

# From Technology-Driven to Human-Centered: Organizational Capabilities for Sustainable Digitalization in SMEs

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## ABSTRACT

Digitalization is rapidly changing industrial work systems. Amidst this globally experienced transformation process Finnish working life has faced slow productivity growth and increasing problems in employee well-being. Manufacturing and logistics sectors are under pressure to adopt new digital technologies, and change is often not managed in a sufficiently human-centered way. This study examines how digitalization is managed in small and medium-sized enterprises (SMEs), and how human factors and ergonomics (HFE) are addressed in this regard. This study is based on interviews with management and expert representatives from 55 SMEs. Data were analyzed using deductive, theory-driven content analysis, structured along dynamic capabilities (sensing, seizing, shifting) across the processes of management, design and HFE. Digital technologies were typically introduced on technological and economic grounds, while HFE was weakly embedded in routines and decision-making. Digital change procedures were often unclear; information on human work was fragmented and rarely used systematically. HFE competence was narrow and focused on physical ergonomics, with limited attention to cognitive and organizational factors. Training needs were seldom assessed in a structured way. Across sensing, seizing and shifting, employee input was common but rarely translated into systematic analysis, decision criteria, or lifecycle monitoring of usability, occupational safety, workload and well-being at work. Building on these findings, the study presents an initial version of a human-centered assessment framework to guide selection, design, piloting, training, and continuous follow-up after adopting new technology.

**Keywords:** Digitalization, Dynamic Capabilities, Human Factors and Ergonomics (HFE), Logistics, Manufacturing, SMEs

## INTRODUCTION

Digitalization and related ongoing technological transformation in industrial working life, often referred to the *Industry 4.0* phenomenon, are pushing manufacturing and logistics companies toward more connected, data-driven,

and automated work systems to develop their business performance. But such technology-first changes can backfire if human factors (HF) are left out. From the employee perspective, jobs can become more monotonous, but on the other hand cognitive workload and stress can rise, and employees' acceptance towards the technologies can drop (Reiman et al., 2021). In addition, to potentially affecting human health, well-being and safety, some of the expected performance gains may also leak away into extra costs resulting from increased errors, underuse and dysfunction, affecting hence also the business performance. In the literature these costs are often discussed as "*phantom profits*" that refer to the anticipated profits of a technological investment that fails to appear as they are eroded by HF problems and resulting underperformance of the system (Grosse et al., 2024; Sgarbossa et al., 2020)

Human factors and ergonomics (HFE) as a design-oriented scientific discipline is meant to improve both system performance and worker well-being (e.g., Dul et al., 2012). In the literature, it has, however, been constantly argued that it is often treated too narrowly (Grosse et al., 2024; Reiman et al., 2021). In manufacturing, HFE is frequently positioned within health and safety functions, which can limit its role in broader design and management decisions (Greig et al., 2023). When examined from a more complex sociotechnical system performance, like from a manufacturing process perspective, more emphasis should be paid to cross organizational, geographical, cultural, and temporal boundaries, which increases coordination needs and failure points. This demands better integration of physical, cognitive, and psychosocial aspects of HFE and a deeper focus on how systems evolve during real use, not only at rollout (Carayon, 2006).

Empirical evidence from industrial contexts highlights how these problems show up in practice during digital transitions. For instance, in a study by Kadir and Broberg (2020), ten industrial case studies showed that the move toward Industry 4.0 often affected employee well-being and performance differently across phases (before, during and after implementation): companies can experience a difficult "during implementation" period where problems and uncertainty peak before things stabilize. At the organizational level, an in-depth manufacturing case study on metrics found a clear disconnect between engineering metrics and HFE metrics, where HFE information can be seen as less credible or less decision-relevant, making it harder to embed human considerations into core decisions. (Greig et al., 2023; Reiman, 2024a).

One useful way to systematically implement HFE in manufacturing and logistics processes is presented by Reiman et al. (2024b). In their manufacturing focused road map study, a well-known business-oriented dynamic capabilities theory (e.g., Teece, 2007) was adopted to HFE. A systematic review organizes dynamic capabilities into a practical taxonomy under sensing-seizing-transforming, offering concrete language for what these capabilities look like in practice (Leemann and Kanbach, 2022). Accordingly, also from the HFE perspective (see Reiman et al., 2024b), companies need the ability to sense opportunities/needs, seize them through decisions and design, and shift or transform their routines so change actually sticks. Building on that logic, Reiman et al. (2024b) argue that manufacturing companies often don't fully

understand the value of HFE, leading to technology- and production-oriented solutions where human skills and capabilities are neglected. It proposes integrating HFE across sensing, seizing, and shifting when seeking, selecting, and implementing new technologies (Reiman et al., 2024b).

Taken together, above literature points to a research gap: digitalization is often justified mainly on technical and economic grounds, while HF are weakly embedded in routines, decision criteria, and follow up especially in sensing and seizing and during the unstable implementation period (Greig et al., 2023; Leemann and Kanbach, 2022; Reiman et al., 2024b). In this study, we delve into this from a small and medium-sized enterprises (SMEs) perspective. SMEs are essential drivers of economic growth all over the world (e.g., Business and Industry Advisory Committee to the OECD, 2025). From the strategic management perspective, they often have more limited resources or competencies (e.g., Durst et al., 2024; Sotamaa et al., 2025), compared to larger companies, making them a fruitful topic for research. The aim of this study is to examine good practices and deficiencies in the structures, processes and practices of an SME for a) searching for new technological solutions, b) planning the implementation of selected technological solutions and c) implementation and use.

## METHODS

Recent Finnish statistics and reports indicate a need for a better allocation of production factors, i.e. physical (e.g. technology, production facilities) and human (e.g. workers, skills) capital to increase productivity (e.g., Fornaro et al., 2021). Simultaneously with that, recent reviews and recommendations of key Finnish working life actors point out worrying trends in employee well-being and its development (e.g., Finnish Institute of Occupational Health 2025; Lahti et al., 2025). We argue that a better design-scientific understanding of human work would provide workplaces with more capacity to seek sustainable solutions and make informed decisions to allocate physical and human capital and thus to simultaneously develop well-being at work and productivity. To participate in this discussion, this study uses a qualitative approach to examine how digitalization is managed in Finnish industrial SMEs and how HF are addressed in decisions on work and technology. The empirical material comes from the ongoing national DigiCompetent project, which investigates digital transformation in manufacturing and logistics in SMEs. For this paper, the analysis draws on semi-structured interview with representatives from 55 Finnish SMEs in manufacturing and logistics. Of those, 10 had 1–9 employees, 28 had 10–49 employees and 17 employed over 50 employees. Companies were recruited via regional development companies and associated networks, targeting SMEs that were actively searching for, piloting, implementing, or using digital technologies.

Company-level interviews were conducted as personal or group interviews with management and expert representatives participating as informants. These informants (1–5 per company) were appointed by the companies themselves. The interviews focused on adoption of digital technology and change management practices, with particular attention to how employee

perspectives, work requirements, and HF considerations are incorporated into planning, investment decisions, implementation, and follow-up. The interview guide was developed in collaboration with the author group, including diverse backgrounds on HFE, industrial engineering and management, futures research, safety, management, manufacturing, and production technologies. The interview guide included six sections (Digi strategy and management; Sensing new technologies; Seizing new technologies; Shifting new technologies into use; Data utilization and management; Wellbeing at work and productivity), all of which included 4 to 9 questions (for total of 31 questions). The questions were tailored to deepen understanding of HFE in the context of new technology implementation in manufacturing and logistics. Interview durations ranged from 43 minutes to 130 minutes, with an average length of 73 minutes. All interviews were recorded, transcribed and analyzed in NVivo using theory-driven qualitative content analysis. Transparency of the qualitative analysis was supported through iterative coding, analytic memos, and regular peer discussions within the research team, with early-stage cross-coding by co-author.

The analysis followed a deductive coding strategy and was structured around three dynamic organizational capabilities – sensing, seizing, and shifting – to capture how organizations identify needs and opportunities, make and execute technology-related decisions, and adapt practices over time. In parallel, the coding was organized across the cross-cutting organizational processes – Management, Design, and HFE see (Reiman et al., 2024b) – to identify the organizational practices and processes, the companies had on these in relation to the aforementioned capabilities when it comes to HFE. In addition, the analysis aimed to identify where and how human-centered considerations enter (or fail to enter) everyday routines and decision-making. The findings are discussed in a first draft version of a structured assessment framework of human-centered digitalization practices in SMEs and enable systematic comparison across organizations.

## RESULTS

This study examined the main practices and gaps observed in SMEs' structures, processes, and day-to-day ways of working when (a) searching for new technologies, (b) planning implementation, and (c) operating and sustaining the use of technologies. These phases align with sensing, seizing, and shifting across the technology lifecycle. Across interviews, digitalization was generally seen as beneficial for productivity, quality, traceability, and competitiveness. At the same time, attention to HFE was uneven. Many companies spoke about occupational safety and personnel risk, but fewer described systematic attention to physical, cognitive, and psychosocial ergonomics when evaluating or using digital technologies. Where ergonomics was addressed, it most often focused on physical strain; cognitive workload and psychosocial factors were mentioned less and handled less systematically.

### (a) Searching for new technological solutions

A recurring pattern was that technology search was not managed as a formal process. In some companies, new technologies were not actively

sought at all, or there were no clear routines, roles, or decision points for scanning and selecting solutions. More often, search was reactive: companies started looking when bottlenecks emerged, capacity had to increase, or a concrete production problem forced change. A smaller group described a more proactive stance where staying ahead of competitors guided scouting. In sensing terms, signals about opportunities were often situation-driven rather than systematically scanned and assessed.

External sources dominated the search phase. Trade fairs, suppliers, and sales contacts were common channels for learning what is available. Customer requirements were another strong driver, (e.g., standards, documentation, data), framing digitalization as compliance/delivery-driven rather than capability development.

Employees were frequently involved in discussions about needs and practical pain points, and in some cases technology search relied heavily on employee initiative. This created a bottom-up pathway for improvement, but it also made search uneven: it depended on who happened to be engaged, how busy production was, and whether management attention was available. Ergonomics was addressed mainly as physical; cognitive workload and psychosocial factors were rarely assessed systematically.

Demos and trials were widely used to evaluate technologies. These trials focused on functional fit, production performance, and safety. Physical ergonomics was sometimes checked, typically informally, while cognitive workload and psychosocial impacts were not often assessed as explicit criteria. This creates a risk that solutions meet production and compliance goals but still increase employee burden.

#### (b) Planning the implementation of selected solutions

Companies differed in how broadly they involved people during implementation planning. A common good practice was whole-team involvement, where planning, commissioning, and early use included both management and shop-floor employees. This helped surface operational constraints early, speed up learning, and improve acceptance.

A second pattern was staged involvement: a smaller group (managers, supervisors, or key users) was involved first, with broader involvement later once the plan was more fixed. This could make implementation manageable, but it increased the risk that early decisions were made without enough worker input, where many HFE issues only become visible in real use.

A clear gap appeared where planning stayed within a small group and did not include workers. In those cases, the process relied on managerial judgement or supplier guidance, and the workers largely had to adapt after decisions were made. This increases friction during roll-out, especially around usability, training needs, and shifts in workload or task allocation.

Across approaches, HFE rarely appeared as an explicit planning target. Even when teams were involved, discussion focused on getting the technology running, ensuring safe operation, and meeting production goals. Ergonomics and employee well-being were more often treated as general values than as concrete implementation requirements or follow-up criteria. In seizing terms, companies emphasized commissioning, piloting, and training (often with external providers), while HFE was mainly present through safety checks and physical ergonomics.

(c) Implementation, operation, and sustained use

During operation, many companies described ongoing monitoring and evaluation using indicators such as safety, quality, productivity, environmental issues, sustainability, and operability. Some used audits and formal standards, where others relied on more informal reviews. This monitoring culture is a strength because it treats implementation as an ongoing practice rather than a one-off project.

However, HFE was not consistently included in what was evaluated. Safety risks were commonly discussed, but fewer described systematic assessments of ergonomics or psychosocial strain related to digital tools and new ways of working. Where ergonomics was considered, it was typically physical; cognitive demands and psychosocial aspects were less visible in routines and metrics. From a shifting perspective, companies tend to monitor operations and compliance over time, while HFE follow-up remained narrower and more uneven.

A second gap was the weak link between data collection and action. Several companies collected extensive operational data, but not all made full use of it. Information about how work is actually done was often scattered across informal observations, isolated incidents, or external reports, and it was rarely integrated into a systematic input for decisions. Similarly, feedback practices ranged from lacking a clear system to relying on informal channels. Informal communication was often effective for surfacing problems quickly, but it could also be uneven depending on team climate and whether concerns were raised consistently.

Training and competence development showed mixed maturity. Some companies provided some training (internally and/or through external systems such as occupational health services), but training related to digitalization and HFE was often reactive rather than planned. Ergonomics expertise was commonly brought in from outside; while this provided assessments and recommendations, the step from report to changes in work design, training, or system configuration was not always clear. This arrangement brought expertise in, but it also meant internal HFE competence often stayed limited, and attention remained biased toward physical ergonomics.

Finally, companies pointed to practical barriers: limited time and money, limited internal competence related to HFE, and a lack of clear guidance linking digitalization decisions to HF. Change management was also a recurring operational issue. Several companies reported resistance to change, often described as more visible among older workers. Where companies described continuous improvement routines and shared learning, they also tend to report smoother adaptation. Where routines were weaker, implementation depended more on ad hoc problem-solving after issues appeared.

## **DISCUSSION AND CONCLUSIONS**

This study examined how Finnish manufacturing and logistics SMEs manage digitalization across three phases of technology adoption process – searching for solutions (sensing), planning implementation (seizing), and operation and sustaining use (shifting) see (Teece, 2007) – and how HFE enters these practices. Overall, digital technologies were typically introduced on technological and economic grounds, while HFE was weakly embedded in

routines and decision-making. Occupational safety and physical ergonomics were more visible than cognitive workload and psychosocial factors, which were less often made explicit as evaluation targets. Across phases, employee input was commonly present, but it was rarely translated into systematic analysis, decision criteria, and lifecycle monitoring of usability, workload, and employee well-being. These findings support the need for practical, human-centered assessment approaches that help SMEs integrate HFE into selection, piloting, training, and continuous follow-up over the technology lifecycle. To guide selection, design, piloting, training and continuous follow-up over the technology lifecycle from a HFE perspective, an initial human-centered assessment framework is presented in Table 1. The framework provides the companies with practical guidance on how HFE should and could be acknowledged when sensing new technologies, seizing these opportunities and shifting the technology in practical use.

**Table 1:** Human-centered assessment framework for SMEs in new technology transition.

Phase	Assessment Criteria
Sensing	<ul style="list-style-type: none"> <li>• Make HFE (physical + cognitive + psychosocial) an explicit criteria when looking for new technology, rather than focusing only on functionality.</li> <li>• Use HFE competence early to gather observations and feedback on organizational factors before acquiring new technology.</li> <li>• Move beyond reactive scouting triggered only by immediate operational constraints or capacity issues. Identify technological opportunities proactively.</li> <li>• Use systematic processes to involve employees in identifying opportunities and defining technology needs.</li> <li>• Identify digital skills and training needs early and reserve time for learning.</li> </ul>
Seizing	<ul style="list-style-type: none"> <li>• Set HFE as an explicit planning target and specify the conditions required for workable daily user experience.</li> <li>• Use demos and trials to assess human impact and workload, not just operational performance or occupational safety compliance.</li> <li>• Establish formal, regular feedback channels to review user experience systematically rather than relying on ad-hoc comments.</li> <li>• Broaden involvement beyond a small group of managers. Bring in operations-level employees before implementation plans are finalized.</li> <li>• Integrate training into the implementation plan and tie it directly to real work tasks and use cases.</li> </ul>
Shifting	<ul style="list-style-type: none"> <li>• Include HFE (specifically mental workload and employee well-being) in regular operational monitoring alongside productivity and quality metrics.</li> <li>• Create formal feedback practices that do not rely solely on informal talk, ensuring all concerns are consistently raised.</li> <li>• Ensure training and competence development are planned and proactive as digital tools evolve, rather than reacting to problems after they appear.</li> <li>• Use audits or standards-based reviews to ensure follow-up remains consistent over the long term.</li> <li>• Assign internal responsibility for turning external occupational health reports into practical changes in daily work routines.</li> <li>• Use shared learning routines to address change resistance and help employees of different age groups adapt to new digital tools.</li> </ul>

## LIMITATIONS

The findings came from interviews with managers and company-appointed experts. This gives a good view of how firms describe their processes, but it may miss parts of everyday work on the shop floor and how employees experience new technologies in practice (see Reiman et al., 2024b). The study was also cross-sectional, so it does not track how HFE integration develops over time or how usability, workload, and work-organization effects evolve after digital tools are in routine use. In addition, the analysis was guided by the sensing-seizing-shifting framing and selected HFE themes. This supports consistency across cases, but it can limit what is captured outside the framework. Finally, the sample focuses on Finnish manufacturing and logistics SMEs, so the results may not transfer directly to other sectors or national contexts.

## FUTURE STUDIES

Future research should test practical ways to integrate HFE into SME technology decisions without adding heavy process overhead. First, the proposed initial human-centered assessment framework should be analyzed of its consistency with the literature and then translated into practical tools (e.g., assessment model or checklist that explicitly introduces HFE criteria for selection and piloting, brief usability/workload checks during early use, and a small set of post-implementation review measures, and validated in real implementation projects. In this regard organizational HFE standards like ANSI/HFES 400 (2021) or ISO 27500 (2016) should be cross-checked. Second, longitudinal studies should track implementations from trials to routine use to see how usability, workload, and work organization change. Third, intervention studies could compare implementations with and without HFE checkpoints to assess effects on usability, workload, acceptance, and sustained use. Finally, it is advisable to strengthen evidence through data triangulation (e.g., observations, training materials, incident logs, and operational measures) and by extending sampling across sectors and countries.

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