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RESEARCH ARTICLE

Integrating perspectives on democratization in industry via multi-agent systems: insights from a firm-based case study

Noushin Qeybi[1] · **Stefan Böschen**[1]

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Abstract
Advancements in IT-technology are seen to enable the further development of democracy beyond traditional political governance. Besides mobilizing civil society actors through participatory measures, companies themselves are rethinking their opportunities for democratization. Some now invest in pioneering new technologies and promote 'democratic' decision-making in the workplace. However, specific challenges arise, including the concentration of market power and the circumvention of employee co-determination. At the same time, small and medium-sized enterprises (SMEs) are deploying innovations such as AI-based decision-support systems to offer new decision-making opportunities. Is there any potential for democratization in companies emerging thereby as well, and if so, in which form? On the one hand, this article raises the question of how aspects of *democratization* in companies can be realized and presents a conceptual approach for analysing such ambitions. On the other hand, the specific challenges of *democratization* through digital tools will be explored by analysing a case study from an SME. The key result is that there are options of democratization via Multi-Agent Systems (MAS), but it can only be achieved if key democratic features (representativeness, transparency and fairness) are incorporated into the development and socio-technical implementation process. This ensures that the use of the AI tool not only increases efficiency, but also empowers employees to engage in meaningful participation fostering thereby legitimacy.

Keywords Democracy · SME · Democratization via digital tools · MAS

1 Introduction

Technology and democracy are widely recognized concepts that not only pervade our daily lives but also extend their influence into various domains, including workplaces. On one hand, small and medium-sized enterprises (SMEs) have increasingly focused on developing and adopting new technologies, driven by various objectives. First, organizations aim to overcome supply chain limitations and establish a unique selling point (USP) in highly competitive markets (Stefanovic and Stefanovic 2009; Verma 2022). Second, adopting new technologies may be motivated by the desire to enhance oversight and more effectively monitor workers' activities (Rogers 2023). Third, technologies like artificial intelligence (AI) aim to democratize decision-making, fostering greater participation, fairness and transparency, which is ultimately seen to lead to higher worker satisfaction and improved organizational efficiency (Noorman and Swierstra 2023; Dicks et al. 2021; Kochan 2011; Gomez and Gomez 2016; Charles et al. 2022).

On the other hand, while hierarchical organizations due to their command-and-control structure are typically not an environment for democratic decision-making, studies have acknowledged that democratic and participative approaches can function effectively within workplaces (Hilton et al. 2021; Reuten 2021). Moreover, the European Union (EU) and its governing bodies have emphasized the importance of democratic decision-making processes in companies, given the wide-ranging consequences of AI implementation on both economic and social dimensions (European Economic and Social Committee 2021; Emi et al. 2024). Therefore, and in this specific context, democratization via digital tools and

Stefan Böschen is a contributing author.

✉ Noushin Qeybi
noushin.gheibi@humtec.rwth-aachen.de

Stefan Böschen
stefan.boeschen@humtec.rwth-aachen.de

[1] Human Technology Center, RWTH Aachen University, Theaterplatz, 52062 Aachen, North Rhine Westphalia, Germany

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its utilization in the workplaces opens up new possibilities but raises at the same time relevant questions, demanding additional examination.

Building upon these considerations, AI-driven democratization of decision-making requires the promotion of democratic practices throughout the development, implementation and utilization of the respective digital technologies. This process demands an analytical approach that considers both social and technical factors, aiming to ensure that AI technologies contribute to enhanced democratic decision-making processes. Achieving this involves exploring methods for democratic control over these technologies and understanding how they can foster democratic practices (Noorman and Swierstra 2023). In alignment with this goal, the EU-funded FAIRWork project has designed and implemented a Democratic AI-based Decision Support System (DAI-DSS) integrating various technologies to support decision-makers in companies (Woitsch et al. 2023). To further improve the Decision Support System (DSS) aimed at democratization in workplaces, it is essential to adopt a holistic perspective that considers all aspects of decision-making within companies. Consequently, this study, as part of the FAIRWork project, seeks to explore the potential of democratization in companies through digital tools, specifically MAS, by analysing a case study conducted within a globally diverse manufacturing company.

2 Studies of enhancing democracy via AI: what about companies?

There is an extensive range of literature on topics such as democratization, AI, digitalization and decision-making in the context of industry. However, in this section, we primarily focus on studies that explore various aspects of the democratization of AI, as well as different decision-making factors and issues of legitimacy.

Chen and colleagues argue that the democratization of AI in healthcare through Generative AI remains in its early stages and can be further advanced by adopting a human–machine collaboration approach. Based on a deep literature and abstraction analysis, their study highlights that healthcare AI democratization enables both patients and healthcare providers to benefit from AI, enhancing and supporting healthcare tasks without replacing human expertise (Chen et al. 2024). Noorman and Swierstra approach the democratization of AI from a sociotechnical perspective by developing a conceptual framework. They argue that although decision-making regarding solar energy distribution is conducted using AI technologies, these decisions are political and affect citizens, whether they want it or not. Consequently, they propose that the democratization of AI means developing, implementing and utilizing AI tools in a way that encourages democratic values. This process necessitates an analytical approach that considers both social and technical factors, ensuring that AI technologies contribute to enhanced democratic decision-making processes. They believe that achieving this is possible by exploring methods for democratic control over these technologies and understanding how they can foster democratic practices (Noorman and Swierstra 2023). In another study, Colin Garvey examined barriers to the democratization of AI using the intelligent trial and error (ITE) approach. His evaluation identified several challenges, including hierarchical decision-making in military and industrial settings, the rapid development of AI that undermines precautionary measures and a fixed AI framing that enforces a strict for/against divide. As a solution, he suggests rethinking the decision-making processes governing AI and aligning them with the social values of modern democracies (Garvey 2018). While there are hopes, encouragements and calls for the democratization of AI, some researchers highlight the often-overlooked dimension of affective equality when considering the democratic and participatory design of AI. They argue that love, care and solidarity can genuinely fulfil the justice and democracy needed in unjust AI systems, ultimately contributing to the development of secure AI-driven decision-making systems (Hardt et al. 2024; Jónasdóttir and Ferguson 2013). Despite the valuable insights gained from the mentioned studies, they lack concrete solutions aimed at democratizing AI tools.

Since democracy is inherently a political concept, it is useful to explore specific features such as representation and participation, which are relevant in an industrial context, and examine how these features can be practically implemented through DSS in workplaces. Building on this perspective, Thiel and Kailitz highlight the power of AI in continuously transforming forms of citizen participation and representation. However, they argue that AI-driven decision-making has specific limitations and must be both responsive and efficient to be perceived as legitimate in the long run. A key point in their study is that this transformed representation could lead to a redefined democracy, where legitimacy is derived from efficiency and quiet implementation rather than from discourse and debate (Thiel and Kailitz 2024). Furthermore, since research indicates that new technologies can enhance decision-making, it is essential for this study to obtain a clear understanding of the current decision-making processes within the SME (Rajagopal et al. 2022; Verma 2022). This includes identifying whether decision-making follows a traditional or flat structure, evaluating the types of decisions made, assessing the effectiveness of the current process, understanding the challenges faced during decision-making and recognizing the factors employees should consider in their decision-making approach. Additionally, involving employees in decision-making not only

significantly enhance organizational efficiency but also fosters their creativity and commitment (Charles et al. 2021). Thus, considering employee engagement and involvement holds great significance and is evaluated based on three key components: the opportunities for employee's objection and suggestion, the methods of transparency regarding decisions made and the importance of trust among team members; which are interrelated concepts according to research findings (Edelman et al. 2007; Rawlins 2008; Chêne 2011). Moreover, according to studies, AI-driven decision-making is still in its infancy, requiring further development and facing pivotal legitimacy limitations (Thiel and Kailitz 2024; Beckman et al. 2024; Fine Licht & Fine Licht 2020; Maas and Duran 2022; Noorman and Swierstra 2023). Consequently, workers' expectations as shop-floor decision-makers play a crucial role in addressing existing limitations and moving toward legitimate automated decision-making. Equally important in the context of decision-making in companies is the challenges the workers face during their daily tasks (Rogers 2023; Verma 2022; Martini et al. 2024). Identifying these issues and incorporating them into the development and implementation of the DSS is highly beneficial for ensuring the legitimacy of decision-making with new technologies. Achieving these objectives requires adopting a holistic perspective and employing empirical research methods, such as case studies.

3 Methods

In this study, we employed a case study approach to examine the dynamics of democratization in industry via exploring the contextual situation for implementing a DSS within an SME (Yin 2014). The DSS in the project FAIRWork is based on a model using a MAS. This MAS is constructed a way supporting production line managers for better attributing workforce of the respective workers to the respective tasks on the shop-floor level. For doing so, the MAS is importing a broad variety of factors to encompass the present situation of the production line as well as one of the workers and offering a recommendation based on this MAS optimization process. The here reported case study focused on a comprehensive analysis of a specific production company, which initially involved verifying operational documentation describing workflow procedures through exploration of specified scenarios. The first scenario, *Automated test building*, begins with a new product order or the need for a production process update, facilitated by the program manager and forwarded to the automation engineer during the design phase. Another significant scenario, *Worker allocation*, occurs prior to or during shifts, based on the assessment of workers' abilities and the production plan. Additionally, in the *Machine maintenance* scenario, triggered by breakdowns or failures during the execution phase, known problems are addressed through a ticketing system.

Deploying the DSS for democratic decision-making required a detailed analysis of the company's work routine. To achieve this, we adopted a two-step procedure in our approach, which facilitated an in-depth examination of employees' daily tasks, potential challenges, individual decision-making processes and overall workplace dynamics. In the first step, conducted in October 2023, the focus was on laying the foundation for the empirical case study, gaining an overview of the company and collecting primary data for initial analysis. For this purpose, our research encompassed first a document analysis, second a visit of various departments within the company, beginning with an examination of company products and production halls, where ongoing tasks such as quality checks, labeling, identification and evaluation were looked at with the method of participatory observation. Subsequently, attention shifted to the operation of collaborative robots with human involvement. Third, we conducted interviews with employees across different hierarchical positions and levels of experience ($N=8$). Through the qualitative analysis of the case study, we identified three key dimensions: decision-making, involvement, and expectations, which will be explained in more detail in the "Results" section.

To gain deeper insights into the workers' perspectives within the company and explore additional options for supporting the democratic implementation of the DSS, the second step was conducted in July 2024. In order to validate the initial results, we partly repeated our research methods, carrying out the second on-site observation and performing the second wave of worker interviews ($N=5$). However, to strengthen our understanding and align the sociological analysis results with the development of the MAS, we additionally conducted a workshop in the form of a focus group interview with four employees. The interpretation process was conducted in accordance with qualitative content analysis (Mayring and Fenzl 2019). Qualitative analysis of the second case study not only affirms the previously identified dimensions but also led to the identification of a fourth prominent dimension: challenges, which is further divided into various groups and subgroups.

The insights gained through our two-step case study approach, including findings from on-site observations, outcomes of individual and focus group interviews and the selected dimensions with their subsequent groups and subgroups, will be explicitly clarified in the next section.

4 Results

To address the objectives outlined in the previous sections, we conducted a two-step case study within the selected company and analysed the collected data by coding the

interviews. The findings are organized into two main categories: [Onboarding Step] and [Precision Step], which are discussed in detail below. The method of analysing sociotechnical practices allows thereby, first, the check of the adequateness of the technical representation of the workers' status; second, it focuses on the quest of legitimacy: Which aligning social procedures are needed to safe the legitimacy of the application of such a system in a hierarchical organization.

4.1 Onboarding step

This step aimed to acquire a general understanding and gather foundational data from the company. After analysing the company documents, which included its operational processes and corresponding scenarios, we designed an interview questionnaire comprising different modules to address the workers' current situation, task assignments, the implementation of the DSS and its future prospects. Following the development of the questionnaire, eight interviews were conducted with staff across the organizational hierarchy, encompassing managerial personnel, supervisors and technicians from logistics and production teams, in addition to representatives from the workers' council, inquiring about their decision-making situations, associated problems, and characteristics. Additionally, participants, whose experiences vary from 2 years to more than 10 years, were invited to discuss their involvement within the company, sharing their opportunities for objection and suggestion, as well as addressing the status of decision-making transparency and the significance of trust. Moreover, their expectations from the DSS and potential functionalities to optimize its performance were explored. Thus, in the following sections, we investigate deeper into the insights gained from the interviews, focusing on three key dimensions: decision-making, involvement and expectations, subsequently examining their respective categories. Each aspect offers valuable perspectives shared by participants, revealing finer details of developing a democratic DSS within the organization.

4.1.1 Decision-making

According to participants, decision-making *situations* can vary, ranging from decisions regarding the production line, such as assessing the authenticity of machine failure, determining when to report recurring errors to the supervisor and potentially shutting down the line, to addressing stock differences or product shortages affecting production. These situations may also involve attributing fault, whether to internal parties, customers or transport companies, in cases such as product failures and transport damage, and deciding whether to dismantle material returns. Moreover, decisions may involve personnel matters like overtime management, task allocation and determining roles and timing for redundancy. Additionally, managerial and works council decisions may include adjusting budget allocations, managing staffing levels, handling dismissals and addressing employee issues.

Based on statements from interviews, in the decision-making process, employees may face various *challenges*, with one of the most crucial being feelings of uncertainty regarding decision accuracy. This uncertainty may arise due to a lack of experience or insufficient information about the system, components, customer, employees and timestamps. Consequently, the uncertainty presents itself differently: experienced individuals tend to accept the consequences, while amateurs often experience significant stress. Uncertain decisions can also jeopardize production line stability, particularly when made amidst disparities. These situations can become even more challenging, especially when superiors or experts are unavailable for consultation or conversely when multiple decision-makers hold differing ideas, resulting in slower progress in the production line. Other issues that may affect the decision-making process include work and time pressure, planning weekend work shifts, decisions with partial fairness and budget constraints, which can lead to project cancellations.

In light of the mentioned situations and challenges, certain qualities and *characteristics* define the decision-making process within the SME. These include carefulness in decision-making and, notably, consideration of risks, and subsequently accepting their responsibility. In addition to utilizing the skills matrix, which outlines employee task assignments, supervisors should also take into account shift scheduling and workload when making decisions. Considering the priority of tasks is also crucial, as it determines the allocation of responsibilities, whether to highly qualified individuals or to those with lower experience. Based on the interviews, it was also found that most tasks in the company are repetitive, with rare occurrences of new tasks. This could explain why decision-making relies more on experiential knowledge, prompting employees with less experience to frequently seek guidance from their supervisors to ensure the accuracy of their decisions. While decisions are primarily reached collectively through discussions and regular meetings, hierarchical decision-making, particularly at the managerial level, is also observed.

4.1.2 Involvement

The data show that *suggestions and objections* receive primary consideration when they contribute to enhancing production or when failures or problems are identified in the production process. Additionally, while the ideas are conveyed to the management team through supervisors, annual employee discussions also provide an opportunity for individuals to express their views directly. Moreover,

opinions regarding staff assignment planning can be widely acknowledged. Surprisingly, some employees may refrain from offering suggestions or objections, arguing that intervening in superiors' decisions is not expedient and that everyone should focus solely on their own work, believing this approach leads to a stress-free environment.

The insights into the *transparency* topic can be divided into two categories: On the one hand, decision-making transparency can be achieved through explanations from experts, addressing uncertainties raised by employees, clarifying new themes and decisions during weekly and monthly meetings, involving all relevant staff in decision-making and fostering expertise and knowledge among the team over time. On the other hand, the transparency of decisions is context-dependent, and in certain cases, some decisions, particularly those at managerial levels, may not require understanding by others.

The participants emphasized the high level of *trust* among the team, highlighting that without trust in their team members, progressing in the work process would be impossible. They remarked that this existing trust minimizes the need for negotiation on every subject, thereby accelerating the work process. Direct interaction between team members was cited as a key factor in increasing trust, leading employees to have a high grade of trust in their superiors due to awareness of their knowledge and experiences. Additionally, system functioning contributes to building trust between superiors and employees. However, mismatches between decisions reached and their implementation in the workplace were noted to harm the trust employees have in their superiors.

4.1.3 Expectations

An essential purpose of this study is exploring optimization prospects for the DSS while considering the experiential insights of employees engaged in the workflow. To achieve this goal, the third dimension investigates participants' expectations of this system with the aim of simplifying, ensuring and to some extent accelerating the working process. Given that the primary objective of the DSS is to *simplify* workflow by offering solutions, it is crucial for workers to have access to multiple proposed solutions for various scenarios. Recognizing work and time pressures as key challenges in decision-making, employees express a preference for reduced human intervention and alleviated time pressure through the digitalization of time-consuming and effortful tasks. For instance, the systematic categorization of the severity of various incoming errors would allow employees to easily identify the appropriate course of action when encountering specific types of errors. This approach would bypass the necessity for extensive time allocation to initially determine the error type, thereby reducing uncertainty in decision-making processes. Additionally, there is a desire for data within the system to be organized in a comprehensible manner, especially considering the vast amount of data across the entire company. Providing self-familiarization tools for both new hires and existing staff with the workflow is also seen as essential for facilitating the work process. Another highlighted point focuses on relieving employees and reducing workload by delegating risk assessment tasks to the system. Within this context, decision-makers also express a desire to automate fault attribution processes, potentially by establishing specific criteria to streamline the determination of responsibility for particular damages or errors, thereby simplifying decision-making procedures.

The expressed expectations encompass points aimed at *accelerating* the work process. Recognizing staff assignment planning as a particularly time-consuming task, especially on weekends, underscores the necessity of implementing an automated system for assignment planning to assist supervisors, thereby significantly enhancing workflow efficiency and alleviating work-related pressure. Moreover, considering the aforementioned work pressure within the company and the potential for oversight regarding certain tasks and deadlines, employees have proposed the implementation of a signalling reminder system for upcoming plans. Additionally, access to a well-defined procedural framework would reduce challenges in finding experts and supervisors for consultations, thus furthering the acceleration of the work process. Other strategies, such as personally managing vacations and sick leave arrangements, along with task assignments tailored to individual preferences and competencies, serve to increase workflow efficiency. In addition, the implementation of automated customer service functionalities, such as email drafting, has the potential to mitigate time pressure. From a more technical perspective, it is advantageous to establish a structured inspection sequence for prioritizing error, enabling employees to accelerate the identification of the primary issue and address other errors effectively. The fulfilment of these requisites not only fosters punctuality but also enhances staff productivity and creativity.

The expectations articulated by the employees regarding their anticipated functionalities of this system can significantly contribute to the DSS's development and *ensure* the effectiveness of its workflow processes. The suggestions provided underline the critical need for accessing precise and reliable solutions, alongside secure access to all production and employee data. Therefore, establishing a comprehensive database containing all relevant company information is imperative. Additionally, enabling data and workflow reviews can enhance the accuracy of system data and contribute to the efficiency of the decision-making process. Moreover, it is essential to provide insights into the consequences of proposed solutions, ensuring a thorough understanding of potential outcomes. Indicating resource

availability and their precise whereabouts through system would ensure the progression of workflow processes, covering aspects such as product, machinery and even substitute employee availability. From another perspective, employees anticipate that the integration of the DSS would ensure equitable treatment for all staff members. However, the comprehensiveness of this system should not hinder critical thinking, as creativity and innovation must remain essential. Finally, there is an emphasis on protecting human discretion, recognizing the value of human judgment and autonomy within decision-making frameworks. Particularly, the participants envision the system as a tool that provides guidance, with ultimate decisions resting in human hands.

4.2 Precession step

After gathering primary data and gaining a general perspective on the company during the Onboarding Step of the empirical research, we proceeded to the step to examine the company more closely, refining and expanding upon the initial findings. This step (Precision) involved conducting additional individual interviews with employees, holding a workshop in the form of a focus group interview, and taking a tour to observe the company's operations.

As mentioned earlier, through the analysis of the first step of the case study, three dimensions were identified (decision-making, involvement, and expectations). In the second case study, we were able to expand upon these dimensions and explore a fourth dimension: challenges. Given that we gathered over 250 min of interviews, in addition to unrecorded conversations and discussions, it was necessary to categorize the new dimension in greater detail. We identified three main groups of challenges: resource allocation, production management, and personal competences. Furthermore, each group was further divided into specific subgroups to provide a more precise understanding of each topic, which will be discussed in the following parts. Apart from the individual and focus group interviews, we conducted an on-site observation at the company, which provided us with an overarching perspective on our case, including its mission, outlook and both potential and actual obstacles.

4.2.1 Challenges

The evaluation of the interviews led to the identification of the new dimension of challenges, which was further categorized into three main areas. The first category, resource allocation was broken down into four subcategories: responsibility allocation, worker allocation, training allocation and component allocation. The second category, production management, was divided into two subcategories: workflow and product. Finally, the third category, personal competences, encompassed subcategories related to skill sets, social-contextual learning and supply chain insight. Each of these is described in detail in the following sections.

4.2.2 Resource allocation

Starting with the first category, we identified several issues, complaints and desires related to Resource allocation. Among these, the issues related to the responsibility and worker allocations were the most significant. Regarding *responsibility allocation*, employees from different hierarchical levels emphasized the importance of balanced team contributions. Additionally, experienced workers noted the need for better alignment between responsibility and competence, particularly for the younger generation. One of the prominent issues regarding responsibility assignment is the employees' reluctance to make decisions independently, which was repeatedly mentioned in the first step of the case study as well. Meanwhile, the employees stated that they do not trust the tool's decisions when made autonomously. Another issue raised by top-floor employees involved the strict adherence to defined role and responsibility boundaries, where workers would pass on tasks that fell near the edges of their responsibilities, even if they were capable of handling them. The top-floor employees argued that if a task needs to be done and someone has the ability to do it, they should step up. In addition, the tendency to focus on what individuals are not responsible for led to slowed progress.

Apart from the challenges related to responsibility allocation, *worker allocation* in the company also faces specific issues. As we discovered in the previous step, worker allocation is a time-consuming task for supervisors, and reallocating workers due to frequent and sudden paid time off (PTO) makes this task even more challenging. Unclear workforce information further complicates worker allocation. Worker allocation could also be challenging from the worker's perspective, for instance, due to the varying complexity of tasks and perceived preferential task assignments or because of interpersonal dynamics. Due to the mentioned issues, supervisors and managers must justify their decisions, especially when it comes to worker allocation. Additionally, the loss of temporary employees was a concerning topic for all staff, which came up several times in the interviews, as well as in conversations during on-site observation and even in the company canteen. As employees expressed a desire for self-management of tasks and PTO, we identified the issue of limited access to the worker allocation plan. This desire faces significant barriers, as only shift supervisors and the boss have access to the work assignment plan.

Resource allocation issues extended into *training allocation*, with some aspects interpreted as conflicting with each other. We found that some experienced employees had a strong ambition for self-improvement, learning new skills and being involved in different tasks; however, they were

not always able to access further training opportunity. On the other hand, employees on the top floor emphasized their commitment to encouraging cross-training and skill development. Another concern in this context is the lack of trained operators for medical devices, such that the aim is for every operator from different halls to be able to operate the medical devices and the production line related to the medical hall. The issues surrounding training allocation are often made more challenging by the overload amount of theory and practice that newcomers and apprentices must take in. The large amount of learning material can be stressful, especially when it must be absorbed within the limited and intensive training period. However, employees from higher levels believed that within a training period of 1 to 2 months, everyone could learn the training material.

The final factor in resource allocation that caught our attention was *component allocation*, identified as a significant issue within the company. Employees across different hierarchical levels acknowledged the challenges in component placement, emphasizing the necessity of applying the four-eye principle. They also suggested that a digital tool could help resolve this issue by providing notifications about the necessary components or actions.

4.2.3 Production management

To delve deeper into the challenges faced by the staff in our case, we turn to the second explored group: production management encompasses various tasks, including planning, overseeing and controlling the production process, with the goal of delivering the right quality at the right time while minimizing costs. Based on our findings, which stem from employee criticisms, obstacles and limitations, we categorized these challenges into two subgroups: workflow and product.

Focusing on the *workflow*, inadequate system functionality was identified as a well-known problem. This issue occurs so frequently that employees consider it a default condition within the company, asserting that machines cannot completely replace humans. Another issue related to the workflow is dealing with multiple systems with different procedures, which makes handling and familiarizing with processes difficult. This results in delayed adaptation to the workflow, particularly for younger employees. The diverse operations of each production line may cause quality issues due to minor mistakes, as the machines might produce the same product but operate differently. The absence of precise procedures was first identified in the initial step of the case study and later reiterated as a significant challenge in the workflow. The workers, especially those at the entry level, faced serious problems regarding the operation of the production lines, particularly when it came to errors and defects. This was evident to the extent that skilled workers often defended junior employees, who struggled to manage system errors independently. Further on this topic, the workers pointed out the extended error identification in machinery, as the machines sometimes remain in error for an extended period before being detected. This issue, seen as trivial by younger employees, was thought to be easily solvable with system support. However, implementing a support system requires certain prerequisites, such as the availability of digital forms of necessary parameters. Therefore, limited digital data availability can be considered another challenge in the workflow.

The products in the company have a wide variety, ranging from industry to automotive and healthcare sectors. Thus, it is not surprising that some challenges in production management are related to the *product*. Besides the diversity of production lines, the different types of products are also considered by employees as a difficulty in the workflow. As mentioned above, this process variation could affect the quality of products, particularly if the quality checkers do not master the entire system. The issues related to the product can be traced back to unclear quality boundaries, which results in a product interruption. The workers suggested that providing support for cross-checking and identifying whether the products are good or defective would be a good idea. Moreover, the workers in the quality section explained that such errors must be identified as soon as possible because, once they progress to the next step, the entire assembly of that product becomes blocked and requires inspection.

4.2.4 Personal competences

Challenges at this company extend to personal competencies, including employee skills, the organization and management of those skills and the quality of skills needed to address production line issues. According to the findings, three subgroups — Skill set, Social-contextual learning, and Supply chain insight — were recognized, which encompass all the mentioned items from the employees.

In terms of *skill set*, as part of the challenge regarding unclear workforce information, discussed in the worker allocation context, employee competencies also remain unclear, which complicates decision-making. Limited access to workforce competencies was also pointed out by skilled workers, who mentioned that access to competencies is possible by asking. While juniors did not mention this as an issue, it is likely because they were unaware of it. Insufficient skilled workforce, especially in the medical area and quality control, was also highlighted as an issue, which was explained earlier in the training allocation section.

Focusing on the fact that environmental factors can shape the level and quality of skills, challenges regarding *social-contextual learning* attracted our attention. The first issue in

this category was the variation in learning experiences due to different mentoring styles, where two mentors had different perspectives on the tasks their operators should focus on:

> "Mentor1: But if I don't do it, then I will never learn it. That's how I see it. Actually, the operator does it themselves, right? Or is it not like that anymore? But actually, it's part of their job. Mentor2: Actually, it's part of their job. But since many mistakes have already happened, we now have to deal with it. Either they call me, I go directly to the line, and look at the error on the X-ray. Mentor1: No, no, that's not right."

In line with the discussion about the company losing its competent temporary workers, employees further explained that these workers often outperformed the permanent staff. This could be due to differences in their learning environments or the concern of being let go if they did not perform well. The influence of context in learning or adopting a new method is so significant that employees in management view early involvement as essential for the success of any innovation; otherwise, it may fail. Thus, the early engagement of workers was seen as a solution to the challenge of acceptance resistance due to unfamiliarity with new changes, facilitating the acceptance process and assisting in the gradual adaptation to those changes.

Working closely with this company during the first and second steps of the research led us to conclude that managing the complexities of different production lines requires the competence of *supply chain insights*. According to Helo and HaoClick or tap here to enter text., the supply chain integrates every stage of production and distribution, beginning with suppliers, progressing through manufacturers and distributors, and concluding with delivery to the final customer. Therefore, nuanced quality knowledge is essential for being recognized as a skilled worker. Apart from quality knowledge, employees need multifaceted system knowledge to address issues arising on production lines. Recording to the manager in the company, this cross-functional expertise requires at least 2 to 3 years of experience.

Since one of the challenges this company faces is the limited number of skilled workers, and considering that many temporary workers have been dismissed, the company's new challenge is to enhance the skills of the remaining employees. This is achieved by rotating employees through various departments at different times, ensuring they gain proficiency across all areas. However, this department rotation is often met with employee reluctance, especially because they feel comfortable in their current positions. Despite their complaints, they ultimately have no choice but to accept the new role in the new department. Due to the critical role humans play in the production process, employees emphasized that human competences, such as alertness, interest and the ability to read, cannot be replaced by any tool.

4.2.5 Workers' insights on overcoming challenges

The various challenges faced by workers in their workplace were explicitly explained. The employees also shared their expectations and proposed solutions to address these issues. In terms of *resource allocation*, regarding difficulties in responsibility allocation, the main demand was for a balanced team contribution. To this end, and to avoid any mismatch between responsibility and competence, it is important to ensure role clarity. Additionally, since there was reluctance to make decisions independently and doubt about the autonomous tool's decisions, the workers demanded a collaborative decision-making process with AI. Furthermore, one expectation from higher-level employees was not to strictly adhere to defined responsibilities but to think beyond role boundaries.

The expectations related to workers' allocation are mostly anticipated. Supervisors need an automated staff assignment planning system that allows them to spend less time reassigning tasks when changes occur. A prerequisite for this is providing an automated employee profile system, enabling supervisors to rely on it to check if employees are available and if they meet the requirements to fill vacant roles. Given the regular justifications from supervisors regarding worker allocation, it is beneficial for both workers and supervisors to make the worker allocation process clear. Another expectation from top-floor employees is achieving the company's goal of maximizing resource utilization, including staff, arguing that the resources on the production line remain unused for two-thirds of the time, which they consider inefficient.

Demands for training allocation are significant due to the lack of trained workers. Experienced employees, particularly in the quality area, expressed the need for improved staff training to enable them to handle specific quality tasks. They also emphasized that empowering workers to make decisions would be a valuable advantage for the production line. The problem of a lack of skilled operators, especially in medical fields, can also be addressed through cross-training programs. The supervisors find it useful for each operator to be qualified in both medical and non-medical areas, helping to tackle the shortage of personnel.

One of the suggestions regarding component allocation was already highlighted above. In addition to providing a notification system for tracking the next required action, automating component placement and replacement could contribute to faster progress on the production line. In alignment with this, one employee explained how the machines currently work: "When the machine, for example, makes a sound and flashes, he has to go and check, okay, the component is running out, I need to splice the next roll immediately so I can continue. So, he has to be alert and stay on top of it to ensure the production doesn't stop."

The challenges in *production management* were divided into two categories: workflow and product. To address the existing workflow-related issues, employees need a system for monitoring the production flow, including component tracking, action notifications and ensuring system functionality. Given that multiple systems with different procedures make operations and tasks particularly challenging—especially for new workers—simplifying system usage would be advantageous. This includes addressing discrepancies in the production line and providing well-defined procedures to ensure that tasks are clear, standardized, and organized. Additionally, rapid error identification is crucial, as employees frequently encounter errors. These recurring issues require an error review process, which is currently handled in an analogue format. Shop-floor workers view an automated error review system as essential for reducing challenges in this area:

> "Employee 1: Exactly, when the error message appears, I can just run the tool and think, 'Okay, there's the error message—what can I do?' That way, I can react faster. Employee 2: Yes, but we already do that. We have a logbook where, next time, or for the next person, it shows, 'Look, that error has already occurred.' Employee 1: What kind of logbook is that? Is it digital? Employee 2: It's ours—either a system-based or written one. Employee 1: Yeah, but flipping through twenty pages, that's just a hassle. Employee 2: No, but some errors you simply don't forget. Employee 1: No, not certain ones. But it's usually the less frequent errors, right? Employee 2: And there are always new errors cropping up—that's just how it is."

Management extended the expectations related to workflow by emphasizing the goal of an adaptable production process, where different parameters can be modified to achieve true flexibility within the company. Given that this organization is regarded as a high-cost-function company, managers aim to expand the use of technology, particularly AI, to balance high operational costs and position the company as a USP among competitor companies.

Regarding the product, the main issue focused on quality. In addition to the wide variety of products, quality testing needs to be automated. The complexity and difficulty of the current quality-check process have already been highlighted. Apart from testing, employees believe that the quality of products can be enhanced through certain changes. They wish to contribute to this improvement due to their nuanced experience within the company. Clarifying quality thresholds is another priority for the workers, as unclear standards could frequently lead to production interruptions.

The desires regarding *personal competences* are partly evident when we look at the associated challenges. Automating the skill matrix is a recurring demand from supervisors, as it would facilitate task assignment. Multiple systems and different operations require adapted skills so that apprentices and new employees are not completely in charge while still unqualified. Additionally, the high volume of products and the need for quality testing lead quality checkers to request qualified assistance to help relieve their workload. Due to some resistance to acceptance, management suggested providing hands-on learning when introducing new methods and tools, as it could foster acceptance and ensure the success of new methods: "And if you make small steps and fix the errors in parallel, the acceptance is greater." In alignment, the managers suggested providing continuous learning during the deployment of a new tool so that workers remain in contact with the tool for a longer period, which helps with its implementation while simultaneously allowing them to learn it: "If it is implemented this way, you work for several months during the entire integration process in parallel. This means the tool is used, and during its development, the people also learn how to use it. This already brings advantages." This active and early involvement of the workers in the implementation process of the new tool facilitates their acceptance and ensures continuous use of the tool. Lastly, a significant expectation from the workers, which was also mentioned in the previous case study, is to have support in tough decision-making through a digital tool. They do not want the digital tool to make final decisions autonomously, as workers with extensive experience in the details of this large company cannot trust the system's decisions. Instead, they suggested having an Option Identification Tool that still empowers them to make decisions and actively participate in the decision-making process.

Following the above-mentioned workers' expectations on overcoming challenges, some of their expectations also reflected key features of democracy, such as fairness, transparency, and trust. During the focus group interview, workers expressed their desire for *fairness* in the workplace, emphasizing the importance of fair recognition and appreciation. Additionally, they highlighted the value of personal engagement from their superiors, suggesting that even brief check-ins could enhance their sense of appreciation. Another point highlighted by workers across all hierarchical levels was the importance of promoting fair treatment and fostering an inclusive environment free from discrimination. They emphasized the challenges of maintaining equal treatment in the workplace despite differing levels of effort. Since workers' competences vary, they debated whether equal treatment is always necessary:

> "Employee 1: You can't treat everyone equally because not everyone is on the same level. Employee 2: Yes, but I can do it in terms of human behavior. Employee 1: In terms of human behavior, absolutely. From that perspective, it's possible, but from other aspects, it's

harder. Employee 2: But I say, from a work-related perspective, you naturally sort them based on who has general knowledge or who shows interest—because you can see whether someone is interested or not. That's how you assign tasks."

The demands extended to ensuring fair PTO allocation for employees who are frequently absent. The interviewees expressed a desire for a digital tool that could contribute to more reliable PTO management, as frequent PTO disrupts planning. Ultimately, recognizing favouritism as one of the challenges in worker allocation, ensuring fair employee assignments was another expectation regarding fairness expressed by the employees.

Expectations regarding *transparency* may not be numerous, but they are significant in quality. The employees from the top-floor level believed that for a digital tool to be successfully implemented in the company, its tangible advantages must be transparent from day one. Apart from the DSS, experienced employees who have been part of the workforce for a long time emphasized the importance of timely and clear communication about changes with workers. They noted that workers expect to be informed about every restructuring as soon as possible, even if it does not directly relate to them.

In order to *trust* the digital tool, workers needed at least 70% alignment between their preferences, opinions and choices with the tool's suggestions. They argued that a 30% difference would not be problematic because the tool cannot account for some personal matters. However, they asserted that they would still have to get along with the tool's suggestions, even if they did not agree with them. The workers also emphasized their own effective role, based on their experience and awareness. Considering the ethical concerns regarding AI, the workers were reluctant to expose private data to the digital tool in the workplace. However, they believed that over time, further exploration could build trust in AI.

5 Discussion

Findings from the two-step case study demonstrate two key points that stand out. First, due to diverse interviewee perspectives, we were able to identify key socio-technical parameters for the development of the DSS. Second, our case study company, as a production enterprise, addresses the challenges of exploratory research to achieve greater flexibility through the application of such digital technologies and to position itself as a USP in this context. Starting with the first point, the focus on the socio-technical parameters and the consideration of social processes contribute to fostering the legitimacy of implementing the DSS within the company. This legitimation helps address the tensions that arise between the known social calls for representation and technical forms of representation. As the DSS is not inherently democratic, we needed to address the fundamental research question: how can a democratic character emerge in such a system and be asserted? Given that the legitimate implementation process creates a socio-technical environment offering opportunities for transparency, representation and fairness, the digital tool can potentially be considered democratic, as these are fundamental democratic features. Thus, the democratization of decision-making in socio-technical settings can imply that essential democratic features are integrated into the implementation process. This ensures that the implementation of the DSS not only enhances efficiency but also improves the company and empowers employees to engage in meaningful participation. Moreover, during the Precision step, we identified additional factors that interviewees regarded as democratic features (Fig. 1). Besides the primary features, Learning Implementation is recognized as a key factor that fosters democracy because it enables a long-term, comprehensive learning period from scratch, in which all employees are actively involved. Such implementation is less likely to be denied or forgotten, and any limitations of the digital tool can be identified quickly and resolved. Customizability also enables last-minute adjustments for customers and decision-makers, giving them more control over how the system operates and enhancing the system's flexibility. Additionally, according to the employees, accountability is an important democratic feature because it fosters transparency and fairness. This allows individuals to track the decisions made by the system and ensures that decisions can be changed or improved if necessary. Consequently, these features empower employees by providing tools and opportunities for active engagement in decision-making, ensuring their voices are heard and fostering a more inclusive, collaborative environment that promotes collective decision-making.

Moving on to the second point, the case study company operates in three main sectors: Industry, Automotive, and Health. As the application of AI in industry is no longer deniable, it has progressed beyond its early stages and is approaching readiness for broader use. This organization, operating in a high-cost environment, faces increasing competition from regions with lower production costs. To remain competitive, it aims to focus on technological innovation. Providing advanced technology and achieving greater cost efficiency are essential strategies for attracting and retaining customers, ensuring long-term success in a highly competitive global market. The company's ambition to position itself as a USP can be realized through an optimal and comprehensive plan, which primarily aims to ensure customer satisfaction and optimize the use of resources. Strengthening

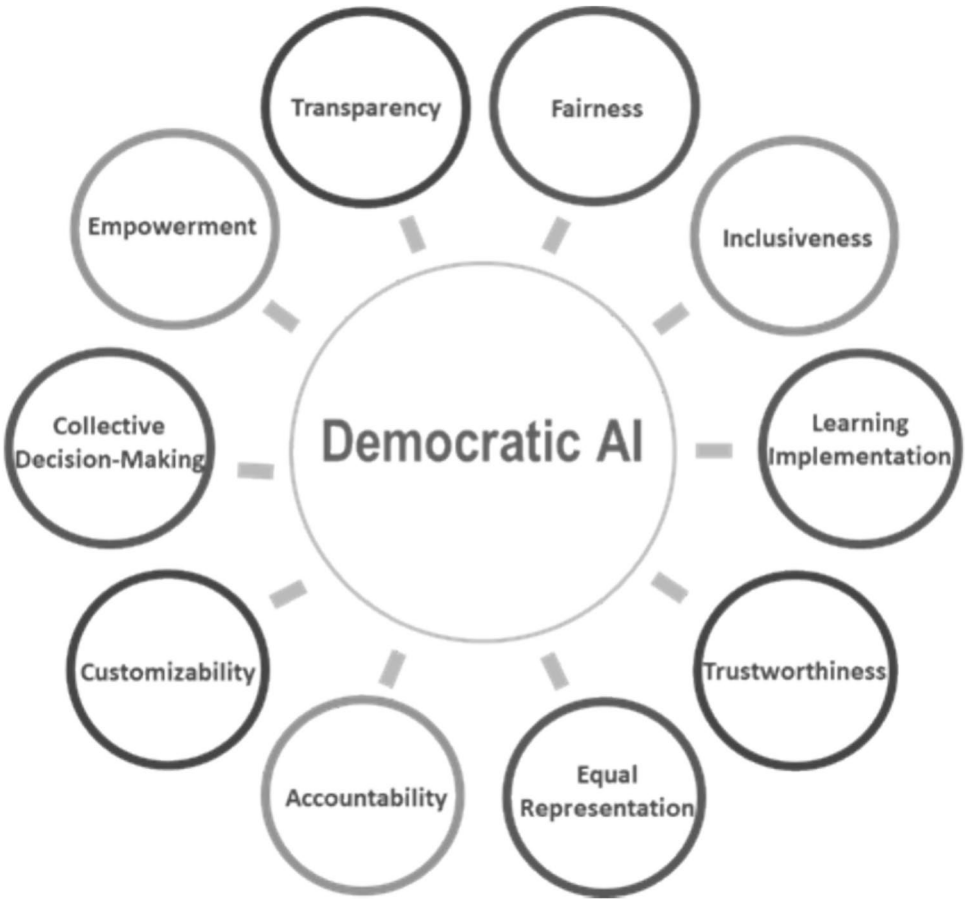


Fig. 1 Features of democratic AI in companies

the USP can be achieved by implementing a legitimate DSS that incorporates key democratic features.

An important aspect to be discussed is the contextual limitations of this study. First, during both phases of the case study, the workers involved had no prior knowledge of how the envisioned DSS would look. This made it difficult for them to imagine how such a tool could function, what expectations would be appropriate or what limitations it could entail. This issue was particularly pronounced during the first phase, as the DSS had not yet been developed, making it even more challenging to convey how the tool might support their work. As a result, many workers focused on describing their current challenges and experiences on the shop floor, rather than articulating expectations or reflections specifically related to a DSS. A second limitation relates to the interdisciplinary nature of the project, which required parallel processes of research and technical development. Due to this simultaneity, not all democratic features identified later in the project could be incorporated into the DSS from the beginning. As a consequence, prototype testing occurred after the case study research was completed. A follow-up case study after implementation would have allowed for gathering workers' feedback based on actual use of the tool.

6 Conclusion

This study undertakes an exploration of industrial democratization through MAS, focusing specifically on a two-step case study of a production company. Through the utilization of a comprehensive methodology involving documentary analysis, observations, individual interviews and a focus group interview, we have acquired valuable insights into the current decision-making processes, the degree of employee engagement within the company, as well as the anticipated functionalities of the DSS by employees. Additionally, we have identified nuanced challenges that workers face within extensive contexts such as resource allocation, production management, personal competencies and their expectations and possible solutions for addressing these challenges.

The findings underscore the need for the development of a robust DSS to initially offer production-line responsible persons a diverse array of solutions, thereby facilitating informed decision-making. Subsequently, such a system can serve as a tool to provide relevant data, whether related to workforce assignment plans, customer data, inventory management or other important factors such as components, employees and timestamps. Providing data, solutions and the experienced consequences via a system allows to asses

superiors' experience and simplifies the familiarization process for each newly hired employee. Moreover, they get enabled to gain sufficient confidence to make informed decisions. The implementation of such a system, coupled with the delegation of tasks and responsibilities to the system, shows potential for alleviating existing workloads and time pressures, ultimately fostering employee productivity and innovation across all organizational levels.

With regard to the exploration of employee involvement, we found that the dominant high level of trust among team members has led to a decreased tendency to raise objections or offer suggestions. However, there is a desire for self-management of PTO and task assignments through the system. Despite the presence of a strong level of trust within the team, such trust may be weakened in instances where a mismatch arises between decisions reached collectively and their subsequent implementation within the company. However, with the implementation of a DSS, such problems can be addressed, as they may arise from the involvement of several decision-makers, each with potentially conflicting perspectives and suggestions. In addition, the analysis of outcomes within the involvement dimension indicates that decisions made at the shop-floor level are typically characterized by a higher degree of transparency, often resulting from regular meetings, active inquiry and the inclusive participation of all relevant staff members. Conversely, decisions formulated at the upper management level are less frequently perceived as transparent to the entire staff. Furthermore, notably, employees view the DSS as a supplementary tool, rather than a replacement for human decision-making.

Addressing the challenges in the second step of the research reveals a significant area for discussion. In addition to the issues identified in the individual interviews, the focus group interview provided shop-floor workers with an opportunity to share their core concerns within the workflow. Notably, the most prominent issues discussed were related to personal matters rather than work-related concerns. The workers emphasized the importance of balanced team contributions, equitable work assignments and the need for fair recognition, appreciation and inclusive treatment in the workplace. Even when asked which areas a digital tool could alleviate or where support was needed, they ultimately focused on interpersonal matters related to their feelings as individuals—concerns that can hardly be directly addressed by a DSS.

However, there is a tension emerging. The tension between the needs and ambitions of the ones being represented in the DSS and the forms and logics of representing within the tool. This tension can be seen as the litmus test of the development of these kinds of tools. If there are no further options to get an insight or to intervene into the ways of being represented, the tool's legitimacy is at risk. In alignment to this, the workers express a firm belief that such a system should not take away their autonomy in decision-making but should instead enhance their ability to make informed, efficient and simplified decisions. The consensus among employees is that the DSS should act as a guiding mechanism or an option identification tool, providing insights and recommendations to facilitate improved decision-making processes, while the ultimate responsibility for decision-making remains with human actors.

Building on this perspective, we can conclude that forms of democratization via MAS can only be achieved if key democratic features are incorporated into the development and implementation process. This ensures that the use of the AI tool not only increases efficiency but also improves the company and empowers employees to engage in meaningful participation. According to our findings, these democratic features are transparency, fairness and representation. This implementation process leads to continuous stabilization and fosters legitimacy.

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Data availability The data used in this study are available upon request and can be accessed with the authors' approval.

Declarations

Ethics approval This study was conducted in accordance with relevant ethical guidelines. All participants received sufficient information about the research and provided their informed consent to participate.

Human ethics This research complies with the ethical principles and standards established by the World Medical Association's 1964 Helsinki Declaration.

Consent for publication All authors have given their consent for the publication of this article.

Competing interests The authors declare that there are no financial or non-financial competing interests related to this study.

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