

Enhancing workers' participation in technological transitions through a work-centered approach: insights for industrial stakeholders

Promover a participação dos trabalhadores nas transições tecnológicas através de uma abordagem centrada no trabalho: contributos para os agentes industriais

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Abstract: This study was conducted within the scope of a technological transition project in I4.0, implemented in a supplier of technology and services company from the industrial sector in Portugal. In this context, we aim to understand how workers can be actively involved in technological transitions processes to ensure that the specificities of their work are recognized, and their voice is acknowledged. Using a mixed-methods approach (e.g., work observations, interviews, questionnaire), the research followed three technology use-cases at different stages, involving the point of view of the company's development engineering and digitalization team, direct team leaders, and workers whose tasks or functions were to be impacted by the technological changes in the use-cases. Complementarily, other stakeholders (HR, OHS, Production and Logistics managers, Quality manager), and workers also participated. Findings reveal that workers' participation is still often absent or delayed - impacting workers' leeway, collaboration, learning, meaning of work, and work recognition. Individual, collective, and organizational resources were identified as leverage points for action. A participatory and evidence-based framework was developed to support human-centered decisions, enabling the reflection and action of stakeholders that lead technological transition processes, promoting decent, sustainable work through the integration of workers' voices throughout these processes.

Keywords: Industry 4.0; Industry 5.0; Technological transitions; Participation; Work activity.

Resumo: Este estudo foi realizado no âmbito de um projeto de transição tecnológica no contexto da Indústria 4.0, implementado numa grande empresa multinacional fornecedora de tecnologia e serviços do setor industrial em Portugal. Neste contexto, o objetivo é compreender de que forma os trabalhadores podem ser ativamente envolvidos nos processos de transição tecnológica, de modo a assegurar que as especificidades do seu trabalho sejam reconhecidas e a sua voz valorizada. Recorrendo a uma metodologia mista (p.e., observação da atividade de trabalho, entrevistas, questionário), a investigação acompanhou três casos de uso de tecnologia em diferentes fases, considerando o ponto de vista das equipas de engenharia de desenvolvimento e digitalização, das chefias diretas e dos trabalhadores cujas tarefas ou funções seriam impactadas pelas mudanças tecnológicas analisadas. Complementarmente, em momentos-chave, participaram também outros intervenientes (Recursos Humanos, Segurança e Saúde no Trabalho, gestores de Produção e Logística, gestor de Qualidade), bem como trabalhadores de diferentes áreas operacionais. Os resultados revelam que a participação dos trabalhadores continua frequentemente ausente ou tardia - afetando a sua margem de manobra, a colaboração, a aprendizagem, o sentido do trabalho e o reconhecimento do trabalho. Foram identificados recursos individuais, coletivos e organizacionais como pontos de alavanca para a ação. Desenvolveu-se um quadro de referência participativo e baseado em evidências para apoiar decisões centradas nas pessoas, promovendo a reflexão e a ação dos agentes industriais que conduzem processos de transição tecnológica, no sentido de um trabalho digno e sustentável, integrando a voz dos trabalhadores ao longo de todo o processo.

Palavras-chave: Indústria 4.0; Indústria 5.0; Transições tecnológicas; Participação; Atividade de trabalho.

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1 Introduction

The world of work is constantly evolving, driven by digitalization and technological transformation processes. However, the increasing pace of this evolution, and the emphasis placed on the technical-organizational dimension of these processes - even when the promises of increased productivity remain unfulfilled (Ernst, 2022) - do not appear to be matched by the same pace at which operators and their actual work are considered, involved, and given a voice in these processes (Muniz et al., 2023).

Numerous studies have highlighted the lack of workers' participation in the design and transformation of work systems (Barcellini, 2022; Bellantuono et al., 2021; Muniz et al., 2023), and a disregard (even if unintentional) for work activity — that is, the work actually performed on a daily basis, the constraints encountered, and the individual and collective strategies employed to address them (Bolis et al., 2023; Broberg, 2007; Carneiro et al., 2021; Garrigou et al., 1995).

From an organizational and technological transition management perspective, it has also become evident that operational workers still tend to be situated in the I4.0 paradigm far from the construction of a sustainable work (Barcellini, 2022; Thatcher, 2024). Additionally, a lack of accountability among those key stakeholders who typically lead technological transition projects (e.g., engineers, managers) persists in these contexts (Broberg, 2007). Nonetheless, various contributions in literature reinforce the importance of work activity and work analysis (Delgoulet & Santos, 2022; Garrigou et al., 1995), and the relevance of incorporating participatory and constructive principles into transformation processes (Daniellou, 2007; Lacomblez, 2021). These align with current efforts by international organizations to promote sustainable and decent work conditions (European Union, 2021; ILO, 2025), further emphasizing the need to give a voice to workers.

This broader landscape, which seems to characterize professional contexts widely - including the Portuguese context (e.g., Santos et al., 2024) - highlights the urgency of implementing regulatory actions that support stakeholders and decision-makers in adopting human-centered and work-centered processes that actively engage the workers' voice.

Building on these premises and considering the literature gap regarding how workers and their contributions can be meaningfully integrated into technological transition processes, this paper is grounded in a work-activity oriented and work-centered approach to ergonomics and work psychology (Delgoulet & Santos, 2022; Garrigou et al., 1995). It presents a research project in an industrial company in Portugal which has been introducing work digitalization processes across various operational areas.

Aiming to understand how workers can be actively involved in the processes of technological transitions, to ensure that the specificities of their work are recognized and their voice is acknowledged, the study identifies individual, collective, and organizational resources as opportunities for action, and proposes an evidence-based and participatory framework to promote stakeholders' reflection on workers work activity, to understand working conditions, and to anticipate potential impacts on health and professional development. It seeks to implicate decision-makers in technological transitions from a work-centered approach, addressing the why, what for, what, who, when and how to consider work activity and workers in transition processes, providing guidelines and tools as support mechanisms for co-constructed and sustainable transitions that give visibility to the voice of workers, particularly through the inclusion of their work activity in technological transition processes.

2 Theoretical background: linking workers, their work activity and technological transitions processes in industrial settings

2.1 Disregard of work activity with consequences for employees and businesses

Technological changes and innovation processes in work contexts are not new, but their pace has accelerated, particularly since the post-Covid-19 period, becoming a priority for companies in industrial settings (Rani & Grimshaw, 2019). Whether radical discontinuities with significant changes in technical systems and the way work is carried out or incremental improvements in productivity, efficiency and service quality (Briggs et al., 1998; Fogaça et al., 2025; Geels, 2004), these transitions tend to follow techno-centric and "supply push" logics (Ernst, 2022; Neumann et al., 2021), often overlooking demand-pull orientations and broader sustainability-oriented policy goals (Ernst, 2022; Fogaça et al., 2025).

Within this logic, the role of work activity - both present and future - tends to be absent or limited (Broberg, 2007; Garrigou et al., 1995). Central questions such as "What is the current work?", "What are the real constraints?", or "What strategies do workers use to solve problems?" are often overlooked (Broberg, 2007; Carneiro et al., 2021). This disregard for the activity has led to deficient projects, with consequences such as systems that do not meet workers' real needs for performing quality work (Bellantuono et al., 2021).

Within scientific approaches that prioritize activity analysis as “a unique prospective on human work” (Garrigou et al., 1995, p.312) and as a way of understanding industrial processes and transformations (Wisner, 1989), a key issue is highlighted: the lack of consideration for what workers actually do in their work to overcome constraints and solve problems, as well as the regulation strategies they implement to ensure quality and productivity, while preserving their health (Carneiro et al., 2021; Clot, 2008). From this perspective, work activity does not correspond to the carrying out of the prescribed tasks, but rather refers to managing unpredicted variability, mobilizing individual and collective resources, experiences, and value-based debates; to a density that is built over time in response to changes in the work situation itself, and the evolution of individuals (age, seniority, experience, developed skills) (Garrigou et al., 1995). Complementarily, a recent systematic review on Human Factors and Ergonomics (HF/E) and sustainability highlights the absence of intervention at the level of work activity - in contrast to action at an organizational multilevel, external systems, or focus on outcomes/products (Bolis et al., 2023).

In this regard, the literature identifies two main reasons for the lack of consideration of this point of view in the discussion, design, and implementation of technological transitions: i) decision-makers and engineering designers often lack knowledge about real working conditions and how workers manage their tasks (Broberg, 2007; Garrigou et al., 1995); ii) time pressures linked to efficiency goals lead to rushed design processes and limited worker involvement (Broberg, 2007; Ipsen et al., 2020).

In this scenario, how has employees' work been positioned? What do studies show about the kind of concerns that exist about workers during the technological transition processes? The focus of stakeholders in TT tends to be almost exclusively on workers' upskilling and reskilling, assuming that skills updates alone ensure participation (OECD, 2019; WEF, 2020). This approach overlooks scenarios where jobs are eliminated or altered, requiring workers' relocation (Santos et al., 2024).

Recent studies reaffirm earlier findings that any change impacts work activity (Garrigou et al., 1995), extending the debate beyond training issues: AI, in particular, is expected to affect working conditions for those who are employed (Ernst et al., 2024). Yet, there are aspects that tend to be overlooked when discussing the introduction of AI in work contexts, such as its impact on work quality, working hours, mobility, employer-employee relationships (Ernst et al., 2024), as well as more specific elements such as autonomy, work pace, and the overall meaning of work (Bobillier-Chaumon, 2023).

Given this scenario, it becomes crucial to examine how the literature addresses workers' participation and voice in the design and transformation of industrial work systems shaped by technological transitions.

2.2 Workers' lack of participation

Participation in the workplace can be formally defined as “the involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals” (Wilson, 1995, p. 1071). Rooted in participatory ergonomics, which supports the understanding of how different parties can be involved in a design process, this concept is based on the premise that operators should play an active role in shaping changes to their own work environment (Vink et al., 2006).

Despite the extensive body of evidence related to “good ergonomics is good economics” (Vink et al., 2006, p.1), underscoring the importance of acknowledging human work within design and innovation strategies, recent literature on workers' involvement in technological transitions echoes previously raised concerns regarding the neglect of work activity. While the participation of operators in process and technical system design is crucial - given their contextual knowledge of work situations and their ability to speak about the future based on past experience (Garrigou et al., 1995) - workers' contributions are not often involved in transition processes, especially in technology design (Barcellini, 2022; Bellantuono et al., 2021; Muniz et al., 2023). Their participation is most often confined to final implementation stages or training initiatives, based on the assumption that these are sufficient to secure technological acceptance - a perspective that typically results in non-participatory and non-collaborative transitions. Excluding workers from decision-making moments in the projects, and the opportunity to propose suggestions, can limit opportunities to reflect on their own work activity and hinder their development (Barcellini, 2022). This exclusion can affect the quality of their work and, consequently, their health and well-being (Bonnefond & Clot, 2018).

It is important to recognize that technological transitions and the design of new tools or future work systems constitute complex processes of planning and decision-making. At different stages of a project, the project manager (typically from engineering fields) must make technical decisions, often under time and budget constraints (Garrigou et al., 1995). Yet, these decisions still tend to disregard the perspective of those doing the work, as well as their potential impact on workers' health and development.

According to the data from the European Working Conditions Survey (Eurofound, 2017), 31% of workers report that they rarely or never participate in improving their work organization or processes (44% in Portugal), and 27% state that they rarely or never influence decisions important to their work (37% in Portugal).

Evidence suggests that, in the absence of support from leadership - which is essential to facilitate people's involvement - the lack of participation can lead to the development of a "futile voice" (Bonnetfond, 2019), with negative impacts on workers' health (Bonnemain, 2025). Literature further reinforces direct participation as a key factor in the success of such processes (Vink et al., 2006), particularly when groups of workers are invited to participate in simulations of future work systems (Daniellou, 2007). When workers are actively involved, there is a higher likelihood of identifying and mitigating issues that may affect their performance and the quality of their work (Broday, 2021), allowing for the integration of some real work constraints into interventions (Rodrigues & Rocha, 2023).

Further elements critical to the success of these processes include the involvement of diverse stakeholders - such as ergonomists, occupational health representatives, designers, and engineers (Vink et al., 2006) - as well as the role of supervisors, who can either encourage or undermine workers' voice, both directly and indirectly (Rybnikova, 2016).

2.3 Opportunities provided by participatory and work-centered approaches

Building on previously discussed elements, this section outlines key opportunities for promoting the involvement of workers and the recognition of their work activity as a means to improve design processes. These opportunities draw on work-centered approaches that emphasize worker participation in the design of new work situations and technological transitions, aiming to explore how workers can be more effectively included in such processes (Hall-Andersen & Broberg, 2014).

In summary, the literature highlights three main findings: i) while technologies significantly affect work activity, they do not necessarily eliminate all jobs; instead, they often lead to the reassignment or reconfiguration of work roles (Fleming et al., 2019; ILO, 2023); ii) workers are seldom involved in transition processes (Bellantuono et al., 2021), with their participation typically limited to training or to late-stage involvement (Barcellini, 2022); iii) work activity itself is often overlooked (Bolis et al., 2023; Broberg, 2007), resulting in the development of systems misaligned with workers' actual needs for performing quality work and that may pose risks to both professional development and occupational health (Barcellini, 2022; Bellantuono et al., 2021; Muniz et al., 2023).

Given these constraints - and considering recent reflections suggesting that work sustainability implies allowing workers to express themselves not only about their current tasks, but also about how work is done and the nature of goods or services provided (Méda, 2025) - three main opportunities can be identified, aligned with participatory and work-centered approaches. Firstly, the emerging Industry 5.0 (I5.0) emphasizes sustainability principles while adopting a human-centered perspective, aiming to value workers in technological transitions, fostering opportunities for skills development as well as the preservation of their occupational health and safety (OHS) (European Union, 2021; European Commission, 2025). Secondly, these sustainability principles can be integrated from a bio-compatible, ergo-compatible, and socio-compatible perspective (Vendramin, 2016), acknowledging the evolving nature of workers, including age, skill development, working conditions, concerns about career paths, and the need to balance between work and personal life. Thirdly, the design of work situations must incorporate key dimensions: the analysis of work activity and co-design methods that enable the projection of potential future work scenarios (Barcellini, 2021); the promotion of collective action as a driver for improving working conditions, particularly through ongoing dialogue among all involved stakeholders (Lacomblez, 2021); and also, the establishment of representative forms of social dialogue among workers, employers, and governments, which are essential for designing and implementing the changes required to achieve decent work (Rani & Grimshaw, 2019).

3 Method

3.1 Objectives and study conducted

The research was conducted within a technological transition project in an Industry 4.0 context in a large multinational industrial company in Portugal, involving the design and implementation of digitalization use-cases across different operational areas.

In this context, we aim to understand how workers can be actively involved in technological transitions processes to ensure that the specificities of their work are recognized, and their voice is acknowledged. The following research questions have guided the research: i) How are workers and their work activity involved in the design and implementation process? ii) What positions are taken by the stakeholders responsible and involved in the transition processes? iii) What are the main constraints arising from the forms of participation for workers and their work? iv) Conversely, what resources can be identified as opportunities for reflection and action?

In the company, it has been possible to follow three use-cases implemented in the warehouse and production site. The following box (Box 1) clarifies the scope defined by the company's project team for the use-cases.

Box 1. Use-cases under study.

Use-case 1: Introduction of a pallet tracking system in the warehouse, which affected two job functions.
The research was conducted during the use phase (technology was already fully operational and in use by the workers).
Use-case 2: Replacement of a conventional vehicle for delivery of materials in cyclical route systems by a vehicle with a digitalized delivery system, affecting one job function.
The research was conducted both during the implementation (testing of the technology in the operational site) and use phase.
Use-case 3: Digitalization of a product storage warehouse area.
The research was conducted in its current stage - the design phase (discussion around the technology to be implemented and its development).

In the results section, details of the purposes of these use-cases will be presented, as well as the relationship with the impacted functions and the forms/timings of workers' participation throughout the processes.

This study was approved by the Ethics Committee from the Faculty of Psychology and Education Sciences of the University of Porto, Refª 2024-12-17b.

3.2 Methodological approach and participants

This research encompassed an in-depth understanding of the technological transitions in the company's use-cases, focusing on the workers' point of view and on the impact on their work activity. Following a work-activity oriented and work-centered approach to ergonomics and work psychology, a mix-method and participatory methodology (Delgoulet & Santos, 2022; Garrigou et al., 1995) was used, as will be presented in the following section.

The research involved, in closer proximity, the company's development engineering and digitalization responsible/project manager (PM) and a team member, direct team leaders (TL) of workers from each use-case (n = 3), and workers whose tasks or functions were to be impacted by the technological changes in the use-cases – Logistic Operators (LO) and Production Operators (PO) (n = 14). Complementarily, at key moments, other stakeholders (HR, OHS, Production and Logistics managers, Quality manager) (n = 7), as well as workers from different operational areas (n = 95) also participated.

The next section details the data collection and analysis process, considering the data collection moments involving the different participants.

3.3 Data collection and analysis

Over an 18-month period, the research prioritized workers' voices, modes of participation, and knowledge of work activity, focusing on their perceptions of work organization, performance, health, and skill development. Data collected from key stakeholders complemented this analysis, enabling a comprehensive understanding of the purposes, concerns, and worker involvement across the technological transition use-cases.

The data collection and analysis process were adapted to the specific work activity in each use-case and to the data collection modalities that were possible to pursue in the company. Data collection combined: i) document analysis; ii) meetings with key stakeholders (understanding of the process of

designing and implementing the technologies in the respective workstations); iii) observations of work activity and individual interviews (to characterize the change experienced and potential impacts of the transition process); and v) a diagnostic questionnaire (current working conditions, health and training, technology usage experience and perceived impacts, determinants of technological acceptability; current participation and conditions to be ensured in future technology implementation projects in the workplace). The detailed description of methods and instruments in each use-case is presented in Supplementary material (Table S1).

Drawing on the analysis of the different data, the results section integrates and cross-references the findings from the three use-cases, the questionnaire, and the complementary data from stakeholders, to address the main objective and research questions.

4 Empirical findings

4.1 Work activity impacted by the technological transition processes

The data collected through the reconstruction of the process with stakeholders and the analyses of the work activity allowed us to situate, from the outset, the purposes defined for each project (by the company) and the corresponding changes in the functions involved and in the work activity (Table 1).

Table 1. Company's purposes for each use-case and corresponding changes in the functions involved and in the work activity.

	Purposes of the TT	Functions and impact	Impact on work activity
Use-case 1	Reorganization of the warehouse to ensure product traceability.	– 2 functions: 1) Logistic operators that receive the pallets; 2) Logistic operators that verify and label the products;	– Work activity without significant changes;
		– Functions maintained; no reduction in team members.	– Work activity with autonomy and the possibility to have control over work.
Use-case 2	Ensure timely supply to the production line, optimizing the resources used.	– 1 function: Logistic operators that drive the vehicles;	– Work activity with significant changes in the management of work routes; Work activity constrained and restricted mainly to following instructions from a tool, without the possibility of anticipation.
		– Function maintained; no reduction in team members.	
Use-case 3	Enhanced product (PCB) and stock traceability	– 2 functions: 1) Operators who supply the storage area; 2) Operators who pick up the necessary products and transport them to be delivered and used by the final production lines;	– No evidence to report since the project is in the design phase;
		– Existing functions will be replaced by a new one;	– It is expected that constraints could be felt in the new function, as it will encompass the responsibilities of two previous functions;
		– Previous functions will be partially retained (tasks not involving contact with the warehouse area will be preserved)	– It is expected that constraints could be felt in the partially retained previous functions, given the absence of functional variety.

The results highlight specificities associated with each project, even when the stated purposes (resource optimization and system improvement) were similar.

Use-case 1 involved the development of technologies in the warehouse that included integrating a sensor for identification, creating a pallet ID and, consequently, developing software to support product verification and labelling. Two workstations interact with these technologies in distinct ways. Workstation 2

(product verification and labelling) interacts directly with the software and perceives the imposed work pace derived from the sensor's registration of the pallet at Workstation 1. In this case, of the two previously existing functions (logistic operators – LO1), both were maintained, with adjustments in how the activity is performed, but preserving possibilities for autonomy and control over their work.

Use-case 2 included the purchase of vehicles with a digitalized delivery system that began to be driven by the operators. To this end, software was developed for use by the logistic operators (LO2) on personal digital assistant (PDA) devices. This software, powered by a route optimization algorithm for delivering raw materials to production, began to guide the operators' work: the LO2 must follow the instructions on the device (e.g., which wagons to hitch to the vehicle, which route to take), recording each step completed in the PDA. Only once the route has been completed does the PDA generate new instructions for workers about the next route, creating a continuous workflow. In this case, the work activity became constrained and restricted mainly to following instructions provided by a tool, without the possibility of anticipation and full control over their work.

Use-case 3 (still ongoing) involves several changes: elimination of the highest storage level in the warehouse; a shift in the way products are transported (from a PCB unit to PCB cassette containing 50 units); and the organization of the warehouse as a chaotic storage area (i.e., products will be stored in available spaces rather than in specific and exclusive locations). The design team anticipates that a new function – the “warehouse manager” – will be created, replacing both current functions. These functions will be maintained as operators perform other tasks unrelated to storage in the warehouse, leading to a functional reduction. In this case, the discourse of the design team members during concept discussion meetings, notably after the first research team feedback from the collection of data on current work activity, indicates that if knowledge of the work activity is not taken into account in concept discussions, constraints may arise: *“the new worker will probably have to walk many kilometers in the warehouse...”*; *“we still haven’t thought about the people, that’s a fact...”*; *“I didn’t know workers did the work this way... this could be a problem for the concept.”* (Digitalization responsible/project manager).

These findings directly address the research question (i) “How are workers and their work activity involved in the design and implementation process?”, showing that, despite similar organizational purposes, technological transitions lead to markedly different effects on work activity depending on whether autonomy, anticipation possibilities, and workers' margin of maneuver are preserved or constrained.

4.2 Participation forms and work activity consideration: stakeholders' perspectives

It was understood that workers' participation in the processes was absent in some cases and very late in others. Table 2 presents the results in detail, considering the duration of the technological process, moments of workers' participation, and forms of participation.

Table 2. Duration of the technological process, moments of workers' participation and forms of participation (in each use-case).

Process duration and moments of workers' participation		Workers' participation forms
Use-case 1	7 years:	Direct:
	– 4 y. design phase;	– Collection of workers' inputs by their leader; Possibility to suggest improvements to the technological systems.
	– 1 y. implementation; workers' participation	
	– 2 y. use phase; workers participation	
Use-case 2	3 years:	Lack of active participation in the process:
	– 2,5 y. design phase;	– Use of the new tool (PDA) for performing their tasks.
	– 0,5 y. implementation;	
	– 0,5 y. use phase; workers' participation	
Use-case 3	Ten Months; workers' participation	Indirect:
		– Through contributions shared with the research team during observations of their activity; clarifications about how the work is done, constraints felt, suggestions.

Several points stand out, particularly in use-cases 1 and 3. Use-case 1 was unique since workers, supported by leadership, were able to participate directly in the process, albeit late during the implementation phase. While they did not influence the design phase with substantive concerns about their work, they provided improvement suggestions, some of which were implemented.

In use-case 3, workers have not been involved directly. However, they and their work activity were considered indirectly through the research team's mediation, drawing on work activity observations and the identification of workers' concerns, constraints, and suggestions related to the new technology. The research team's activity analysis enabled these workers' indirect participation by bringing their work and voices into early discussions with the design team. Other elements from use-case 3 should be noted. In the monitored design meetings, the technology to be defined and its operationalization fall into two predominant perspectives: an operational management vision, emphasizing production impacts and error reduction (*"Since it would be just one worker [in the new function], it's easier to figure out who made the mistake. (...) The more people handle the warehouse, the harder it is to understand who made the mistake."* Logistic manager), and a technology designing vision, focusing on process optimization and digitalization (*"if we switch to PCB cassette transport, we need to think about the concept for the transport vehicle for the people, otherwise, how will the label on the cassettes be read by the portal?"* (Digitalization responsible/project manager). This reinforces the absence of the workers' perspective and their work in this process. Nevertheless, the feedback provided by the research team in restitution moments gave visibility to critical points of the activity, leading the team to reflect on the process to be designed - *"that very low number of PCBs that you show they transported could be a problem for us... we need to think this through better"*.

Overall, the project manager (and responsible for the digitalization team) also stated that it is not common to consider the perspective of work and people: *"We do not address the work or the project's impact on operators. Sometimes, the operator is discussed in terms of changes in their tasks."* Active participation by OHS and HR was also notably lacking in the TT processes, despite their potential to advocate for worker-related concerns.

The questionnaire data reinforces these findings: 62% of workers reported not being consulted to give their opinion at any phase of the process; and, in future situations, 84% would like their opinion to be considered and valued in technological transition processes within the company.

Following this, the interviews with the different stakeholders revealed some reasons for workers' non-participation and stakeholders' concerns, despite partial recognition of workers' knowledge, as illustrated by the following statement: *"The operators' point of view could be discussed earlier, because they have knowledge of operations. But not only that, they also have knowledge about digitization."* (Production manager). These are summarized in Table 3.

Table 3. Stakeholders' reasons and concerns related to workers' non-participation.

Stakeholders' reasons and concerns	Verbalizations
Concern about not knowing how to involve workers and which ones to involve	<i>"I know when to involve people; namely, during concept validation. But I don't know how... and also, which employees can participate?"</i> (Digitalization Responsible)
Difficulties in taking workers from the production lines to participate	<i>"The main obstacle is how to take workers out of production. This cost will be charged somewhere."</i> (Digitalization Responsible)
Existence of a "comfort" factor associated with isolated conduct/ leadership of the process	<i>"it's more comfortable [for those leading the process] to create a theoretical perception. It's still the path of resistance, although I don't agree (...) the test phase is when the possibility of making adjustments arises [with input from operators]"</i> (Digitalization Responsible)
Concerns that the inclusion of workers may translate into suggestions for digitization that lead to inefficiencies/ non-compliance with procedures	<i>"We must also pay attention to how processes are conducted, because overcustomization [of the work carried out in the respective area] can also lead to the digitalization of inefficiencies."</i> (Digitalization Responsible)
Process of replicating projects in different areas	<i>"Yokoten [replication of proven processes, improvements across different areas] has some problems too, especially with the introduction of technologies... not everything works everywhere"</i> (Production Manager)

Table 3. Continued...

Stakeholders' reasons and concerns	Verbalizations
Urgency and project timelines (sometimes associated with different priorities of stakeholders involved (e.g., Project/technology development vs. Industrial Management))	<i>"The timings are very tight and must be met in every project. (...) and the priority is to always move forward and fast with the project"</i> (Production manager) <i>"The main test of the technology should not be at the end, but rather during the concept phase with the workers. I am trying to convey the message that this would bring gains later on, but it is not easy... Industrial engineering is not set up for this. For them, what matters is the speed [of project achievement]"</i> (Digitalization Responsible)
Perception that workers' participation occurs through their leaders	<i>"In the design phase, the leaders of the project only receive clear feedback from the operators in prototyping. Until then, it's filtered by the operational leader who says it can be one way or another. It's only in the prototype that we adapt and the operators are already taken into account and adjustments are made."</i> (Digitalization Responsible)
Assuming workers will know how to use the technologies introduced and that it will have a positive impact on them	<i>"Teams assume that everyone is capable of using the technologies developed; that people are happy with the new technological tools..."</i> (Quality manager)

The results reveal the presence of: (i) challenges in operationalizing worker involvement (uncertainty about which workers to involve; how and under what conditions to take workers from production lines; need for deeper understanding of operational work); (ii) perceptions of process 'agility' (preference for "solo execution"; replication of processes; short and urgent project timelines; concerns about potential suggestions that could lead to inefficiencies/non-compliance with procedures; priorities of stakeholders); and (iii) a disregard for the importance of work activity and participation (assumptions of positive technology impacts on workers and reliance on leadership to ensure participation). These factors, alongside other previously identified elements, have significant consequences for workers and their work, as detailed in the following section.

These results respond to the research question (ii) "What positions are taken by the stakeholders responsible and involved in the transition processes?", highlighting that workers' participation is most often absent, delayed, or mediated, and that techno-centric and time-driven logics continue to prevail over the systematic consideration of work activity and its potential impacts.

4.3 Workers' point of view: perceived impacts and possibilities for continuing their work

The analyses conducted with workers, through activity analysis and interviews, revealed that techno-centric processes - characterized by a disregard for work activity (both before and after the change) and limited worker participation - led to impacts across five main dimensions: workers' leeway; overall meaning of work; learning; collaboration with colleagues; and work recognition. Table 4 illustrates the impacts associated with each of these dimensions, based on qualitative data from the use-cases and quantitative data from the diagnostic questionnaire administered to a group of operators from different areas of the company. Where relevant, the data differentiates impacts across use-cases for the same dimension. It should be noted that: i) qualitative data from use-case 3 were excluded from this analysis as it remains in the design phase; and ii) selected questionnaire items illustrate the identified dimensions in relation to the current situation and workers' future expectations.

Table 4. Impacts perceived by workers associated with workers' leeway, overall meaning of work, learning, collaboration with colleagues, and work recognition.

	Qualitative data (use-cases)	Quantitative data (diagnostic questionnaire)
Workers' leeway	– Leeway possible; Activity is not thwarted by technology, rather supported by leadership (use-case 1);	– 45% agree partly/totally that the technology they work with has led to a loss of control over their work;
	Vs. – Leeway constrained by work systems that promote prescription and reduce control over one's own work (use-case 2).	– 81% agree partly/totally that their work pace has become dependent on how technology works.

Table 4. Continued...

	Qualitative data (use-cases)	Quantitative data (diagnostic questionnaire)
Overall meaning of work	– Ability to integrate the new tools adapted to the work to be done (use-case 1);	– 71% report they never/rarely participate in decisions relating to their work;
	Vs. – Feeling of wasting time, frustration due to work impeded by the new tools (use-case 2).	– 67% agree totally/partly that, when new technology is introduced, they are afraid that it will prevent them from doing their job as they have learned it.
Learning	– Continuous learning associated with a recognition of the importance of TT and the perception that the system is useful for the work (use-case 1);	– 47% agree totally/partly that technology prevents them from doing their job as they had learned to do it;
	Vs. – Difficulty in mobilizing previous skills to solve problems and develop strategies considering the constraints imposed on mobilizing strategies for anticipating and solving concrete problems (use-case 2).	– 40% agree totally/partly that, if faced with the introduction of new technology, they would feel under great pressure to constantly learn new things to be able to work with it.
Collaboration with colleagues	– Strengthening of workers collective (use-case 1);	– 32% totally disagree/disagree that the technology they must work with contributes to fewer opportunities to learn with colleagues;
	Vs. – Redefinition and weakening of work collectives (use-case 2).	– 55% report that the people who trained them to work with the new technology were their colleagues; – 78% report that, if faced with the introduction of new technology, they totally agree/agree that they could continue to count on the support of their colleagues.
Work recognition	– Recognition by management of workers' experience and knowledge and their potential contribution to improvements to new systems (use-case 1);	
	Vs. – Devaluation of the impacts of TT by management, since three-quarters of the tasks continue to be performed in the same way; perception, by several stakeholders, that the function will remain the same (use-case 2).	– 61% report that they are never/rarely recognized and valued for the work they do.

The qualitative results, which reflect the background of each use-case, reveal both enablers and constraints in preserving work activity. In use-case 1, key enabling factors included: the preservation of autonomy, continued learning, sustained collaboration with colleagues, recognition of work by leadership, and the maintenance of a sense of purpose. In contrast, use-case 2 highlighted constraints such as reduced autonomy, loss of overall meaning of work, difficulty in mobilizing prior skills, and the weakening of work collectives.

The diagnostic questionnaire results reinforced these perspectives, showing that similar views are shared by workers in other operational areas. Key constraints included perceived technological control over one's work, low levels of work recognition, and limited participation in work-related decision-making. On the positive side, the value attributed to colleagues emerged as a perceived protective factor against difficulties related to managing and working with new technologies. Regarding future outlooks, the importance of work collectives is especially emphasized as a source of continuity even in the face of changes and other constraints that may be felt.

Additionally, the way these processes have been managed, and their associated impacts, have revealed consequences for workers' health. In the use-cases, workers reported general fatigue (*"I just feel tired at the end of the day... but I was like that before"* – LO1-2) and, in use-case 2, increased frustration (*"I feel less exhausted, but more frustrated"* – LO2-3). These findings are supported by a high percentage of workers (83%) reporting that their current job (now involving new technologies) negatively affects their health, with 50% stating they feel particularly frustrated when technology fails, and this weighs heavily on them.

The impacts identified across the five dimensions — workers' leeway, overall meaning of work, learning, collaboration with colleagues, and work recognition — address the research questions (iii) and (iv) "What are the main constraints arising from the forms of participation for workers and their work, and what resources can be identified as opportunities for reflection and action?", showing that limited participation and activity disregard tend to generate constraints, whereas recognition of work activity supports continuity, learning, and meaning at work.

5 Discussion

5.1 Work activity (still) adrift from the technological transition processes

The study argues that longstanding issues concerning the consideration of work activity in the design and transformation of work situations remain highly relevant today. Building on the research questions that guided this study, the discussion articulates the empirical findings with: (i) the concrete forms of workers' involvement in technological transitions, (ii) the positions and constraints experienced by key stakeholders, and (iii) the resources identified for supporting a work-centered and participatory approach.

Firstly, the findings reinforce the argument presented by Garrigou et al. (1995) that "design is a fragmented process" (p.315). The data showed that processes remain fragmented and that there is no local regulation, that is, no internal formalization within organizational contexts that ensures the participation of workers or the consideration of their work activity. Stakeholders such as HR and OHS professionals are not actively involved, despite the identified impacts - sometimes negative on control over work, meaning of work, and health. The results reinforce the need to invest in organizational commitment at multiple levels and in worker participation (Burgess-Limerick, 2018) to ensure the successful implementation of projects. Since organizational contexts influence workers' willingness to speak up (e.g., Morrison & Milliken, 2000), conditions must be created to support their participation, ensuring that they do not feel threatened or vulnerable in the process.

Despite these recommendations, the study reveals that it may be necessary to take a step back in this process of giving a voice to workers and their work, in order to understand the constraints and concerns experienced by stakeholders. On the one hand, the lack of participation stems from time constraints, a lack of knowledge about work activity, or the assumption that the activity is already fully understood, as noted in the literature (Broberg, 2007; Ipsen et al., 2020). On the other hand, there are operational issues regarding how participation could occur (e.g., When is the right moment to remove a worker from the production line? How should participation in meetings be structured?) and an opportunity to understand the importance of this point of view for proper technology design.

Secondly, technological transformation processes do not always imply a disruption in work trajectories or tasks. Rather, they tend to reconfigure how work is carried out, particularly in terms of autonomy and control over technology. In such situations, it becomes imperative that workers have a voice in processes that affect their working and living conditions, allowing them to mobilize their knowledge and experience, highlight constraints and contribute to the co-design of tools and solutions that support and facilitate their work while preserving their health. In this regard, supporting stakeholders through the simulation of probable future work situations (Barcellini, 2022; Daniellou, 2007) and fostering collaborative arrangements (worker representatives, development engineers, OHS or HR members, or external professionals such as work psychologists and activity ergonomists) can enhance the legitimacy of workers' voices and contribute to more effective innovation processes (Fiorini et al., 2024). Early worker involvement is therefore crucial to move discussions beyond efficiency and resource optimization toward real work needs, enabling high-quality and meaningful work (Bobillier-Chaumon, 2023).

It is also important to reflect on situations where work activity will be modified or job roles altered, as illustrated in use-case 3. Such changes should be addressed from the outset, with equal recognition of the contributions employees can make to the development of appropriate technologies (Pereira et al., 2025). However, this participation must not become an exercise of expropriating operators' knowledge for the company's sole benefit, as underscored by previous studies (Fuchs-Kittowski & Wenzlaff, 1987). Rather, it should involve valuing experience, accompanied by opportunities for reconstructing career paths and/or redesigning functional content, in line with principles that preserve health and promote decent and sustainable work.

In this regard, the third idea to be discussed relates to the understanding that participation entails confronting the knowledge and representations of different participants (Garrigou et al., 1995), which remains challenging for organizational contexts. The gap between workers' willingness to participate and stakeholders' preference for leading processes without integrating real work perspectives highlights the continued marginalization of work activity in technological transitions. Also, it is important to emphasize that this participation and the possibility for workers to have a voice in the process must go beyond a voluntary expression of suggestions, concerns, and information (Morrison, 2014). The study showed that workers' voice consideration can occur through the

inclusion of their work activity in technological transition processes, implying that their contributions derive from specialized know-how, work experience and an awareness of the socio-technical changes that occurred through time in the context. This issue deserves to be addressed in an effort to reduce the constraints felt by workers after transitions (affecting their health, learning, meaning of work, collaboration, leeway and work recognition). Furthermore, collecting workers' perspectives means, first and foremost, analysing work activities on the basis of an objective validated with workers (Re & Lacomblez, 2020). Therefore, this is a process that needs mediation provided by work psychologists/ergonomists.

Ultimately, worker participation can foster strategic co-decision-making as a preliminary stage of workplace democracy, which managers should consider when designing workplaces and job roles, particularly during decision-making and communication phases (Rybníková, 2022).

At a time when companies are increasingly driven by productivity principles and ever-higher efficiency targets, while facing labor shortages, notably in manufacturing (ILO, 2024), and as workers are leaving sectors such as manufacturing due to poor working conditions (Ernst & Feist, 2024), ensuring meaningful participation must be recognized as a priority rather an afterthought in professional settings. It is therefore essential to identify resources that can facilitate the understanding and integration of workers' participation, particularly through the voice of their work activity, and to provide concrete guidance for doing so.

5.2 Resources identified as opportunities to action towards the consideration of work activity

Workers' and stakeholders' perceptions of work digitalization processes, as well as the forms of worker participation and consideration of work activity, revealed several key dimensions. For instance, the importance of having control over one's own activity and the ability to mobilize one's experience; the value attributed to the existence of worker's collectives by the workers (across all use-cases and in the questionnaire - both in relation to current and potential future situations); and the facilitating role that leadership can play (as illustrated in use-case 1).

These results supported the identification of certain conditions that may guide the consideration of work activity and forms of worker participation as opportunities for action within technological transition processes, and for acknowledging workers' contributions toward transitions that promote decent and sustainable work. These are resources at the individual, collective, and organizational levels that interact with each other. The corresponding key points are presented in Figure 1.

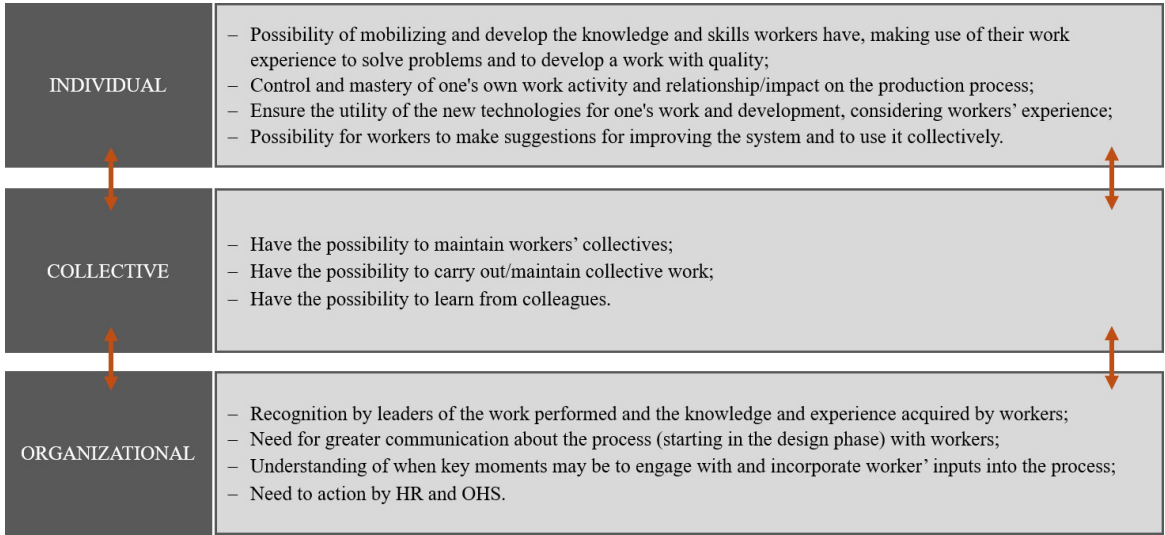


Figure 1. Resources to guide the consideration of work activity and forms of worker participation at the individual, collective, and organizational levels with main key points identified in the qualitative and quantitative analyses.

It is expected that these elements may contribute to a deeper understanding of the importance of considering employees in technological transition processes and provide insights into fostering greater involvement.

The organization of the contributions into these key points allowed the identification of a transversal element across the three levels of resources: the work activity. In different ways, whether through reflection on it (from a more organizational perspective), its development (at an individual level), or its (trans)formation (at a collective level), work activity stands out. This aspect, along with the elements highlighted in the theoretical framework regarding the importance of work activity (e.g., Bolis et al., 2023; Broberg, 2007; Daniellou, 2007; Garrigou et al., 1995), led to the understanding that it should be regarded as a first step towards strengthening the workers' voice in technological transition processes. In this sense, the individual, collective, and organizational resources identified empirically contributed to the empirical grounding for the evidence-based and participatory framework proposed in the next section.

5.3 Contributions of the research: an evidence-based and participatory framework

This study highlights the pressing need to design and implement locally anchored actions that contribute to the regulation of technological transitions, considering both work and the voices of those who perform it.

Drawing on the I5.0 principles, the empirical data collected from the perspectives of both stakeholders and workers, and grounded in the principle that the adoption of technologies in work contexts should benefit societies and workers by enhancing skills and productivity, increasing the meaningfulness of work, and improving opportunities for decent work (Rani & Grimshaw, 2019), this research proposes the development of an evidence-based, participatory framework. This framework provides guidelines and tools that can be considered during the different phases of a technological transition process to support reflection on work activity and working conditions, and to assess potential impacts on workers' health and professional development.

The proposed framework is not conceived as an abstract or prescriptive model detached from practice, but rather as an analytical and operational synthesis grounded in the empirical findings from the different use-cases, considering the five dimensions of impact identified from workers' perspectives, and the constraints expressed by stakeholders throughout the technological transition processes.

Specifically, the framework translates empirical evidence regarding, for instance, limited and late worker participation, the frequent disregard of work activity and workers' previous experience in design and implementation decisions, and the uneven distribution of resources and constraints across projects into a structured set of guiding questions and intervention principles. The empirical grounding and analytical translation of the proposed framework are explained in the Supplementary material (Table S2).

The questions within the framework are designed to support stakeholders in reflecting on technological transitions from a work-centered perspective, by explicitly linking project purposes, work activity, participation modalities, and anticipated impacts on health, learning, and professional paths trajectories. The framework is structured along six main dimensions, each linked to a set of guidelines: (1) Why? and (2) What for? – the purpose and intended outcomes of the technological transition, proposing human-centered indicators related to the consideration of work and its possible impacts on health, career trajectories, and professional development; (3) What? – the technologies to be implemented and the extent to which current work needs are considered, aiming to provide visibility into actual work and existing constraints that can serve as valuable inputs for the design process; (4) Who? and (5) When? – identification of the workers and stakeholders to be involved, and crucial stages for their involvement throughout the transition process; (6) How? – strategies to engage workers and ensure that work and its potential impacts are effectively discussed, including principles such as the simulation of probable future activity, the use of diagnostic tools (e.g., the questionnaire developed and applied within the project), and structured guidelines to formalize reflective discussions on work.

This approach is expected to implicate and support stakeholders in making informed, human-centered decisions by incorporating workers' perspectives into transition processes, particularly by recognizing the value of their work activity and fostering dialogue around potential future work scenarios. Considering the growing recognition of the heterogeneity of technological changes across work situations (Rani & Grimshaw, 2019), the proposed framework does not seek to offer a universal solution or a "magic pill", but rather to provide adaptable guidelines and tools, which content and implementation methods can be co-defined based on actual work-related needs and the companies' specificities. Considering also that putting work activity and experience into words is neither simple nor straightforward (Teiger & Lacomblez, 2013), understanding and translating this framework - as well as the previously identified resources - into concrete actions can benefit from the involvement of professionals like work psychologists/ergonomists who can support stakeholders and workers throughout the process.

While the proposed framework shares common ground with existing participatory ergonomics and human-centered design approaches, its theoretical contribution lies in the way it repositions work activity as the central object of analysis and action throughout technological transition processes. Participatory ergonomics models emphasize the involvement of workers in design and intervention processes, focusing primarily on participation mechanisms, organizational arrangements, and problem-solving dynamics (e.g., Haines et al., 2002).

However, they tend to give less explicit attention to the systematic analysis of past, current and future work activity as a structuring element of technological decision-making.

Similarly, human-centered design frameworks, such as those promoted in the ISO standard ISO 9241-210 (ISO, 2019), advocate user involvement and iterative design processes, yet they often conceptualize work mainly in terms of interaction with systems or usability requirements. In contrast, the framework proposed in this study adopts a work-centered perspective, grounded in ergonomics and work psychology, in which work activity is understood as a situated, collective, and evolving process shaped by constraints, regulation strategies, and professional experience.

By integrating empirical evidence, it explicitly links participation modalities and decision-making moments to concrete impacts on work activity, health, learning, collective dynamics, work recognition, and the overall meaning of work. In this sense, the originality of the framework resides in offering an empirically grounded, process-oriented, and anticipatory approach that supports stakeholders in reflecting on and shaping technological transitions through the centrality of work activity.

6 Conclusions

The research conducted explored how to consider the workers' voice and their work activity in technological transitions, providing innovative contributions that lie in the study's capacity to: (i) identify diverse resources that contribute to the development of the scientific literature; (ii) be grounded in concrete, real-world work situations; (iii) incorporate both workers and stakeholders' perspectives; and (iv) generate societal value by clarifying the importance of work activity in technology transition processes and through the design of the proposed framework. While this research was conducted within a single company, its insights extend beyond the immediate organizational context studied. The combination of the findings - particularly the lack of employee involvement - with the evidence reported in the existing literature, as well as the fact that companies often follow similar organizational logics (in terms of departments, roles, and approaches to digitalization), highlights strong commonalities across contexts. Therefore, rather than restricting the generalizability of the study, this reinforces its relevance for understanding and reflecting on real and current challenges in comparable work environments.

This contribution holds significant policy relevance by offering a pragmatic approach to fostering stakeholders' understanding of workers' point of view and their own work, prioritizing what should be the first level of strengthening the workers' voice in digital transition processes - their work activity. Seeking to align with the principles of I5.0, it thus aims to improve working conditions and career pathways, promoting the construction of sustainable and decent work for those who remain engaged with newly implemented technologies, as well as for those who must reconfigure their professional trajectories in response to future technological transitions.

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Statement on Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Authors contribution

Cláudia Pereira: Conceptualization, Methodology, Investigation, Writing – Original Draft, Writing – Review and Editing. Marta Santos: Conceptualization, Methodology, Investigation, Writing – Original Draft, Writing – Review and Editing, Supervision. Paula Lopes: Writing – Review and Editing. Daniel Silva: Investigation, Writing – Review and Editing. Mariana Magalhães: Writing – Review and Editing. Constança Dias: Writing – Review and Editing. All authors have participated in the discussion of the results and have read and approved the final manuscript.

Supplementary Material

Supplementary material accompanies this paper.

Table S1. Data collection and data analysis process in the conducted research.

Table S2. Empirical grounding and analytical translation of the proposed framework.

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