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The Challenge of Socio-Technical Work Design

An Essay on the Open Issues of Industry 4.0 and Industry 5.0

Abstract

This essay examines the challenges of socio-technical work design in the current phase of industrial transformation. It demonstrates how these challenges are approached differently within the Industry 4.0 and Industry 5.0 concepts. Despite these divergences, it is argued that both visions draw on the socio-technical approach to designing human-centred work. The starting point is the principle of 'joint optimisation' of the socio-technical approach, whereby the interfaces between the technology, human and organisational subsystems can be considered the central design options. However, from a sociological point of view, the socio-technical system approach is criticised for being overly simplistic. This is because it focuses solely on the immediate work process and the 'container' of an individual company. It overlooks structural conditions of work that extend beyond this and have a lasting influence on the socio-technical design of work. This is particularly evident in the context of the current industrial transformation. Finally, prospects for the debate on socio-technical work design and human-centred work, as well as the broader concepts of Industry 4.0 and 5.0, are considered in the context of industrial transformation. It is presumed that the future of this discussion, particularly regarding human-centred work design, as well as the concepts of Industry 4.0 and 5.0 in general, is characterised by significant uncertainty. Given the crisis-level challenges of the industrial transformation, it is assumed that the debate on human-centred work and the concepts of Industry 4.0 and Industry 5.0 will lose their current political relevance.

Zusammenfassung

Gegenstand des Essays sind Herausforderungen sozio-technischer Arbeitsgestaltung in der gegenwärtigen Phase industrieller Transformation. Es wird gezeigt, dass diese Herausforderungen in den Visionen Industry 4.0 und Industry 5.0 in unterschiedlicher Weise aufgegriffen werden. Dabei wird verdeutlicht, dass trotz dieser Divergenzen in beiden Visionen auf den sozio-technischen Ansatz der Gestaltung humanorientierter Arbeit zurückgegriffen wird. Ausgangspunkt ist das Prinzip der ‚joint optimisation' dieses Ansatzes, sodass die Interfaces der Teilsysteme als die zentralen Gestaltungsdimensionen für Arbeit angesehen werden können. Allerdings wird kritisiert, dass der sozio-technische Systemansatz aus soziologischer Sicht als unterkomplex anzusehen ist. Der Grund dafür ist, dass er sich ausschließlich auf die Analyse und Gestaltung unmittelbarer Arbeitsprozesse konzentriert. Darüberhinausgehende strukturelle Arbeitsbedingungen, die einen nachhaltigen Einfluss auf die sozio-technische Gestaltung der Arbeit haben, werden nicht systematisch berücksichtigt. Gezeigt wird, dass dies insbesondere für die strukturellen Herausforderungen der gegenwärtigen industriellen Transformation gilt. Abschließend wird daher nach den Perspektiven der Debatte über sozio-technische und humanorientierte Arbeitsgestaltung gefragt. Die Vermutung ist, dass angesichts der krisenhaften Herausforderungen der industriellen Transformation sowohl die Debatte über humanorientierte Arbeit als auch die Konzepte Industrie 4.0 und Industrie 5.0 generell ihre bisherige politische Relevanz einbüßen werden.

Keywords: Work design, socio-technical system, Industry 4.0, Industry 5.0, human-centred work

Contents

1. The Essential Resource: Work

In the EU, and particularly in Germany, the industrial sector is under sustained pressure to change. Under the banner of ‘industrial transformation’, the challenges of inevitable change and the search for appropriate solutions are becoming the focus of public, political and scientific debates. There is no question that coping with industrial transformation is a complex social and economic problem. On the one hand, there is an ongoing discussion about changes to the institutional conditions of the production and innovation system. In particular, increased institutional flexibility and agility, as well as new forms of policy and regulatory patterns, are considered indispensable (cf. Edler & Walz, 2024). On the other hand, this affects individual companies, where fundamental strategic and cultural change is usually accompanied by technological, organisational and personnel reorientation and design concepts. In many cases, such as in the automotive industry and its suppliers, this cannot be limited to the iterative and path-dependent transformation processes that have been practised and proven successful to date (cf. Hirsch-Kreinsen, 2020). Instead, disruptive leaps in terms of technologies, innovations or even business models are inevitable if the company is to secure its long-term existence (cf. Krzywdzinski, 2024).

A broad spectrum of very different approaches and concepts in terms of industrial policy, innovation policy and corporate policy have been proposed in response to this pressure for transformation (cf. Amaroso et al., 2022; Dullien & Hackenbroich, 2022). At the macroeconomic level, policy measures in the areas of trade, energy, and education are being discussed to initiate and facilitate the transformation process in companies. Additionally, the focus is on innovation and corporate policy concepts for transformation.

In this context, the question of the future role of work is of great importance. Despite the need for a broad perspective on the challenges of industrial transformation, it has been emphasised that work is a vital resource for this process. Firstly, the available qualifications and skills at various work levels, and their ability to adapt flexibly, have always been considered indispensable prerequisites for successfully coping with change and new requirements. This has been clearly demonstrated by numerous studies on the digitisation of industrial work in particular. Furthermore, social science research has consistently demonstrated that the experience, implicit knowledge, and

skills of employees are crucial for successfully managing innovation and change (cf. Hirsch-Kreinsen & Ittermann, 2021).

Therefore, the question of how industrial work should be structured in the future to cope with change is of vital importance in the discourse on transformation. This will be examined in more detail below. The focus is on the modernisation concepts Industry 4.0 and Industry 5.0. These concepts have been extremely prominent in innovation policy and practical application with regard to industrial transformation in Germany, Europe, and far beyond for years. Both address the topic of the future of work, albeit in different ways.

2. Different Understanding of Work Design

Industry 4.0 is a German initiative that began in 2011. In 2021, at the ten-year mark since the introduction of Industry 4.0, the European Commission announced Industry 5.0. As the fundamental difference between the two concepts can be regarded that Industry 4.0 is technology-driven, whereas Industry 5.0 is value-driven (cf. Xu et al., 2021; Fogaca et al., 2025). However, a more detailed analysis is needed to specify this difference. This is particularly relevant when considering the significance of work in each concept and the design criteria discussed.

Industry 4.0

Since 2011, the Industry 4.0 concept has received a great response both nationally and internationally. Many countries have introduced similar strategic initiatives, and considerable research has gone into developing and implementing some Industry 4.0 technologies. As its founders emphasise, the concept's goal was to strengthen the resilience and competitiveness of the German economy by improving adaptability and resource efficiency in response to the global financial crisis. In other words, the aim is to modernise industry by widely using digital technologies (cf. Kagermann et al., 2012; Vogel-Heuser & Hess, 2016). This encompasses leveraging current trends such as industrial AI, edge computing, edge cloud, 5G in factories, team robotics, autonomous intralogistics systems and trustworthy data infrastructures (cf. Kagermann & Wahlster, 2022).

Although the Industry 4.0 concept is a politically promoted initiative of the German federal government, it was developed and initiated by politically influential scientists

and company representatives (cf. Kagermann et al., 2011). These stakeholders came from the fields of computer science and technical sciences, as well as from companies in the electrical engineering, mechanical engineering, and software industries. At the same time, the concept's further development, the drafting of a research agenda and innovation policy measures, and its diffusion were closely integrated into the corporatist German economic system. Consequently, the Industry 4.0 discourse and development process took place within a framework of cooperation between politics, business, science, trade associations and, above all, the influential metalworkers' union.

This had consequences: Firstly, despite the scepticism of many company representatives, the concept was quickly translated into a large number of concrete applications within companies (cf. Forschungsbeirat & acatech, 2022). Secondly, in terms of innovation policy, the topic of work was relevant from the outset despite the strong focus on computer science and engineering in the Industry 4.0 discourse. Questions about the quantitative and qualitative consequences of work, and in particular the potential for human-centred work design offered by new digital technologies, were intensively discussed in the context of Industry 4.0.

Furthermore, this discourse indirectly placed the topic of ‘the future of work’ on the research policy agenda in Germany and on the agenda of a wide range of labour and industrial policy activities. In other words, Industry 4.0 provided lasting impetus for social science research on work and the debate on criteria for human-centred digital work design (see Hirsch-Kreinsen, 2023 for a summary). Therefore, the Industry 4.0 concept cannot be said to be predominantly technology-centric (cf. Howaldt et al., 2017). Rather, work is considered an indispensable element of a digitised production process in this discourse (cf. Kagermann et al., 2012). Accordingly, fundamental design criteria and potential applications for digital industrial work have been developed during the Industry 4.0 discourse. These are based on well-known human-centred work guidelines, such as autonomy and self-determination, teamwork and flexibility, continuing education and participation, and decentralisation and flat hierarchies (cf. Forschungsbeirat & acatech, 2024).

In summary, Industry 4.0 recognises digital technologies as the starting point and driving force for overcoming the challenges of transformation. According to recent

thinking, technology should be used not only to achieve economic goals, but also broader socio-political ones. For instance, social objectives such as autonomy, interoperability and sustainability are emphasised (cf. BMWI, 2020). Work is considered an indispensable element of successful digitisation and overcoming the challenges of industrial transformation. Therefore, work can be regarded as a loosely coupled dependent variable of digitisation.

Industry 5.0

As a complementary concept to Industry 4.0, the EU Commission presented Industry 5.0 in 2021. This concept is based on the idea that economic and technological objectives should be aligned with social and environmental objectives (cf. European Commission, 2024). Some authors note that the conceptual roots of Industry 5.0 can be traced back to Japan's Society 5.0, which focuses on societal transformation beyond manufacturing efficiency (cf. Genest, 2025). Consequently, Industry 5.0 can be considered a concept with a strong political and normative foundation. It is characterised as a top-down initiative in response to the changing societal, environmental, and geopolitical landscape. Its general goal is to expand the I4.0 concept — considered technology-centric and overly economically oriented — by placing social, political, and ecological goals at the starting point of discourse and development, rather than technology (cf. Xu et al., 2021; Banholzer, 2022).

The concept states that digital innovation and its application in the form of services, products and processes must ensure threefold goals of being sustainability, human-centricity and resilience with regard to industry, the economy, society and its citizens and members (cf. Oeij & Dhondt, 2026). However, these objectives are as broad as unspecific: human-centricity, sustainability, and resilience should be promoted within company frameworks, while the work and production processes of companies should contribute to solving societal problems rather than primarily serving the interests of shareholders. Against this background, the concept of Industry 5.0 is understood as a multidimensional innovation ecosystem that can contribute to the humanisation of working life and the democratisation of socio-ecological transformation (cf. Kopp & Schröder, 2025).

As far as can be ascertained, companies have been very limited in their involvement in the Industry 5.0 discourse to date, and it is unclear to what extent it has spread

across the various EU countries. While the literature emphasises that the goals of Industry 5.0 have gained broad political acceptance, its diffusion and practical adoption may be still in its early stages. Research indicates that the current phase is centred on establishing the basis for circular and cross-sectoral practices (cf. Barata & Kayser, 2023). Furthermore, national governments' and industries' response to Industry 5.0 is currently limited. This is particularly true in Germany, where the Industry 5.0 concept is viewed critically as an unnecessary competition for Industry 4.0 (cf. Forschungsbeirat, 2024a). Academia, however, has quickly embraced discussions on Industry 5.0, highlighting its relevance (cf. Xu et al., 2021).

Regarding the design of work, the level of analysis and conception remains relatively unspecific at a meso level across different employee groups beyond the shop floor and manufacturing. Additionally, there is an ongoing discussion about concrete approaches in the context of Industry 5.0 (cf. Oeij et al., 2024; Oeij & Dhondt, 2026).

In summary, unlike Industry 4.0, Industry 5.0 takes human-centred work defined by norms as the starting point for designing work processes. The use of technology must be fundamentally oriented towards this criterion. At the same time, it is hypothesised that this will also facilitate the achievement of broader social goals such as sustainability and resilience. In contrast to Industry 4.0, Industry 5.0 can be characterised by the fact that the normative provisions of human-centred work act as the independent variable and technologies as the dependent variable.

3. The Socio-Technical Design Perspective

Clearly, the two approaches conceptualise the importance of work differently. Nevertheless, there are also clear parallels in terms of how work design can be approached conceptually. This is because both concepts refer to the well-known socio-technical systems analysis and design approach. This provides an important point of reference, in the context of the Industry 4.0 debate (cf. Kagermann et al., 2012), as well as in the current Industry 5.0 discourse (cf. Oeij et al., 2025; Oeij & Dhondt, 2026).

On the Approach

Research on the approach has not always been consistent in its definitions of a socio-technical system, and different approaches exist in Scandinavia, the Netherlands, Belgium, the Anglo-American region and German-speaking countries (cf. de Sitter et

al., 1997; Kuipers et al., 2020; Bendel & Latniak, 2023; Oeij et al., 2025). Without going into detail about these differences here, the following general characteristics can be identified based on the Tavistock approach (cf. Trist & Bamforth, 1951; Rice, 1963): A socio-technical system can be understood as a production unit consisting of interdependent technological, personnel, and organisational subsystems. Although the technological subsystem can limit the design possibilities of the other two subsystems, the latter display independent social and psychological characteristics that, in turn, affect the functioning of the technological subsystem. The technological subsystem includes new digital technologies; the human subsystem refers to employment structures and skill requirements; and the organisational subsystem comprises workplace structures, new management functions, and company business models. The technological subsystem can limit the design possibilities of the other two subsystems; these display independent social and psychological characteristics that affect the functioning of the technological subsystem. In the socio-technical approach, the focus is not on technology or work per se, but rather on the complementary design of the three subsystems, which are adjusted to one another within a total socio-technical system (cf. Trist & Bamforth, 1951). In other words, the specific strengths and weaknesses of technology and human work must be considered equally to meet the demands of production. Furthermore, it is important to note that the socio-technical system is embedded in strategic and normative framework conditions and societal context factors, such as politically established regulations.

The basic principle of the socio-technical systems approach is the joint optimisation of work, organisation, and technology (cf. Cherns, 1987). The intention is to achieve two goals that are usually pursued independently of each other: On the one hand, human-centred work which is essentially normative and based on labour policy considerations. On the other hand, it is expected that efficiency and productivity will increase as a result of better working conditions. In other words, the main goal of this approach is to implement forms of digital work that are both efficient and people-centered (e.g. less stress, alienation or degradation), greater participation and more motivated employees (cf. Grote & Guest, 2017; Bendel & Latniak, 2023).

Design Options

Design criteria based on these considerations can be systematically derived for designing and implementing human-oriented forms of digitised work. Following the principle of joint optimisation, the design criteria should focus on the interdependencies between technology, personnel, and organisation rather than on a single subsystem. Therefore, the focus should be on designing the interfaces between the technological, human, and organisational subsystems of the entire socio-technical system (cf. Hirsch-Kreinsen, 2023; Oeij & Dhondt, 2026). Referring to considerations from the sociology of work, which are loosely linked to the Industry 4.0 discourse and the socio-technical approach in general, the following design options for these interfaces can be identified (e.g. Kadir & Broberg, 2020; Hirsch-Kreinsen & Ittermann, 2021; Hirsch-Kreinsen, 2023):

Technology–Human Interface

The design of the interface between the technological and personnel subsystems is, of course, a matter of considering the well-known criteria of ergonomically oriented dialogue design. However, interaction between machines and human work means more than that. Intelligent digital systems allow new patterns of function distribution and interaction between machine and human to be designed. Important are two basic alternative solutions for designing the technology-human interface: First, digital systems can provide strict instructions to workers to limit their scope of action and reduce qualification requirements. This solution can be termed ‘technology-centred’. Secondly, digital systems can be ‘assistance systems’ that support workers, allow a variety of work, promote on-the-job learning processes, and thereby raise qualification levels. From a human-centred perspective, the second design solution is clearly preferable due to the criterion of human-centred work. This solution should be based on design criteria such as

- *Context sensitivity and adaptivity:* these criteria include aspects of the ergonomic adaptation of digital systems to specific loads and working conditions. Adaptivity means tailoring information and support systems to workers' varying levels of competence to ensure continued learning and enhanced processes at staff level.
- *Complementarity*: this criterion focuses on the flexible and situation-specific allocation of functions between humans and digital systems, as well as ensuring the

system is sufficiently transparent and controllable. Concerning AI-based systems, these requirements can be summarised by the concept of Explainable Artificial Intelligence (cf. Mihály, 2023).

Additionally, human oriented interface design is a prerequisite for satisfactory functional and economic capability of the total system. This requires a holistic view of human-machine interaction and the identification of the strengths and weaknesses of both human work and digital technologies.

Human-Organization Interface

The human–organization interface deals with changes in scope for action, working time models and new demands on skills, qualifications and modes of training. From a human-centred perspective, the human-organisation interface can be designed to sustainably revalue activities and skills. There are options for efficient patterns of work organisation, as well as work situations with particular qualification demands, a high degree of scope for action, the polyvalent deployment of workers and a multitude of opportunities for ‘learning on the job’, where skills and competences can be acquired independently. Both individual and collective learning can take place through job rotation, as well as through ‘learning islands’ or ‘learning factories’. Learning-promotive work organisation and training measures should take into account the various levels of experience and skills of employees. Additionally, tasks will rarely address individual workers, but rather teams. This means that ‘work collectives’ should be able to act in a self-organising way and be highly flexible in addressing the problems to be solved in the technological system.

The main criteria for designing work activities at the human-organisational interface can be summarised by the concept of holism. Firstly, an activity should include not only executive tasks, but also dispositive tasks such as organising, planning and controlling. Secondly, this criterion aims to achieve an appropriate, stress-reducing mix of more or less demanding tasks. Holistic activities are therefore the central prerequisite for a high degree of freedom of action and self-organisation of work. Ultimately, this also creates the organisational conditions for continuous learning and qualification processes.

Organisation-Technology Interface

At the organisation-technology interface, redesigning the work organisation and even the reorganization of the whole company creates new design options. Changes to the production chain in terms of function and hierarchy are possible, e.g. structuring and linking the direct processes with the indirect planning, engineering, management, and support processes. A main prerequisite is that the new digital systems allow a significant departure from the centralised IT systems of previous years due to their decentralised and simultaneous networked intelligence. Consequently, a general shift towards decentralisation is possible.

This affects not only the manufacturing process, but also the hierarchical dimension of the entire company organisation and logistics. Features of social media, and the new forms of communication they bring, also affect indirect areas such as planning, control and engineering, as well as leadership and management functions. Additionally, management functions in manufacturing and business divisions must be reorganised due to changes in their decision-making power and the transfer of responsibilities to subordinates (cf. Kopp et al., 2022).

4. Critique and Open Issues

The socio-technical systems approach is highly valued for its analytical and design-oriented nature. This is because it provides a conceptual basis for systematically determining alternatives and options for designing work processes in a specific operational situation. Additionally, the approach provides a basis for a common understanding among the divergent interest groups involved in system and work design, including management, employees, and their representatives. This is because the functional relationships it describes, and its fundamental premise that work-oriented system design is a prerequisite for economical production, provide a basis for reconciling diverging interests in the process of work design.

From a sociological perspective, however, the socio-technical systems approach and the design principles based on it can be seen as overly simplistic or even voluntaristic. This is because it focuses primarily on the analysis and design of the immediate work process. Structural and societal factors and conditions that extend beyond this and which have a lasting influence on the socio-technical design of work are excluded. The following arguments should be highlighted here:

Hybrid Systems

The approach is rooted in a conventional, static technical-organisational perspective on work situations. Technology is understood in a one-dimensional way as automation technology, and the technical and social subsystems are viewed as interdependent, but only loosely coupled. The approach pays little attention to the technical and organisational characteristics of new digital and ‘smart’ technologies. Research has long pointed out that, in the context of the increasing use of smart digital systems, the technological and work dimensions should be understood as a closely and dynamically linked functional unit (cf. Leonardi, 2012; Winter et al., 2014). The interaction between intelligent systems and worker behaviour has generally to be described as hybrid. This means that the relationship between technology and humans in terms of tasks and actions is constantly redefined depending on the situation. A typical example of this is the dynamic and only situation-specific interaction between AI systems and work. It can therefore be concluded that only a hybrid perspective encompassing both technology and humans can reveal the distribution of activities and degrees of autonomy in socio-technical constellations (cf. Schulz-Schäffer, 2025).

Dynamic Change

Due to its primary focus on the 'container' of internal functional areas, the socio-technical approach does not systematically consider recent trends in cross-company networking (cf. Walker et al., 2008). Firstly, there are the dynamic trends of the current digitisation phase, which can be summarised by terms such as service orientation, new business models based on big data, and the platform economy. Secondly, a company's ecosystem, including customers, suppliers and other social stakeholders, must become the reference point for socio-technical work and system design. These developments require a shift away from a static understanding of the joint optimisation of technology and organisation, in favour of a dynamic understanding of cross-company value chains and the associated adaptation and coordination processes (cf. Winter et al., 2014).

Furthermore, the design of socio-technical work systems must be rapid and adaptable. As the tension between standardised regular operations and companies' pressure to innovate increases, work systems can no longer be set up once and for all; they must be able to adapt quickly to changing conditions. Further developments and

versions — 'learning by using' — must therefore be incorporated into the socio-technical concept and design from the outset (cf. Bender & Latniak, 2023).

Sectoral Conditions

Furthermore, human-oriented socio-technical work design must always consider the working conditions of different sectors. This is because design criteria must be adapted to the specific material, structural and functional characteristics of different process types and work segments in terms of requirements and qualifications (cf. Krzywdzinski, 2022). These characteristics present different obstacles or opportunities not only for the layout of digital systems, but als0 for socio-technical work design. This thesis follows the prevailing wisdom of sociological studies of work, which have demonstrated significant technical, organisational, and work-related differences between different industries and work segments in terms of rationalisation processes and work design (cf. Kern & Schumann, 2023). In manufacturing, for example, these differences can be seen when comparing low-skilled jobs in standardised logistics processes with skilled assembly work in manufacturing industries and complex monitoring activities in process industries. These refer to completely different process logics, technological possibilities, development perspectives and work patterns.

Therefore, the design of the aforementioned interfaces between the three socio-technical subsystems depends on the structural framework conditions of different work segments and industrial sectors. Depending on the constellation of conditions, this results in different socio-technical design options and requirements for work. Consequently, there is no uniform approach to human-centred work design. Rather, one must speak of different development perspectives in different sectors and work segments for human-centred work.

Societal Conditions

Additionally, societal framework conditions are not sufficiently taken into account. Conceptually, it is assumed that a socio-technical system is always linked to overarching structural factors (cf. Rice, 1963). However, it remains unclear what consequences this has for work design strategies. For example, it is an open question whether socio-technical work design always leads to improved process efficiency. Research findings show that human-oriented work design has positive economic

effects, but only in the long term. In the short term, however, they are often associated with costs and risks that are difficult to quantify, and which deters companies from taking such measures. Therefore, companies are often only minimally interested in forward-looking HR strategies due to cost considerations and limited resources. This is particularly true of the large number of SMEs with limited resources.

Also, the influence of dynamic technological development should not be overlooked; companies are under considerable pressure to innovate (cf. ten Hompel et al., 2019). Consequently, contrary to the goal of human-oriented work design, companies are focusing solely on technological applications and relying on their employees' ability to adapt informally to new technological requirements. In this respect, the transformation of work in the context of digitalisation is characterised by a lack of innovative and human-oriented patterns of work and a high degree path dependency (cf. Hirsch-Kreinsen, 2020).

Finally, different normative orientations with regard to desirable work patterns must be acknowledged. However, the current debate on human-oriented forms of work overlooks divergent views among different employee groups, which are associated with varying degrees of acceptance and thus possibilities for implementing such forms of work. Naturally, highly qualified employees expect good, human-oriented working conditions. In contrast, such expectations are not necessarily found among low-skilled workers e.g. in logistics. According to our own research findings, employees in this segment often prefer restrictive, routine-based and predictable working conditions that are familiar to them, as these are less stressful. Experiments with human-centred work design, such as group work, have been rejected by employees on various occasions. These divergences between different employee groups have not yet been systematically addressed in the ongoing discourse on human-centred work. Therefore, one could critically ask, in a variation on the title of an essay on the problem of ”Human-centred AI” (cf. Ahn, 2025), 'Who is the human in human-centred work?'

5. Uncertain Perspectives

In conclusion, the prospects of the debate and the concept of human-oriented industrial work in the context of industrial transformation will be considered. There is much to suggest that the future of this debate and the issue is unclear and uncertain.

Because, recently, there have been signs that the issue of work is increasingly falling out of the focus of experts, politicians and the general public. Instead, questions about the current economic crisis, particularly how to overcome the challenges of industrial transformation and secure industrial locations and jobs, and a strong technological focus on AI are taking centre stage.

One indication of this is that in the German debate the Industry 4.0 vision and the associated work topic have clearly lost their appeal. One reason for this is the persistent discrepancy between Industry 4.0's promises of substantial economic gains and the potential for desirable job design. The benefits are difficult to identify, and the diffusion and implementation of Industry 4.0 systems is clearly reaching its limits. Based on recent data, therefore, one can speak of a 'setback' in the diffusion of Industry 4.0 in German manufacturing in several respects. Hardly any cutting-edge applications have been implemented in recent years. In fact, there has been stagnation and even a partial decline in Industry 4.0 investments in medium and small businesses. At least, there has been an increase in advanced applications in some large companies and equipment manufacturers (cf. Lerch et al., 2024). This setback is certainly also a consequence of the significantly changed economic challenges and location uncertainties that cannot be overcome by Industry 4.0 and digitalisation alone.

This difficult transformation situation also correlates with a strategic reorientation of trade unions due to pressure from production relocation and job losses. To quote a union representative, ‘because of the economic crisis, the hut is burning'. The consequence is a shift away from issues of human-centred technology use and work design. Institutionally spoken, this marks the beginning of the dissolution of the aforementioned typical German corporatist arrangement, of which Industry 4.0 and the work issue have been a part from the outset. This development is additionally being accelerated by a reorientation of national innovation policy towards a pronounced focus on technological developments, especially AI and space technologies. The issue of industrial work design is hardly addressed directly anymore. And, in the social sciences field of labour research, there is also a broadening of research topics and a clear decline in interest in industry and work design issues. The field of research is becoming increasingly confusing due to the countless differentiations and positions, and many actors from the scientific community are seeking new opportunities for profiling and financing with specialised questions.

These considerations raise the question of whether the concept of Industry 5.0 and the issue of job design are in a similar situation with regard to acceptance and dissemination in the entire EU. It can first of all be assumed that the Industry 5.0 discourse and dissemination of this concept face similar problems to those encountered by Industry 4.0. Companies of all kinds need to adapt in the face of economic crises and the challenges of transformation. In particular, efficiency targets are increasingly taking precedence over the human and environmental goals of Industry 5.0 (cf. Weckmann, 2025). Furthermore, EU-level politics will probably have to set new priorities for industrial and innovation policy, mainly due to new technological, geopolitical and geotechnological challenges. From the outset, the Industry 5.0 concept has been linked to the EU Commission's strategic priorities, particularly the European Green Deal (Genest, 2025), but these priorities are becoming less important in politics.

Additionally, structural obstacles hinder the rapid implementation of Industry 5.0's human-centric goals. In the current difficult economic climate, the aforementioned costs and risks associated with worker-oriented design goals may have a greater impact than before, even within the context of Industry 5.0. This issue is particularly pressing for the large number of small and medium-sized enterprises that have limited or no HR resources (cf. Barata & Kayser, 2023). Critics point out that Industry 5.0, as a value-based concept, implicitly presupposes discourse on values and willingness to bear costs. However, this is done without outlining a conception of the public sphere, political discourse or deliberative, agonistic or pragmatic debate in pluralistic democracies (cf. Banholzer, 2022).

Another closely related problem is that Industry 5.0 must be integrated at national levels and within existing ecosystems. This is because the EU's normative concept is confronted with significant influencing factors, such as cultural context dependencies, which have different action and design logics. Different national institutional regulations that may not allow for the uniform implementation of normative standards throughout Europe must be taken into account. For example, principles of human-oriented job design must be implemented within highly divergent systems of industrial relations in individual EU countries. As is well known, unlike in many other countries, work councils in Germany have comparatively extensive co-determination rights with regard to job and work process design. Consequently, the human-centricity criterion

of Industry 5.0 may be interpreted very differently in various EU countries, resulting in different approaches to work processes.

Hence, the visions of Industry 4.0 and 5.0, and with them the topic of human-centred work design, are expected to lose their socio-political significance as symbols of socially and socio-politically desirable progress. As with any innovation, visions are always subject to persistent application problems and uncertain outcomes that contradict and relativise such far-reaching expectations. This tension produces what innovation research refers to as the “promise requirement cycle of innovation” (cf. van Lente, 1993). Through development activities and diffusion processes, actors gain insights into actual technological potential, as well as application challenges and risks. Over time, outcomes are assessed and expectations reformulated in a more specific and critical manner. It is therefore unsurprising that discourses on innovation concepts like Industry 4.0 and 5.0 will be not only increasingly realistic, but also sceptical and critical.

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