A Psychological Integration Model for Local Strategies toward a Sustainable Human-Centric Transformation

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Abstract Industry 5.0 repositions technology in European industry by prioritising human wellbeing, resilience, and sustainability. This chapter develops a framework to operationalise the human-centric vision by integrating Lewin's field theory, vertical (adult) development and the Job Demands–Resources (JD-R) model, supported by Human Digital Twin (HDT) technology. The resulting Field Development Demands (FDD) loop captures systemic forces (field theory), differentiates meaning-making capacities (vertical development), and assesses working conditions, while HDTs enable real-time detection, modelling and adaptation. Three exemplar scenarios demonstrate the application in different European contexts. Ethical and governance issues, including data protection, autonomy, fairness, and participatory control are emphasised as essential safeguards. Industry 5.0 is not presented as a static optimisation, but as a dynamic co-evolution between people and environments, expanding collective capacity for complexity. By linking theory, practise, and technology, the chapter outlines actionable strategies that promote worker development, organisational resilience, and sustainability.

Keywords: • Industry 5.0 • human digital twin • job demands–resources model • vertical development • Lewin's Field Theory

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1 Introduction

Industry 5.0 represents a paradigmatic shift in European industrial policy and practise. In contrast to Industry 4.0, which focused on automation, efficiency, and technological optimisation, Industry 5.0 puts human well-being, resilience and sustainability at the forefront, placing workers' well-being, creativity, and personal purpose at the heart of industrial systems (Breque et al., 2021). At its core, Industry 5.0 is about technological advances serving human development and not simply displacing or replacing human labour. Workers are seen as co-creators of value and active participants in shaping their environment. This vision requires workplaces to evolve from one-size-fits-all models to personalised, adaptable systems that take human variability into account. Rather than simply minimising stressors, Industry 5.0 aims to create conditions that actively promote resilience, learning, and meaning-making. It is in line with the broader policy themes of the European Union (EU): inclusive growth, social innovation, and regional resilience (Breque et al., 2021).

The chapter builds on the realisation that while Industry 5.0 is widely discussed in strategic policy documents and academic debates, there is still a lack of clarity on how to translate this vision into actionable strategies at the local level. SMEs, city administrations, and municipal training centres often lack conceptual and operational tools to integrate the human dimension into daily practise. There is a need for a comprehensive, theory-led framework based on the depth psychological models of human development. This is because the work environment is a complex space in which professional demands interact with individual skills and resources. A modern, sophisticated approach should therefore take into account the dynamic interaction between the individual and their environment, which functions as a continuous feedback loop and influences long-term professional development.

This challenge is addressed by integrating three established theories: Lewin's field theory (Lewin, 1951), vertical (adult) development theory (Kegan, 1994; Cook-Greuter, 2004), and the Job Demands Resources (JD-R) model (Demerouti et al., 2001; Bakker & Demerouti, 2007). We introduce the Field Development Demands (FDD) loop, a system-level model that combines these theories into an operational framework for Industrie 5.0 workplaces. Together, these theories form a powerful lens for analysing how local Industry 5.0 strategies can improve both productivity and human wellbeing. To enable real-time adaptation, we propose Human Digital Twin (HDT) technology as the infrastructural backbone. Case studies from SMEs, public administration, and community-level initiatives illustrate practical local strategies.

The chapter contributes to theory and practise by: (a) formulating a conceptual synthesis that links psychology, organisational science, and technology; (b) presenting a dynamic model (the FDD loop) that integrates human resource development and systemic adaptation; and (c) providing case-based insights into local Industry 5.0 strategies. By going beyond traditional management approaches, this chapter shows how European organisations can translate policy aspirations into concrete, people-centred practises that improve resilience and sustainability.

2 Conceptual Foundations

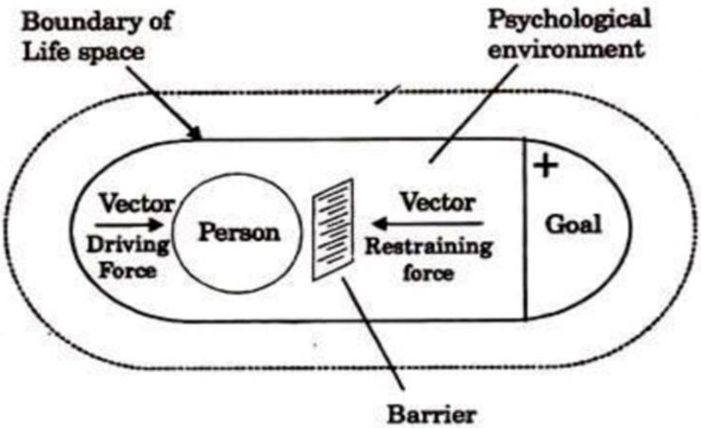
2.1 Lewin's Field Theory

To realise Industry 5.0's vision of human wellbeing, resilience, and sustainability, robust psychological theories are required to understand how individuals interact with their environment to influence motivation, performance, and development. One of the most enduring frameworks in this regard is Kurt Lewin's (1936, 1951) field theory, which understands behaviour as a function of both the person and the environment within a dynamic life space. The relevance of Lewin's field theory to Industry 5.0 focuses on how concepts such as life space, force fields, and quasi-stationary equilibrium influence the design of human-centred, adaptive and holistic work systems. It argues that technology in industrial contexts, should be seen as a field regulator capable of amplifying driving forces and reducing restraining forces to improve worker wellbeing and resilience.

2.1.1 Core Principles

Lewin summarised his view in the equation: $B = f(P, E)$, where behaviour (B) is a function of the person (P) and the environment (E). Central to this framework is the concept of life space — the set of factors that influence a person's behaviour at a particular point in time (Lewin, 1936). The life space includes personal goals, past experiences, current judgements and environmental conditions. Within this field, several psychological forces operate simultaneously, some as driving forces that propel action, others as restraining forces that prevent movement (see Figure 1).

Figure 1: Lewin's Field Theory of Learning (Lewin, 1951)



A change in behaviour occurs when the force field is altered: either by increasing the driving forces, decreasing the restraining forces, or by a combination of both. Lewin emphasised that the equilibrium is dynamic, and described it as a quasi-stationary equilibrium. When new or unmet needs destabilise the equilibrium, changes occur until a new balance is reached (Lewin, 1947). This principle is particularly relevant to the rapid changes in today's workplaces, where digitalisation and sustainability goals are continuously reshaping the psychological field.

2.1.2 Life-space, dynamic equilibrium and change in work environments and Industry 5.0 system design

The life space provides a holistic lens through which behaviour can be analysed. All psychological phenomena (thinking, acting, hoping, and perceiving) must be understood as functions of the life space (Deutsch, 1968). For organisational design, this means avoiding reductionism and instead analysing the situation in its entirety. In the workplace, this includes tasks, roles, relationships, technologies, and cultural norms. For example, team projects, digital collaboration platforms, and informal interactions (e.g., coffee breaks) are all part of an employee's life space. These elements are linked by vectors that reflect preferences and relational qualities (e.g., favouring meetings over emails, collaborative over solitary work). In Industry 5.0, driving forces can be autonomy, opportunities to utilise skills, social support, purpose and meaningful feedback; restraining forces can be cognitive overload, ambiguous goals, rigid hierarchies, digital fragmentation, or technostress.

Understanding life-spaces enables organisations to anticipate behaviour and adapt environments to human needs. In Industry 5.0, for example, this means recognising that technologies not only structure workflows, but also actively shape psychological experiences by influencing perceptions of autonomy, connectedness and purpose, and acting as dynamic field regulators. For example, adaptive AI dashboards can reduce cognitive overload by focussing information, while collaborative platforms can amplify driving forces such as connectedness and feedback. By continuously tuning the field, organisations can promote their resilience and wellbeing.

Lewin's concept of quasi-stationary equilibrium has a close connection to Industry 5.0. Work systems are not static, but evolve through cycles of stability and disruption. The equilibrium is disrupted by technological innovations, environmental crises, or new employee needs, and restored through adaptive reorganisation. Industry 5.0 environments need to embrace this dynamic rather than resist it, and view equilibrium as a process rather than a fixed state. For example, the introduction of Human Digital Twins (HDTs) can destabilise old equilibria by shifting the balance of demands and resources. However, when integrated responsibly, HDTs can help restore balance by providing adaptive feedback that reduces the restraining forces and strengthens the driving forces.

2.1.3 Applications for Industry 5.0 Workplaces

Lewin's theory can serve as a guideline for various applications of the Industry 5.0 strategy. A systemic assessment using force field analysis should be conducted to identify the driving and restraining forces in the workplace to guide interventions at a personal and systemic level (Burnes & Bargal, 2017). Human-centred design should create environments that are not only physically efficient, but also provide psychological benefits — safety, autonomy, clarity, connectedness and growth. Adaptive technology integration should position technologies as active participants in the field, and influence how employees perceive demands and resources. Change management should include an understanding of transitions as shifts between quasi-stationary equilibria, with a focus on managing the psychological forces underlying resistance and adaptation.

The integration of Lewin's field theory into organisational strategy implies several shifts:

- From structure to system: designing workplaces as responsive, living systems rather than static infrastructures.
- From control to co-creation: employees are not passive recipients, but active players who shape and reshape their environment.
- From standardisation to differentiation: recognition of psychological diversity as a design parameter.

Organisations need to move towards flexible, sensor-equipped and human-centric systems that enable real-time adaptation of the environment. This supports not only performance, but also deeper psychological needs — autonomy, competence, and connectedness.

2.2 Vertical (Adult) Development

Industry 5.0 emphasises the integration of human capabilities and values into industrial systems, and thus goes beyond the efficiency-driven paradigm of Industry 4.0. A key aspect of this change is the realisation that employees are not static resources, but evolving individuals with different skills in dealing with complexity, perspective-taking, and meaning-making. Vertical (adult) development theory provides a framework for understanding how individuals' cognitive and emotional abilities expand over time, influence the way they interpret experiences and deal with challenges in the workplace (Kegan, 1994; Loevinger, 1976; Cook-Greuter, 2004).

In this chapter, the theory of vertical development is embedded in the conceptual foundations of Industry 5.0. It argues that understanding and promoting vertical development is essential to building resilient, adaptable and human-centred workplaces. By empowering workers and leaders to embrace complexity and ambiguity, organisations can create conditions that promote both human wellbeing and sustainable innovation.

2.2.1 Horizontal vs. Vertical Development

Developmental theories distinguish between horizontal and vertical growth (Cook-Greuter, 2004). Horizontal development refers to expanding skills and knowledge within a given stage, such as learning new technical competencies without fundamentally alter perspective-taking. Vertical development, by contrast, involves qualitative transformations in how individuals construct meaning, interpret reality, and navigate complexity (Kegan, 2016).

While most organizations have emphasized horizontal training programs, Industry 5.0 workplaces must create scaffolding for vertical development. This includes reflective practices, mentoring, feedback systems, and environments that challenge individuals to reconsider assumptions and broaden perspectives.

2.2.2 Ego Development and Action Logics

Vertical development is modelled by Loevinger's (1976) and Cook-Greuter's (2004) theory of ego development, which describes nine stages of development (see Table 1), that can be divided into pre-conformist, conformist, and post-conformist stages. In each stage, the individual develops new ways of making meaning, which are expressed through characteristic logics of action (Torbert, 2004). These logics of action influence how people interpret demands, goals, and relationships. In the pre-conforming stages (1–3), a person is focussed on themselves and is driven by immediate needs and impulses. In the conformist stages (4–5), a person is guided by social rules, group membership and external expectations. In the post-conformist stages (6–9), a person is capable of self-responsibility, systemic reflection, and the integration of contradictory perspectives.

Table 1: Stages of ego-development (Schneider et al., 2019)

Stage	Character	Cognitive Style	Interpersonal Style	Conscious Preoccupations
E1: Symbiotic	-	-	Symbiotic	Self- vs. nonself
E2: Impulsive	Impulsive	Stereotyping Conceptual confusion	Egocentric, dependent	Bodily feelings
E3: Self-protective	Opportunistic	Stereotyping Conceptual confusion	Manipulative way	Trouble control
E4: Conformist	Respect for rules	Conceptual simplicity	Cooperative loyal	Appearances behavior
E5: Self-aware	Exceptions allowable	Multiplicity	Helpful Selfaware	Feelings problems adjustment
E6: Conscientious	Self-evaluated standards, selfcritical	Formal operations	Intense responsible	Motives traits achievements
E7: Individualist	Tolerant	Relativism	Mutual	Individuality development roles
E8: Autonomous	Coping with conflict	Increased conceptual complexity, complex patterns, toleration for ambiguity, broad scope, objectivity	Interdependent	Self-fulfillment
E9: Integrated	Reconciling inner conflicts, renunciation of unattainable	increased conceptual complexity, complex patterns, toleration for ambiguity, broad scope, objectivity	Cherishing individuality	Identity

Few people reach the highest level of development, but progression improves the ability to tolerate ambiguity, solve complex problems, and lead adaptively. The highest level reached often acts as the individual's centre of gravity, and guides typical responses, although previous patterns may resurface under stress (Hy & Loevinger, 1996).

2.2.3 Relevance for Human-Centric Strategy of Industry 5.0

Research underlines the practical importance of vertical development in the work and organisational environment at different levels and aspects of the work process (leadership, entrepreneurship, workplace design). In line with the Industry 5.0 goal of treating employees as co-creators of value rather than passive resources, development-orientated interventions promote resilience, adaptability, and engagement. Vertical development is particularly relevant for Industry 5.0, as workplaces are increasingly characterised by complexity, rapid change, and ethical dilemmas. Employees and managers at different stages of development assess demands and resources differently. Leaders who develop vertically are better able to tackle systemic challenges, innovate, and build resilient organisations (Jones et al., 2020; Petrie, 2014). Higher levels of development correlate with a stronger innovation orientation among entrepreneurs (Schneider et al., 2019). A challenging workload can feel overwhelming for someone in a conformist stage, while it is energising for a post-conformist person who sees it as an opportunity for growth. Autonomy may be perceived as empowering by a self-empowered person, whereas it may be perceived as ambiguous or stressful by someone who is in an earlier stage. Industry 5.0 thus requires tailoring interventions to developmental stages. Structured, rule-based guidance may suit earlier stages, while reflective prompts and scenario-based simulations may benefit those in later stages. Without such customisation, the measures run the risk of being ineffective or counterproductive. Organisations implementing Industry 5.0 strategies should integrate a vertical development framework into their training and HR systems. Practises such as mentoring, coaching, reflective dialogues and deliberate developmental organizations (Kegan et al., 2016) can foster environments in which employees continuously expand their meaning-making capabilities.

Industry 5.0 emphasises that sustainable competitiveness depends on the development of people in adaptable, resilient, and inclusive workplaces. The theory of vertical development explains how workers gradually develop the ability to deal with complexity, ambiguity, and ethical tensions. By fostering this development, organisations empower their employees to see challenges as opportunities, integrate technology into meaningful work, and develop creativity, ethical judgement and systemic thinking.

This perspective complements frameworks such as Lewin's field theory and the job demands and resources model by showing how individual development shapes the interaction between person and environment. For Industry 5.0, where workers are co-creators of value, vertical development is essential for fostering resilience, innovation, and ethical responsibility. Embedding such practises ensures that technology enhances rather than diminishes human potential, and aligns industrial strategy with human-centred growth.

2.3 The Job Demands–Resources (JD-R) Model in the Context of Industry 5.0

To operationalise the goals of Industry 5.0 - human wellbeing, sustainability, and resilience, - organizations need a theoretical framework that explains how the work environment influences employee motivation, engagement, and health. The Job Demands–Resources (JD-R) model provides such a framework. It conceptualises how the balance of demands and resources determines employee outcomes, providing actionable insights for the design of human-centred workplaces (Demerouti et al., 2001).

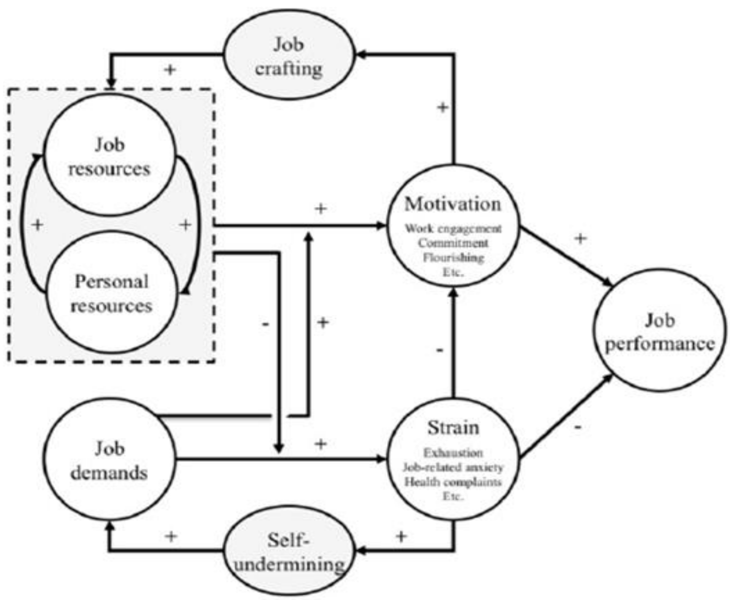
In this chapter, the JD-R model is used in the context of Industry 5.0 both as an analytical tool and as a design framework. It shows how digital transformation is changing demands and resources, and how personal and organisational measures can ensure that technology promotes rather than undermines human well-being.

2.3.1 Core Principles of the JD-R Model

In the JD-R model, a distinction is made between job demands and job resources (Bakker & Demerouti, 2007). Job demands include physical, psychological, social, or organisational aspects of work that require sustained effort, such as workload, emotional strain, role ambiguity, and digital interruptions. Job resources are aspects of work that facilitate goal achievement, reduce demands and their costs, or promote learning and development, such as autonomy, social support, performance feedback, and growth opportunities.

Demands overload predicts stress and burnout, while resources predict motivation and engagement (Schaufeli & Bakker, 2004). Resources buffer the negative effects of demands, and at the same time promote personal development. Personal resources such as self-efficacy, resilience, and optimism mitigate these relationships by enabling employees to mobilise resources and perceive demands as challenges (Xanthopoulou et al., 2007), which subsequently leads to better job performance (see Figure 2).

Figure 2: The Job Demands-Resources Model (Bakker & Demerouti, 2018)



Later developments distinguish between hindrance demands and challenge demands (Van den Broeck et al., 2010). Hindrance demands (e.g. excessive bureaucracy, unclear roles, or contradictory demands) primarily sap energy and reduce motivation. Challenge demands (e.g. high workload or responsibility), while demanding, but can also promote coping, learning, and growth. This distinction emphasises the dual role of demands in shaping outcomes and is in line with Industry 5.0's focus on turning potential stressors into development opportunities. In this way, the JD-R model can be used as a human resource management, tool that identifies the strengths and weaknesses of individuals, work groups, departments, and organisations as a whole (Chen et al., 2017).

2.3.2 JD-R in Digitalized Work Environments and Resilience of Industry 5.0

Industry 5.0 jobs introduce new categories of demands and resources (Scholze & Hecker, 2024):

- Digital Job Demands: technostress, algorithmic management, constant availability expectations, and information overload.
- Digital Job Resources: Adaptive AI coaching platforms, collaborative decision-making tools, real-time feedback dashboards, and digital autonomy enablers.

This demonstrates the flexibility of the JD-R model and emphasises its relevance for Industry 5.0 contexts. When integrated into adaptive systems such as Human Digital Twins, JD-R assessments can guide real-time adjustments that maintain wellbeing.

Resilience is a cornerstone of Industry 5.0, and is defined not only as individual toughness but as a co-created capability of systems and people. The JD-R model complements resilience theory by demonstrating how resources (e.g., autonomy, support) and personal capabilities (e.g., optimism, cognitive flexibility) enable adaptive coping strategies. Organisations can strengthen resilience by continuously monitoring demands and resources, designing interventions that rebalance the system when stresses accumulate, and fostering developmental growth by viewing certain demands as challenges. This approach ensures that resilience is embedded in the design of socio-technical systems and is not left to individual coping alone.

The JD-R model can serve as a guide for several practical applications in various areas of Industry 5.0:

- Human Resource Management: the JD-R model provides a structured diagnostic tool to identify risks and opportunities at the individual, team, and organisational levels (Chen et al., 2017).
- Technology integration: Embedding JD-R monitoring in digital platforms enables continuous feedback loops that support adaptive interventions.
- Customised interventions: Combining JD-R with a vertical developmental framework ensures that interventions are appropriate for the developmental stages of employees.
- Cross-cultural flexibility: Empirical studies confirm the applicability of the JD-R model in different professional and cultural contexts, making it suitable for multinational Industry 5.0 strategies (Schaufeli & Taris, 2013).

By distinguishing between demands and resources and clarifying their interactive effects, the JD-R model provides a measurable and adaptable framework for designing human-centred workplaces. Extending the model to include digital demands and resources ensures its continued relevance in an era of technological change. Integrating JD-R into Industry 5.0 systems enables organisations to move from reactive to proactive strategies, and ensure that technology serves as a catalyst for resilience, engagement, and human wellbeing.

2.4 Human Digital Twins as Enablers of Industry 5.0

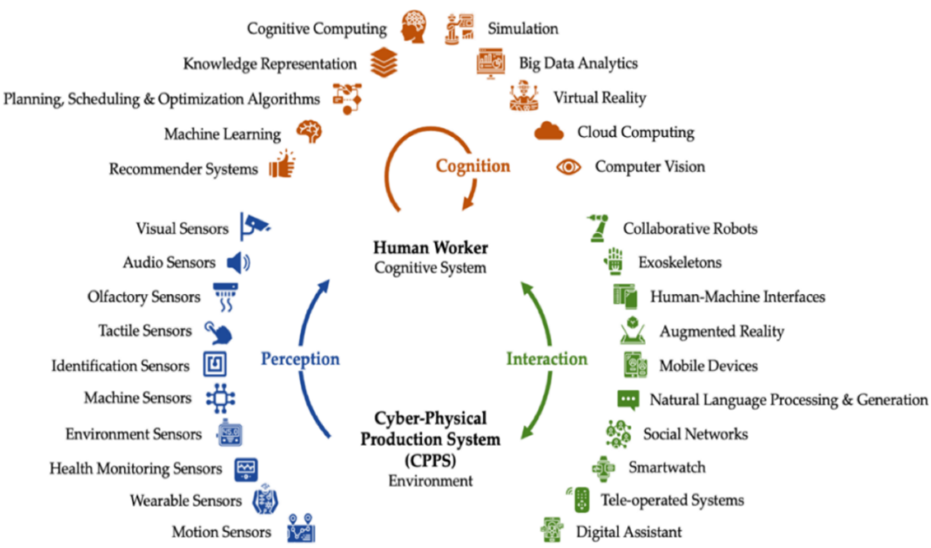
Within the Industry 5.0 paradigm, technology becomes an enabler of human capabilities — creativity, empathy, moral reasoning, and complex decision-making — rather than a substitute for labour (Wang et al., 202). A central concept enabling this is the Human Digital Twin (HDT): a digital counterpart of a human capable of sensing, modelling and responding to cognitive, emotional, and physiological states in real time (Gaffinet et al., 2025).

This chapter examines HDTs as the human interface of cyber-physical-human systems. It emphasises their role in adaptive feedback loops that promote worker well-being, development, and resilience.

2.4.1 Defining Human Digital Twins

The concept of the digital twin originally comes from engineering as a virtual representation of physical systems for monitoring and optimisation (Grieves & Vickers, 2017). Applied to humans, this results in the Human Digital Twin (HDT): a computer model that integrates multimodal data — physiological, cognitive, emotional, and behavioural — into a dynamic representation (Wang et al., 2023, see Figure 3).

Figure 3: Symbolic human-machine relationship in the Industry 5.0 (Longo et al., 2020)



Gaffinet et al. (2025) distinguish three levels of human representation:

- Human Digital Models (HDMs): Static, descriptive profiles (e.g., ergonomics, job roles).
- Human Digital Shadows (HDS): Data-driven, real-time representations that reflect the current state and have no predictive power (e.g., fatigue or stress tracking).

- Human digital twins (HDT): Bidirectional, adaptive models that simulate scenarios and deliver personalised interventions.

HDTs differ from traditional monitoring by enabling personalisation, augmentation, and collaboration. Workers become active participants in cyber-physical-human ecosystems, and not just 'black boxes' Crucially, HDTs prioritise augmentation over monitoring and empower human agency in Industry 5.0 workplaces. For Industry 5.0, true HDTs offer the greatest potential, by integrating job demand and resource (JD-R) assessments, tailoring interventions to developmental stages, and dynamically balancing psychological forces in line with Lewin's field theory.

2.4.2 Technical Architecture for organizational human-centric applications

A generic HDT architecture for organisational contexts comprises four functional layers (Kumar et al., 2025; Wang et al., 2023):

1 Sensing Layer: collects physiological (e.g., heart rate variability), cognitive-behavioural (e.g., typing patterns, task switching), contextual (e.g., workload), and self-reported data.
2 Modelling layer: Integrates multimodal data with psychological frameworks (JD-R, vertical development). Machine learning estimates states (e.g., risk of fatigue).
3 Simulation layer: Tests "what-if" scenarios (e.g., changed workload or autonomy, based on Lewin's force field analysis).
4 Intervention layer: Provides adaptive responses (e.g., redistribution of tasks, micro-breaks, development coaching, personalised learning modules).

This architecture positions HDTs as active regulators of the working environment, continuously shaping person–environment interactions to advance Industry 5.0 objectives. For example, they can recognise early indicators of burnout (e.g.increased workloads or physiological stress markers) and suggest preventative measures like micro-breaks, peer support, or stress reduction practises, to ensure employee wellbeing (Gaffinet et al., 2023). Personalised micro-learning tailored to employees' developmental stages further enhances learning and growth, supporting both horizontal skill acquisition and vertical meaning-making (Kegan et al., 2016). In terms of safety and resilience, HDTs enable the simulation of human–machine interactions, identifying unsafe patterns (e.g., fatigue-related errors), and adapting machine parameters to prevent incidents. Such capabilities strengthen organizational resilience by anticipating risks and proactively realigning workflows (Choi et al., 2022). Collectively, these applications highlight HDTs as pivotal enablers of human-centric vision of Industry 5.0.

3 The Field–Development–Demands (FDD) Loop in the Context of Industry 5.0

To follow the Industry 5.0 paradigm, which places human wellbeing, resilience, and sustainability at the heart of industrial systems, organisations need integrative frameworks that align psychological theories, development models, and adaptive technologies. We propose the Field Development Demands (FDD) loop which integrates Lewin's field theory, vertical (adult) development and the job demands and resources (JD-R) model into a recursive process, supported by human digital twins (HDTs) as technological enablers.

In this chapter, the conceptual and practical foundations of the FDD loop are developed. It shows how technology can act as a field regulator, how developmental stages shape responses, and how recursive cycles promote both immediate adaptation and long-term developmental growth.

3.1 Core Structure of the FDD Loop

The FDD loop comprises six interconnected phases (see Figure 4):

1 Field Mapping (E): environmental scanning with HDTs and analytics. Following Lewin's field theory, the workplace is viewed as a dynamic system of interacting forces shaping behaviours such as learning, safety, and innovation. Organisations identify driving forces (e.g., autonomy, feedback, support) and restraining forces (e.g., overload, ambiguity, fragmentation).

2 Evaluation (P): Individuals interpret the perceived conditions (environment) on the basis of their personal resources (self-efficacy, optimism, psychological capital) and their vertical level of development. For example, lower-stage action logics may perceive a high workload primarily as a threat, while individuals at a higher level can integrate complexity as an opportunity for growth.

3 JD-R diagnosis: Based on the JD-R theory, which states that work performance and well-being depend on the balance between job demands (e.g., workload, multitasking) and available resources (e.g., autonomy, learning opportunities, peer support) (Bakker & Demerouti, 2007), the assessment of them is performed.

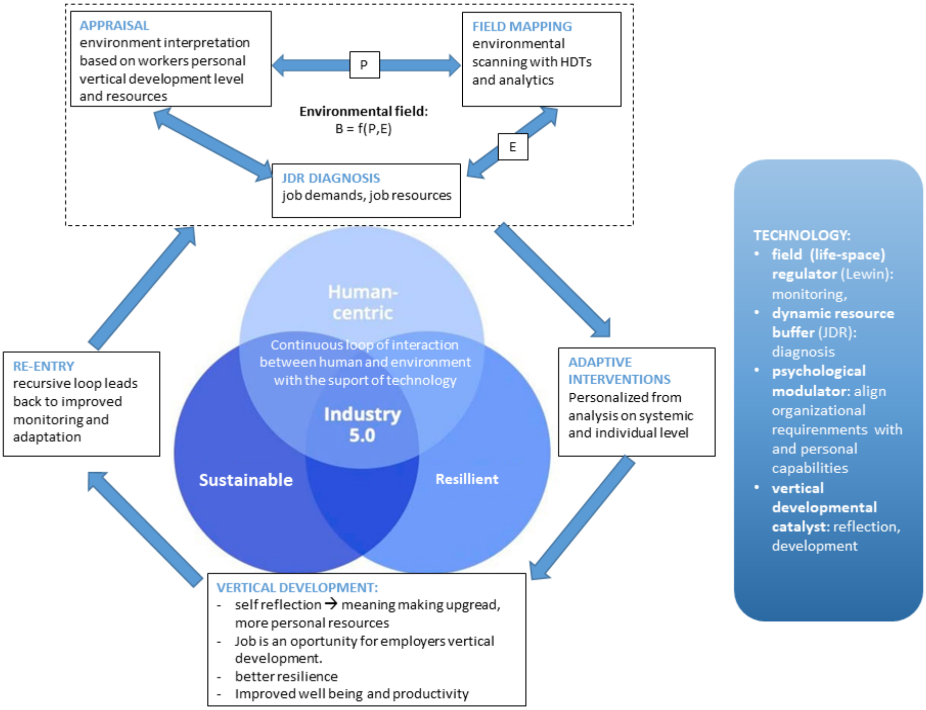
4 Adaptive intervention: Based on the recorded states and assessment, interventions are made at both systemic and individual level. Based on the collected data and assessments, adaptive systems can redistribute tasks, adjust the pace of work or provide customised feedback— - thus changing the balance between resources and demand. At the same time, individuals engage in job crafting(e.g., renegotiate boundaries, seek feedback, adapt workflows), leveraging the autonomy and transparency offered by Industry 5.0 tools. This dual adaptation operationalises Lewin's principle of field regulation. This is the dynamic centrepiece of the FDD control loop that supports Industry 5.0 visions of cyber-physical systems that evolve

through real-time feedback from human operators. It is based on an iterative, feedback-driven evolution, that combines human and systemic intelligence. The workplace itself should be viewed as a two-way feedback loop that influences both personal growth and environmental change. Individuals are constantly interpreting and responding to their environment, which in turn evolves based on these responses. Technology, when integrated appropriately, can reinforce these cycles.

5 Vertical development (growth): A key innovation of the FDD loop is that it tailors interventions not only to the demands and resources, but also to the meaning-making abilities and vertical development levels of workers. This represents the assessment of the workers' developmental order, e.g., whether they start from a socialised, self-authorising or self-transforming mind. From this assessment, we can predict how each individual will assess and respond to field forces, facilitating customised interventions. For example, feedback can be provided in different ways — structured, directive prompts for socialised people, reflective cues for self-determined people, and meta-framing for people who are changing themselves (Kegan et al., 2016).

6 Reintegration: outcomes such as engagement and wellbeing are monitored. As developmental capacity increases, the environment is perceived differently, altering subsequent cycles. The forces of the field are remapped: Increased driving forces (e.g., perceived support) and decreased restraining forces (e.g., cognitive overload) gradually shift the field, in line with Lewin's theory, promoting sustained behavioural and developmental change This recursive dynamic means that behaviour (B) evolves over time as a function of the person and the environment. As the person's developmental capacity expands, the same environment (E) is now experienced differently — demands are reformulated, resources are mobilised more effectively. Over time, this contributes to organisational resilience and is in line with the goal of Industry 5.0 to achieve continuous co-evolution between people and technology.

Figure 4: The Field-development-demand (FDD) loop



Data on the different phases of the FDD cycle can be collected using both quantitative and qualitative methods. Job demands, job resources, burnout, and engagement can be assessed using standardised instruments from the JD-R framework, such as the Utrecht Work Engagement Scale or the Maslach Burnout Inventory. Vertical stages of development can be determined using validated measurement tools such as the Sentence Completion Test (SCT), the Leadership Development Framework (LDF), or reflective development diaries that capture changes in meaning-making skills over time. To monitor real-time states, physiological and behavioural data — such as heart rate variability, sleep quality, task switching frequency, and workload metrics — can be captured using (HDTs. In addition, qualitative approaches such as interviews and focus groups offer insights into subjective experiences with development measures, cultural interpretations of job demands and resources, as well as perceptions of HDT-supported procedures.

The resulting data should be analysed within a multi-layered framework: (1) at the individual level, focusing on personal resources, developmental status, and indicators of well-being; (2) at the team and organisational level, assessing collective engagement, collaboration, and resilience; and (3) at the systemic level, assessing long-term outcomes such as employee retention, innovation capacity, and community resilience.

By embedding recursive cycles, the FDD loop enables both short-term adaptation and long-term development. Workers not only cope with stress, but gradually evolve in their ability to deal with complexity. Together, they represent a cyclical process in which individuals and environments co-evolve through adaptive feedback and technological mediation. This loop highlights that Industry 5.0 is not a static optimisation, but a dynamic co-evolution between humans and the environment. It is not just about balancing stress and engagement, but about gradually improving the system's capacity for complexity.

3.2 The Role of Technology in the FDD Loop

In Industry 5.0, technology is not a neutral tool, but an active participant in the psychological and organisational sphere. In the Field Development Demands (FDD) loop, technology acts as a field regulator, resource buffer, and development framework. It continuously modulates the interaction between people and the environment, helping organisations to balance job demands with resources while promoting vertical development and human well-being (Breque et al., 2021; Gaffinet et al., 2025). Technology enables every stage of the FDD loop:

- Monitoring with sensors, HDTs, wearables to detect work stress, fatigue, cognitive overload, etc.
- Diagnosis with AI dashboards, JD-R analyses to detect an imbalance between needs and resources or to assess the vertical stage of development.
- Adaptation through redistribution, of tasks and breaks to dynamically adjust and balance the workflow. Smart environments adjusting lighting, acoustics, and work pace based on detected fatigue or concentration levels. AI-driven task prioritisation can reduce cognitive overload by automating repetitive tasks. Workflow-based digital twins simulate peaks in demand and enable organisations to proactively reallocate resources.
- Reflection with AI reflection prompts, simulations to customise feedback loops. Adaptive interfaces tailored to employees' cognitive styles, reduce overload and improve concentration. Vertical development with customised instructions: In the early stages, employees can be reminded to take breaks or reassign tasks, while in the later stages they
- can be prompted to think with reflection prompts. In this way, technology helps sustain equilibrium by balancing restraining and driving forces in the field.
- Development with virtual/artificial reality enhances experiential learning. Dashboards that integrate purpose-driven metrics (e.g., Ikigai-inspired tools) promote alignment between personal and organisational goals and improve vertical growth. Personalised coaching applications promote self-efficacy, resilience, and

autonomy. On-demand learning platforms (e.g., LinkedIn Learning, Coursera) provide just-in-time development opportunities, reinforcing resources to buffer demands. Reflective AI tools encourage self-questioning, simulations allow employees to immerse themselves in ethically complex scenarios

- A recursive loop leads back to improved monitoring and adaptation.

In line with Lewin's field theory, technology shapes the "life space" of employees by structuring experiences of autonomy, competence, connectedness and meaning. In resource-constrained contexts, technology also acts as a psychological modulator, making incremental adjustments to align organisational requirements with individual capabilities, in line with Industry 5.0 principles of inclusivity and sustainability. Beyond regulation, technology acts as a dynamic resource amplifier within the Job Demands–Resources model (Bakker & Demerouti, 2007), which strengthens resilience, self-efficacy, and adaptability by redistributing tasks, automating routine processes, and providing timely development opportunities. These systems ensure that employees experience demands not just as hindrances but as challenges that foster growth. Technology also contributes to vertical development by promoting sense-making, perspective-taking, and the alignment of personal and organisational goals through reflection and experiential learning mechanisms (Kegan, 1994; Cook-Greuter, 2004). Through these functions, technology within the FDD loop operationalises the human-centric vision of Industry 5.0, by embedding sustainability and adaptability into organizational practice while integrating productivity, well-being, and long-term development progress.

4 Organizational and Policy Implications in the Context of Industry 5.0

The introduction of Industry 5.0 in practise requires not only technological innovations, but also organisational and political changes. Successful implementation of the FDD loop depends on moving from control-orientated management to adaptive, collaborative leadership. At the same time, supportive policies at local, national, and EU level are needed to embed ethical safeguards, enable local implementation, and ensure inclusive access to Industry 5.0 practises. Effective governance requires participation at multiple levels: at the organisational level (ethics committees with worker representatives), at the regional/local level (alignment with local cultural norms and development priorities) and at the EU level (policy frameworks that incentivise people-centred, ethical HDT adoption). Such participatory oversight aligns with the emphasis on subsidiarity in Industry 5.0, which ensures that decisions are made at the most locally competent level while maintaining European alignment (Breque et al., 2021).

4.1 Organizational-Level Implications

At an organisational level, the transformation to Industry 5.0 requires new forms of leadership and personnel management. Managers must act as adaptive facilitators of the co-evolution of people and technology, cultivating trust, transparency, and co-creation rather than exercising hierarchical control (Torbert & Associates, 2004). Human Resources (HR) needs to integrate JD-R diagnostics into surveys, incorporate developmental feedback, and create conditions for job crafting. HR should also adopt the logic of deliberately developmental organisations (Kegan et al., 2016), where vertical growth is treated as a key organisational outcome. Learning systems should include reflective practises, mentoring, and peer dialogues to ensure that vertical development is encouraged in everyday work. Organizational policies must explicitly ensure the ethical use of HDTs, to prevent surveillance or misuse, while ensuring transparency and employee participation in the design of adaptive interventions.

Exemplar Case: Regional SME Manufacturing Cluster

Small and medium-sized enterprises (SMEs) form the backbone of European manufacturing, and often lack the resources for sophisticated HR systems in countries such as Slovenia, Italy and Germany, but are central to the adoption of Industry 5.0 at a local level (Mihajlović, 2022).

Application of the FDD loop:

- **Field mapping**: interviews with managers and workers reveal restraining forces such as unpredictable spikes in demand, physical fatigue, skills gaps (in digital literacy), limited financial and human resources for large-scale change, and driving forces such as community identity and cohesion, pride in craftsmanship, flexibility in experimenting with new tools.
- **Development profiles:** Many workers operate from a socialized mind, valuing team norms and external guidance. Others (especially younger engineers) show signs of self-authoring, prioritizing autonomy.
- **JD-R diagnosis:** They show high physical demands combined with moderate autonomy and limited structured feedback.
- **HDT integration:** Low-cost, wearable sensors could detect fatigue; HDTs would model and balance workload and provide adaptive assistance. For socialised workers, nudges emphasise collective responsibility ("Let's rotate tasks to help the team"); for self-authoring workers, nudges emphasise autonomy ("You can optimise your own cycle by taking a break now").

Such an assessment and corresponding measures can lead to less strain on the musculoskeletal system, a better perception of fairness, and greater work commitment. By aligning Lewin's forces, developmental tailoring, JD-R balancing and the use of modular HDT systems adapted to the local context, SMEs improve sustainability without high capital expenditure. The key lies in adapting technological interventions to the cultural norms and development profiles of the workforce.

4.2 Municipal and Regional Policy Implications

Local authorities act both as employers and as political mediators. They can lead by example by embedding HDTs in their own administrations, and demonstrating how technology supports wellbeing and resilience. Local governments also play a catalytic role in supporting SMEs by providing subsidies, tax incentives, or grants for human-centred technologies. Regional innovation centres can coordinate pilot projects, linking academia, SMEs, and public administrations to jointly develop scalable Industry 5.0 solutions, fostering trust, transparency, and inclusivity.

Exemplar Case: Municipal Administration

Municipal administrations in Europe are facing increasing pressure to digitalise, while at the same time having to ensure equitable citizen services. Employees are confronted with administrative overload, changing (fragmented) digital platforms, and political responsibility stress.

Application of the FDD Loop:

- **Field mapping:** driving forces include commitment to public service, existing participatory administrative traditions, and pressure to modernise digital services for citizens; restraining forces include bureaucratic burden and digital fragmentation, and high cognitive demands on staff due to policy complexity.
- **Development profiles**: Staff are diverse — some with socialised orientations (following policy scripts, structured digital training modules), others with self-authoring capacities (dealing with ambiguity through adaptive planning).
- **JD-R diagnosis:** High cognitive demands (digital tools, regulations) combined with insufficient resources (clarity, training).
- **HDT integration:** A municipal pilot uses HDTs to monitor the switch between digital tasks and workload. When overload thresholds are detected, employees receive adaptive interventions: The use of tutorials for those who prefer structure, or prompts to redesign systems for those who prefer autonomy. Collective framework are used for retraining ("Progressing together as a community.").

The measures would lead to a lower error rate, higher employee satisfaction (who feel more supported and autonomous), and more efficient service delivery. As HDTs support the development framework, employees gradually move to more complex meaning-making through resource-rich stimulation.

Municipalities are often early adopters of participatory governance models. Integrating Industry 5.0 principles is not only about efficiency, but also about building public trust and transparency. A municipality that exemplifies people-centric practises can set a precedent for local businesses and community organisations.

4.3 National Policy Implications

At national level, the principles of Industry 5.0 must be integrated into labour, education, and innovation strategies. Key mechanisms include: (1) national funding programmes that enable SMEs and public organisations to adopt HDT and adaptive learning systems, (2) regulatory frameworks that protect workers from technostress and algorithmic intrusion while ensuring the right to continuous learning, and (3) reforms that embed Industry 5.0 principles into vocational education and training curricula, with a focus on digital literacy, resilience, and vertical development.

Exemplar Case: Community Reskilling Initiative

European rural and peri-urban regions often experience demographic changes that require retraining initiatives to prepare workers for the tasks of Industry 5.0 (Breque et al., 2021).

Application of the FDD Loop:

- **Field mapping:** Restraining forces include low digital literacy, economic uncertainty and scepticism towards new technologies. Drivers include a strong local identity and a willingness to learn when the relevance is clear.
- **Development profiles:** Some operate at socialized stage (seeking community support), others at the self-authoring stage.
- **JD-R diagnosis**: High demands (learning curve, uncertainty), low resources (training, digital access).
- **HDT integration:** HDTs are integrated into the community training programmes, adapting the digital learning tasks to the individual's pace and level of development. For socialized learners, messages emphasise collective progress (“Your peers are making great progress, join in!”). For advanced learners, the messages emphasise individual mastery and contribution to local innovation.

Outcomes include improved training completion rates, greater confidence in using new digital tools, strengthening community resilience, and enabling smoother adoption of Industry 5.0 practises. The FDD loop here directly supports regional cohesion, resilience and inclusive growth, by ensuring that vulnerable groups can also actively participate in the digital transition and fostering intergenerational solidarity.

From these cases, several cross-cutting insights can be identified. Scalability is facilitated by modularity, as HDT architectures can be configured along a continuum ranging from simple wearable applications in small and medium-sized enterprises to comprehensive digital ecosystems in the public sector. Furthermore, the effectiveness of such interventions depends on their cultural and developmental appropriateness, which requires sensitivity to both local value systems and the developmental sequence of individuals to ensure contextual relevance and user acceptance. Finally, the FDD loop proves to be a resilience-building mechanism by simultaneously strengthening individual capabilities to cope with job demands and organisational capabilities to adapt to changing environmental conditions.

5 Ethical and regulatory considerations in the use of human digital twins in the FDD Loop

While HDTs and the broader FDD loop create opportunities to balance industrial performance with human well-being, they also raise profound ethical and regulatory challenges. Ethical safeguards are not optional add-ons, but essential elements of responsible, human-centred Industry 5.0 innovation (Breque et al., 2021).

Data Privacy and Ownership

HDTs rely on highly sensitive personal data, including physiological signals, emotional states, behavioural patterns, and developmental assessments. The misuse of such data — whether for surveillance, punitive practices, or commercial exploitation — poses a significant risk to the dignity and trust of workers. Effective governance must therefore ensure data ownership (workers retain full ownership of their HDT data), informed consent (explicit, informed consent with clear boundaries), regulatory alignment (in line with the General Data Protection Regulation and the forthcoming EU Artificial Intelligence Act). Equally important is transparency about how data is collected, modelled and used. Without transparency, employees may perceive HDTs as surveillance tools rather than development supports, which undermines trust and engagement.

Autonomy and Non-Manipulation

Adaptive interventions must respect the autonomy of employees and avoid manipulative interventions. Labelling a workload adjustment as a 'team contribution' may be developmentally appropriate for employees at earlier stages of meaning-making, but if applied coercively, it risks reinforcing dependency rather than fostering growth. Ethical deployment requires a participatory design, in which employees actively shape the interventions that affect them. This ensures that the technology serves as a framework for development and well-being rather than a mechanism of subtle control.

Fairness and Non-Discrimination

Developmental assessments harbour the risk of being interpreted as fixed labels. Misuse could reinforce exclusion, stigmatisation or stratification within organisations. Instead, development profiles should be used to tailor learning opportunities, align resources, and provide supportive feedback. Fairness also requires equal access across organisational contexts. The benefits of HDTs should not be limited to large, well-resourced companies; SMEs, municipalities, and community organisations must also have access to people-centred technologies to prevent widening social and economic inequalities.

Participatory Oversight and Governance

To be consistent with the principles of Industry 5.0, governance frameworks must emphasise participatory oversight. Workers, managers, policy makers and civil society actors should jointly create oversight bodies that ensure ethical accountability, transparent communication, and continuous improvement of HDT applications. Participatory councils and ethical review bodies can ensure that implementation considers both collective and individual well-being.

6 Conclusion

Industry 5.0 is not just a continuation of the digital transformation, but a systemic reorientation that integrates technological, psychological, and ethical dimensions into industrial practise. The proposed Field Development Demands (FDD) loop shows how Lewin's field theory, the Job Demands–Resources model, and the theory of vertical development can be operationalised through Human Digital Twins (HDTs) to create adaptive, human-centric workplaces.

The framework shows that behaviour in organisations is dynamic, and arises from the continuous interaction between person and environment, moderated by developmental capability and balanced by resources and demands. Technology, when used ethically, acts as both a field regulator and a development catalyst, ensuring that industrial systems evolve in line with human needs rather than against them.

Empirical examples at the local level show that the principles of Industry 5.0 can be effectively implemented even in resource-constrained environments, as long as the measures are developmentally tailored and culturally sensitive. This emphasises the flexibility and inclusivity, of Industry 5.0 and its potential to scale resilience, sustainability, and empowerment in different European contexts.

Policy implications emphasise the importance of multi-level governance. Organisations need to adopt participatory and developmental approaches; municipalities should act as laboratories for people-centred governance; national frameworks need to embed Industry 5.0 into education, work and innovation systems; and EU-level initiatives such as Horizon Europe and the Artificial Intelligence Act need to ensure ethical alignment and scalability.

Methodologically, future research needs to address gaps in validity, scalability, cross-cultural adaptation, and longitudinal impact. By combining quantitative JD-R measures, developmental diagnostics, HDT-based sensing, and qualitative insights, researchers can empirically validate and refine the FDD loop as a scientifically robust paradigm.

Looking to the future, Europe's leadership in Industry 5.0 will rest on its ability to harmonise theory, practise, and governance in the service of human well-being. Industry 5.0 offers the opportunity to reconceptualise work as an area of productivity and personal growth, moving from efficiency to resilience, from horizontal training to vertical development, and from standardised designs to adaptive systems. If realised, this transformation has the potential to create not only smarter industries, but also stronger and more resilient communities across Europe.

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