaries between technological, human, and environmental domains.

Based on these reflections, specific competencies were methodically identified and graded using the two-round Delphi technique. The importance scores (e.g., 4.90 for human-machine collaboration) reflect the average scores from the expert panel evaluations across the rounds of data collection. These competencies are also categorised to have a systematic career growth within the workforce, including higher specialised roles, specialised roles, technician roles, and entry-level employees.

Within the human-technology integration cluster, there are very specialised leadership roles that deal with human-machine collaboration (mean rating of 4.90), which is the core capability within the human-centric technologies orchestration. Niche activities prioritise digital transformation management (4.87), training leaders to drive transitional changes in technical directions. For technician personnel, ethical technology deployment (4.70) is also essential, making these competencies vital for maintaining an ethical view of the innovation. In parallel, the human-centred design thinking (4.63) and digital wellbeing facilitation (4.23) work at the level of elementary employees to realise their leadership potential by integrating human values into daily relationships with technologies.

One similarity in the sustainability cluster concerns the parallel structure. It is also expected that highly specialised leaders will become proficient in sustainability leadership (4.83), through which organisations will integrate environmental and social stewardship into the strategic decision-making process. Specialised roles are aimed at local resource optimisation (4.73), which will encourage the efficient utilisation of resources depending on the various regional settings, applicable to Indonesia. The technician jobs are focused on supply chain resilience (4.57), guaranteeing operating stability, and ethical supply in the times of growing global turbulence. At the basic level, competencies such as social value creation (4.40) and circular economy implementation (4.33) enable the extension of sustainability throughout the workplace. As a Delphi participant commented, “Everyone, from directors to floor staff, must own a piece of the sustainability agenda”.

The systems and innovation cluster similarly reflects a scaling complexity of leadership needs. Higher specialised roles require cross-cultural management (4.77), which is critical for managing Indonesia's integration into global supply networks. Specialised roles focus on developing systems thinking (4.73) to handle dynamic, interconnected production environments. Technician-level leaders are tasked with strengthening data-driven leadership (4.67), making operational decisions based on real-time insights. At the frontline, elementary employees are expected to contribute through competencies such as cross-functional integration (4.60), technological foresight (4.57), SME integration capability (4.37), multi-stakeholder engagement (4.30), and cultural intelligence (4.20), supporting agility and innovation at the system periphery. As a plant manager emphasised, "Innovation happens when insights flow freely across functions, hierarchies, and cultures - and that must start from the ground up".

Collectively, this organisational competency clustering, grounded in rigorous Delphi data, reflects a necessary evolution from rigid, siloed skill models towards dynamic, systemic, and sustainable leadership development pathways. It enables Indonesian manufacturing organisations to integrate human-machine collaboration with environmental imperatives and systemic innovation across all operational layers, creating a robust foundation for thriving in the increasingly complex and volatile ecosystems of Industry 5.0 (Bianco et al., 2023; Oeij et al., 2024). Through this approach, leadership becomes not just a set of technical capabilities, but an organisational fabric woven with ethics, adaptability, and systemic awareness.

4.2. Micro-level: Individual Leadership Competency Development

At the micro level, based on the organisational clusters introduced at the meso level, the development of leadership competencies needs to be differentiated by tiers of leadership responsibility. It is important to differentiate competencies for specific strategic, operational, and contextual roles required by leaders at various organisational levels and adopt a top-to-bottom approach, instead of a one-size-fits-all model. This was supported by all participants in the Delphi study, who indicated that the ability to be an effective leader in the Industry 5.0 context depends on competency specialisation across multiple hierarchical levels. As one senior operations director explained, "You cannot expect plant supervisors to think about global ESG policies daily, but you must empower them to make resource-optimised, adaptive decisions on the ground". Complementing this, an executive from the food and beverage industry noted, "Top executives must be visionary but grounded in the operational realities that middle and lower tiers experience daily". These insights highlight the necessity for a carefully tiered leadership development strategy that reflects both the strategic ambitions and the operational complexities of manufacturing organisations.

At the senior leadership level, the emphasis is on driving broad, transformational initiatives aligned with Industry 5.0 imperatives. The human-technology integration competency at this level is digital transformation management, enabling senior executives to lead enterprise-wide technological renewal. Their adaptive competency and sustainability leadership ensure that strategic initiatives are pursued with a balance between profitability and broader environmental and social responsibilities. Meanwhile, systems thinking emerges as the contextual competency, equipping senior leaders to manage complexity and to integrate disparate operational units under a coherent strategic framework (Braun & Clarke, 2006; Kwiotkowska et al., 2022). Senior leaders, thus, are positioned as architects of integrated, sustainable, and resilient organisational transformation.

Transitioning to middle management, the focus shifts towards operationalising strategic initiatives and managing the interface between technologies, people, and processes. Their technical competency in human-machine collaboration becomes essential for harmonising human and technological contributions to manufacturing performance. The adaptive competency of cross-functional integration supports middle managers in facilitating collaboration across organisational silos, ensuring agility and coherence across units. Simultaneously, cross-cultural management as a contextual competency prepares middle managers to navigate increasingly diverse teams and stakeholder networks (Pinto et al., 2024). In this way, middle managers act as critical conduits, translating strategic direction into actionable, operational results.

At the entry-level leadership tier, competencies are designed to foster agility, responsiveness, and localised innovation. The technical competency of data-driven leadership equips young leaders to leverage analytics and digital tools for real-time decision-making. Meanwhile, adaptive decision-making strengthens their ability to respond flexibly to fast-changing conditions. Supporting this, local resource optimisation as a contextual competency instils an early awareness of sustainability and efficiency at the operational level (Kaur & Anand, 2022). Entry-level

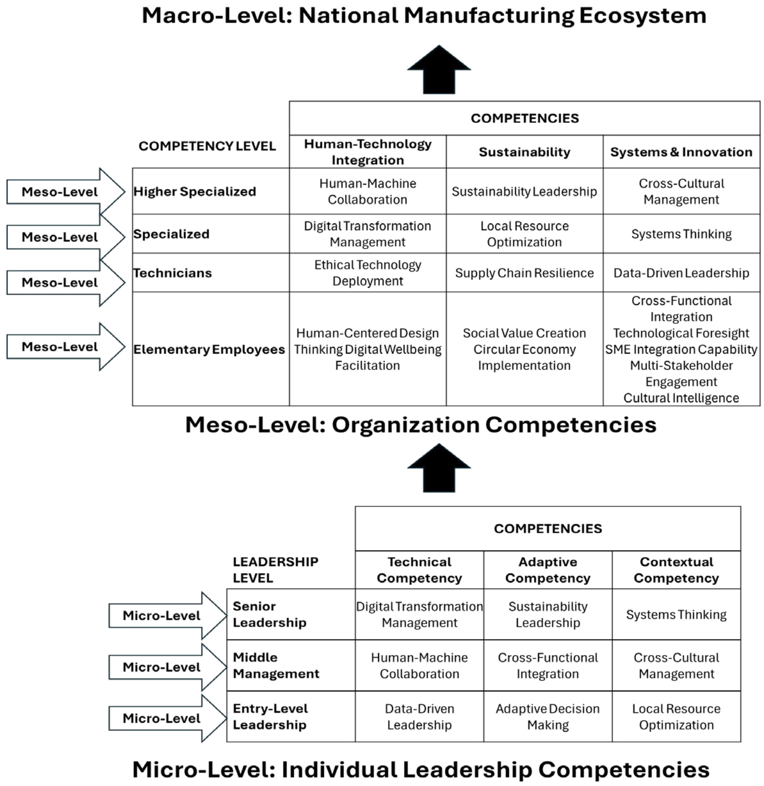

Fig. 2. Multilevel Leadership Competency Structuring Tool for Industry 5.0 Development (adapted from Tommasi et al., 2022)

leaders, therefore, play a vital role in embedding Industry 5.0 principles at the grassroots, sustaining innovation and adaptability from the bottom up.

These capabilities, taken in their combination, will indeed make sure that the leadership development pipelines are not merely resilient but dynamically constructed to the realities of Industry 5.0, which are complex. Techniques to promote systemic and consistent leadership development within organisations include sharing leadership potential throughout the hierarchical strata of any organisation, as well as integrating the principles of innovation, adaptability, and sustainability within the organisation at the very top and flowing down to its very foundation. The visual representation of this multi-tiered structuring strategy is illustrated in Fig. 2, which is the Multilevel Leadership Competency Structuring Tool for Industry 5.0 Development, suggested by Tommasi et al. (2022), and on which the offered leadership development technique is based.

4.3. Towards an integrated leadership development framework for Industry 5.0

Leadership development models will not only need to be refined to accommodate the move towards Industry 5.0, but also reimagined. Earlier frameworks, discussed by Ghobakhloo et al. (2023) and Moldovan (2019), were mostly focused on technological competence, i.e., digital fluency, mastery of automation, and systems control. Nevertheless, these technology-driven solutions can no longer be considered adequate in the modern world, where the manufacturing environment is influenced not only by technologically-driven innovation but also by ethical principles and sustainability demands. In the proposed study, these emerging dimensions are considered intentional and incorporated into a multilevel framework, which represents a paradigm shift towards upskilling models of Industry 4.0 that are largely linear, in contrast to the systemic, interconnected approach to Industry 5.0 transformation (Suciu et al., 2023; Tommasi et al., 2022).

One of the most important innovations of the offered framework is its responsiveness to the local context, which is among the most overlooked aspects of globalised leadership theories. Leadership competencies in the Indonesian manufacturing sector are characterised by diverse resources, vulnerable supply chains, and varied workforce capabilities, requiring skills that are not merely international but must be executed locally. Majczyk et al. (2022) argued that

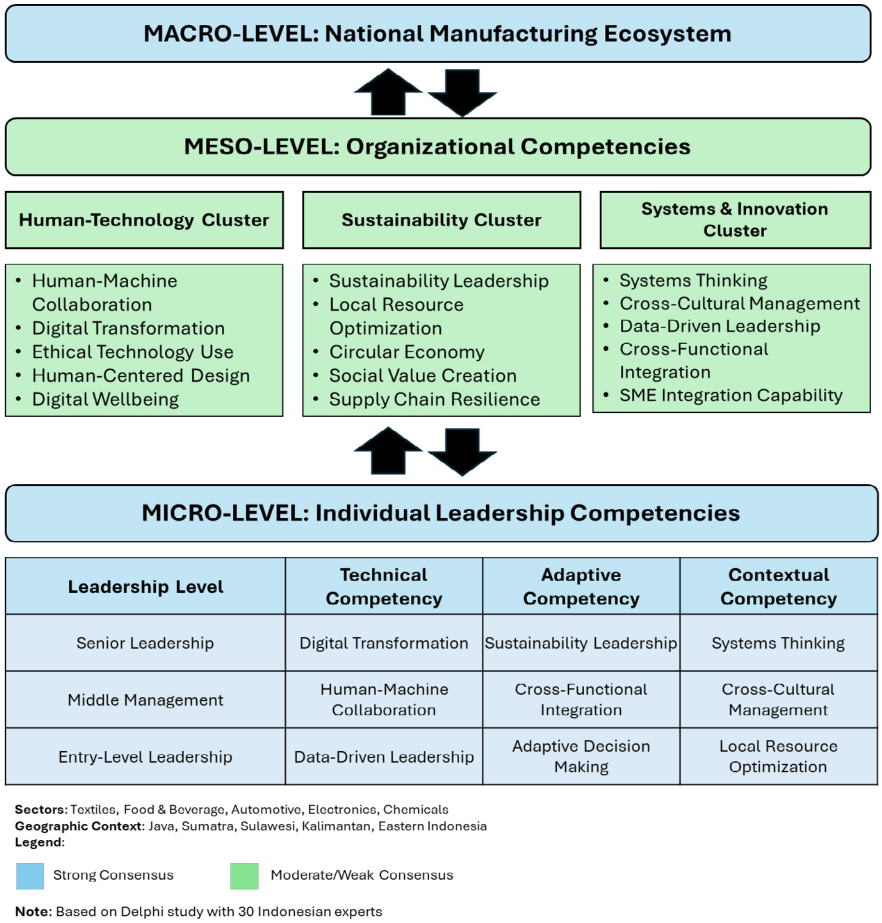

Fig. 3. Manufacturing Leadership Competency Framework for Industry 5.0 Transformation

leadership development should consider national priorities and realities, and this idea is supported by Gudanowska et al. (2018), who proposed the idea of proactive and adaptive leadership approaches to fit regional industrial ecosystems. Thus, local resource optimisation, SME integration capability, and multi-stakeholder engagement competencies are tailored as inherent parts of this framework to align with Indonesia's plans under the Making Indonesia 4.0 roadmap and Sustainable Development Goals in general. Through this, it supplements previous studies by providing a more area-specific model that can integrate global leadership theories with the local operational requirements.

Further, the leadership competencies must be structured at the macro, meso, and micro levels to increase strategic alignment and operational resilience. At the macro level, leaders should influence national manufacturing policy and sustainability agendas, and proactively engage in industry transformation efforts. Unless competencies are developed on the macro level, as Tommasi et al. (2022) believe, national strategies will be vulnerable to becoming disjointed and unbalanced. At the meso level, organisational leadership must learn to incorporate human-technology collaboration, ethical digitalisation, and systems innovation as operational practices, as Pinto et al. (2024) and Tschiedel et al. (2025) indicated as necessary. Micro development of leaders should be very specific at a certain level, providing adaptation, contextual, and technical skills adapted to the reality on the ground that governs the leaders at various levels. This tiered organisation must directly counteract the lack of such integration, which was lacking in previous competency models.

This tiered solution is needed to avoid the traps epitomised in previous leadership systems. Perini (2021) demonstrated a discrepancy among leadership levels: senior leaders change vision, whereas middle and frontline managers lack the skills to implement it, which can potentially be disaster-causing for changes. The proposed framework would achieve strategic alignment, operational unification, and the capability to handle results of systematic disruption by aligning leadership development across the macro, meso, and micro levels. Next, integrating sustainability, human-centred ideals, and an ethical vision will ensure that leadership growth does not become technocratic skill-drilling but rather a driving force of social change and care for the natural world (Pereira & Lacerda, 2021). To this end, the framework follows previous research in applying a humanistic and sustainability-centred paradigm at the heart of leadership competency development.

To graphically combine this concept design, Fig. 3 is a particularisation and extrapolation of the multi-level comprehension tool designed by Tommasi, Perini, and Sartori (2022). The figure describes lively dynamic encapsulation of macro (nationwide ecosystem alignment), meso (organisational competency clusters), and micro (personally leadership pathways) spheres with a final focus on the systemic nature of leadership development in the post-industrial technological age of Industry 5.0. In contrast to the more linear models, the proposed framework supports the development of competencies through the paradigm of continuous, iterative stratification of leadership skills on strategic and operational fronts, with the Indonesian manufacturing companies preparing to attain long-term competitiveness, human-centred innovativeness, and sustainability.

This figure represents the Manufacturing Leadership Competency Framework. The research development in this study focuses on responding to the systemic leadership problems arising in the Industry 5.0 context. Contrary to the more traditional linear leadership models, this framework is a dynamic, multilayered framework that engages a highly systematic connection of macro (national policy and ecosystem alignment), meso (organisational practice and capability building), and micro (individual leadership development) levels (Pinto et al., 2024; Tommasi et al., 2022). It represents the increasing school of thought provided by the approach that leadership strategies should not only be technologically competent but also people- and sustainability-focused and resilient to socio-technical complexity (Ghobakhloo et al., 2023; Pereira & Lacerda, 2021). The structure pays utmost attention to the strategic importance of leadership in influencing and keeping pace with the national industrial ambitions, as in the macro-level initiative titled Making Indonesia 4.0 (Majczyk et al., 2022). Competencies at this level primarily focus on integrating sustainability, advocating policy, cross-sectoral cooperation, and orchestrating an ecosystem to ensure that industrial renewal is not disjointed but rather tactically unified (Tschiedel et al., 2025). Next, the framework establishes such essential organisational competencies at the meso level as human-technology collaboration management, cross-functional integration, and ethical innovation leadership, just as it has been recommended recently to integrate the principles of Industry 5.0 directly into the practice of organisations (Bianco et al., 2023; Pinto et al., 2024). Such competencies enable manufacturing companies to adopt new technologies while remaining highly dedicated to human welfare, environmental stewardship, and sustainable manufacturing processes (Suciu et al., 2023).

At the micro level, the structure identifies the competencies that the individual leaders working in complex, dynamic manufacturing conditions require, including adaptive, technical, and contextual skills (Kwiotkowska et al., 2021; Schinner, 2022). Whether line management and governance, middle leaders, or senior leaders, each has the differentiated but interdependent competencies, including data-driven leadership, resilience building, and cultural intelligence, all of which have been identified as part of the skills needed to become a future-ready leader (Dahl et al., 2023; Wickramaratne et al., 2014). Such bottom-up empowerment strengthens top-down strategic imperatives and builds a feedback cycle, enhancing the organisational learning, flexibility, or innovation resilience at every level of hierarchy. Establishing these three levels in mutual engagement and development enables the Manufacturing Leadership Competency Framework to build a strong basis for transforming leaders who will be able to lead through the technological, environmental, and social changes that define Industry 5.0 (Ghobakhloo et al., 2023; Oeij et al., 2024). This way, it partially fills the gap which was created by the past leadership development models, giving an inclusive, capable, and context-sensitive framework that helps provide sustainable, inclusive, and human-centred development of the manufacturing industry in the Indonesian context.

Conclusions

The shift from Industry 4.0 to Industry 5.0 calls for an essential reconsideration of the term manufacturing leadership, which may entail a fundamental transition from strict technological capability building to a holistic form of leadership that balances human-driven innovation, a moral orientation, and environmentally minded development. The study was driven by the important research gap revealed by previous studies, in which leadership models were still overly focused on digitalisation and flawless operations and were concerned with human-machine partnership, emotional intelligence, strategic flexibility, and sustainability requirements. Although the requirements of Industry 4.0 possess significant technical skills, which were proposed by earlier research, they could not foresee the extraordinary socio-technical requirements that constitute the current Industry 5.0 landscape. The absence of an integrated, multilevel leadership competency framework - especially in emerging manufacturing contexts such as Indonesia - posed a serious challenge for sustainable and resilient industrial transformation.

Through a systematic and context-sensitive approach, this study developed the Manufacturing Leadership Competency Framework, addressing both the immediate competency gaps and the broader strategic needs of organisations operating in Industry 5.0 ecosystems. By adopting a multilevel structure - macro (national policy and ecosystem alignment), meso (organisational practice and systems integration), and micro (individual leadership development) - the framework reimagines leadership development as a dynamic, iterative, and contextually grounded process. It not only complements but extends previous research by embedding sustainability leadership, local resource optimisation, SME integration, and ethical human-technology collaboration at the core of leadership development pipelines. In doing so, this study offers a robust and actionable model that enables manufacturing organisations to cultivate leaders capable of driving innovation, maintaining operational excellence, promoting human-centric workplaces, and achieving resilience against future disruptions. The framework directly answers the research gap framed in the Introduction: providing a comprehensive, adaptive, and sustainable leadership development approach for Industry 5.0 transformation.

Theoretical implications

Theoretically, the study adds to the body of knowledge on leadership and competency development, as it offers a novel model of leadership and development with multilevel, systemic orientations, directly aligned with the Industry 5.0 framework. In contrast to earlier frameworks, where competency building was systematically flat or siloed, emphasising only the technical skills, the new model integrates the macro, meso, and micro approaches into a consistent direction. The identified studies have critical gaps because of the underrepresentation of human-centric and sustainability competencies (Ghobakhloo et al., 2023; Grzybowska & Lupicka, 2017). Moreover, including localised capabilities, including the capabilities of SME integration and local resource optimisation, within the competency map, the given research will highlight the significance of contextual and regional specificity, following the arguments advanced by Majczyk et al. (2022) and Gudanowska et al. (2018). This means that the framework contributes to the theoretical knowledge of leadership development as a repetitive, iterative, and multi-actor process that is important in the delivery of successful transitions into Industry 5.0 ecosystems.

This paper also helps address the increasing demand for leadership theories to meet the challenge of encompassing socio-environmental factors and the ethical requirements of leadership constructs within general leadership theories. This implies that, in future theoretical models, cross-level interactions must be considered, and that national policies, organisational systems, and individual behaviours must be identified as dynamically linked. These results provide a basis for further empirical studies that can be undertaken to determine the extent to which the multilevel leadership framework can be applied in different national backgrounds, industrial types, and levels of digital maturity.

Practical implications

In practice, the Manufacturing Leadership Competency Framework developed in this study offers a concrete guide for policymakers, organisational leaders, and training institutions seeking to prepare leaders for Industry 5.0 challenges. For policymakers, the findings underscore the necessity of designing national industrial strategies that are not merely aspirational but systematically translated into organisational competency-building initiatives. Embedding sustainability and human-centric leadership development into national programs such as “Making Indonesia 4.0” will be crucial for achieving systemic industrial transformation.

For manufacturing firms, the framework provides a structured roadmap for aligning leadership development programmes with the evolving demands of the Industry 5.0 environment. Organisations are encouraged to move away from fragmented, one-size-fits-all training approaches and instead develop tiered competency pathways that address strategic, operational, and individual-level leadership needs simultaneously. Human resources departments, corporate universities, and professional development providers can use the identified competencies to design more targeted learning interventions, mentorship programmes, and evaluation metrics. By doing so, firms will not only enhance their innovation and operational resilience but also ensure long-term sustainability and competitiveness in a rapidly changing global landscape.

Limitations and future research

While the Delphi approach enabled expert-driven validation, several limitations remain. First, the panel was primarily composed of Indonesian experts, which may limit cross-cultural generalisability. Second, the framework was validated through perception-based consensus rather than empirical implementation evidence. Future research should include pilot applications or case studies within diverse manufacturing environments to examine the operational effectiveness of the competency framework and mitigate potential cultural and contextual biases. Expanding the panel to include international experts would strengthen applicability across different Industry 5.0 maturity levels.

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Author Contributions

Donald Crestofel Lantu contributed to the conceptualization, methodology design, data analysis, and manuscript writing. Yuliani Dwi Lestari contributed to the literature review, data collection, and manuscript editing. apt. Aghnia Nadhira Aliya Putri contributed to the research design, data interpretation, and critical revision of the manuscript. All authors reviewed and approved the final version of the manuscript.

Ethics Declarations

This study was approved by the Research Ethics Committee of Institut Teknologi Bandung under Ethical Clearance Number KEP/II/2024/X/M96564377NJ-EESB. The committee confirmed that the research adheres to ethical standards and guidelines, ensuring its compliance with the required ethical considerations.

Consent to Publish

All participants who may be identifiable in this manuscript have reviewed the final version and provided written consent for publication.

Conflict Of Interest

The authors declare no conflict of interest.

Declaration of Conflicting Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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