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Industry 4.0: Options for Human-Oriented Work Design

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Abstract: This contribution deals with the diffusion of Industry 4.0 technologies and their consequences for work. Additionally, design options for work in Industry 4.0 are discussed. The following are outlined: First, since there are as yet no concrete future prospects for digital work, different development perspectives can be envisioned. Second, the development of Industry 4.0, therefore, has to be regarded as a design project. One theoretical basis for this is the "sociotechnical systems" approach. Third, this approach enables criteria for the design and implementation of human-oriented forms of digitized work to be systematically developed. The empirical basis of this contribution derives from research findings on the implementation of Industry 4.0 technologies and the development of digitized work in German industry. The research results are based on qualitative research methods such as company case studies and expert interviews.

Keywords: Industry 4.0; development of work; sociotechnical systems approach; human-oriented work design

1. Introduction

The diffusion of Industry 4.0 and digital technologies are changing the world of work in the industrial sector. These changes will become commonplace in the future, but predicting the consequences for jobs and skills is a much more difficult task. In the scientific and public debate, the economic and social consequences of Industry 4.0 are still the subject of intensive discussions, and clear trend statements hardly seem possible.

From a sociological point of view, at least two economic and societal consequences of the now more than ten-year discourse on the vision of Industry 4.0 [1] should be singled out: It has underscored the enormous structural economic importance of the industrial sector for many countries, and with this vision, forward-looking and innovative prospects have opened up for industry. Furthermore, Industry 4.0 puts the long-forgotten question of the future of industrial work back on the political agenda. It can be assumed that Industry 4.0 will by no means offer clear—negative or positive—consequences for jobs and qualifications. However, Industry 4.0 opens up a wide scope of development possibilities for work that can and should be used in its qualification- and human-oriented design.

Following this, the contribution draws on research findings on the development of industrial work as a result of the diffusion of Industry 4.0 systems. Especially, the prerequisites and chances of a human-centered design for industrial work will be outlined. These considerations refer to the approach of the "sociotechnical system", which assumes that new technologies entail both personnel and organizational changes. On this basis, the different and sometimes contradictory perspectives of human, technology and organization are brought together to develop a complementary design approach to industrial work under the conditions of a progressive digitization of industrial processes.

The goal of this article was, therefore, to emphasize design options for industrial work under the conditions of Industry 4.0. This should make clear that the process of change in work is by no means just a technologically caused process. Rather, it is strongly determined by economic and social factors, especially by the decision makers in companies involved in the introduction of digital systems.

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2. Materials and Methods

Methodologically, the contribution is based on theoretical considerations and the findings of empirical studies analyzing the diffusion of Industry 4.0 and the development of work in industrial sectors in Germany during the last few years. These are social science studies with a special focus on issues in the sociology of work and labor [2–4].

In detail, the methodical-empirical basis of the contribution includes information that the author and his research group have gained through the digitization discourse at various levels of politics and companies in recent years, secondly, the results of a continuous document and literature research on the digitization of work, and thirdly, research results from relevant, methodologically qualitative empirical research projects that were carried out between 2014 and 2019 at the TU Dortmund University on the change in work in the context of digital technologies.

The examined sample comprised around 23 company case studies. As a rule, expert talks were held with management representatives and works councils, as well as through detailed and sometimes repeated company visits. These were companies in the metal and furniture industry, companies from sub-sectors of the process industry, and logistics companies. The majority of these were medium-sized and small companies. The technical digitization solutions examined are diverse. There were applications from all functional areas of digital technologies in the case-study companies. These ranged from data-based applications, e.g., for process management in real time, to assistance systems for order picking and production planning and various forms of human–robot collaboration and largely autonomous floor conveyor technology to advanced cyber-physical production systems. The digital systems were in different stages of development. Some were still in the pilot phase or were operated as isolated solutions, while others were future-oriented implementation projects that had been approached rather cautiously for technical, economic or work and personnel-related reasons.

3. Divergent Perspectives on Industrial Work

The current debate suggests that digital technologies will change the nature of work in many sectors, especially in manufacturing—from the the shop floor to related areas such as planning, control systems and product development [5,6]. Therefore, leadership and management practices may also change significantly [7,8]. Although studies predicted thorough change in concrete processes of work, they did not agree about how industrial work and employment will change and what this will mean in terms of job structures, worker qualifications and skill requirements [9–11]. This was also shown in our own detailed research results. Companies will follow different approaches to work design and personnel strategies as they introduce Industry 4.0 technologies. No definitive prospects for the development of digital work can be identified, and one has to speak, therefore, of different development scenarios. On the base of our research findings, the development scenarios can be summarized as follows:

One scenario can be characterized as pessimistic about how the future development of industrial work will affect workers. On the one hand, this scenario contends that the demand for many tasks and qualifications will decline and the number of available jobs will be reduced dramatically. In particular, many jobs consisting of routine tasks will be replaced by the new technologies [12,13].

Our empirical findings show also that an increasing diffusion of technology will reduce jobs requiring only medium-level skills, while jobs demanding higher qualifications or low-skilled jobs that cannot be easily automated will benefit. Therefore, this scenario can be interpreted as an increasing “polarization” of high- and low-skilled jobs. In particular, trends towards distinct operational structures were elucidated in our research in the context of intelligent networked logistics systems—automated supply and distribution management systems that leverage digital technologies, such as self-checkout storage systems used by manufacturing companies. A clear polarization of the work is underway: on the one hand, more complex and skilled occupations such as those of managers and supervisors

have been established to operate new technology systems. On the other hand, low-skilled tasks and simple operations such as packaging and assembly have been retained, since the cost of automating these tasks has always been higher than the cost of paying cheap labor enough. As our findings show, companies often avoid fully automated systems due to their high technological complexity and high cost, but the tasks they automate are tasks that should be performed by skilled workers. The British sociologists Goos and Manning describe this trend as the emergence of "lousy and lovely jobs" [14].

Another scenario suggests more positive consequences of Industry 4.0 for work: job creation, higher levels of skill requirements, and a general revaluation of jobs, so that a new and more humane turn in work will be take place [15]. This optimistic scenario suggests that efficiency gains, new products, new markets and new employment opportunities will compensate for the short-term negative effects on jobs [16].

In our findings, many company management representatives predicted for Industry 4.0 high productivity gains and higher economic growth rates as well as a positive development in jobs. A majority of experts expect the share of the employed workforce to remain relatively stable and significant over the next few years, with no significant negative employment effects. With respect to skills, the perspective is that Industry 4.0 will bring a growing revaluation of qualifications and skills, the result of an increasing substitution of routinized simple jobs (such as machine monitoring or assembly work) by digital technologies. In line with this trend, nearly all other employee groups will be affected by increasing qualification requirements. The reason for this is that digitization makes a wide variety of information about ongoing processes available to the workers. The resulting complexity and potential applications of new technologies could result in fundamentally new and as yet unknown requirements for all job-related activities.

For example, under these conditions, skilled machine operators can make decisions about workflow sequences based on optimized information and control systems. The new technology provides data and assessment capabilities that allow for a much higher level of transparency in the manufacturing process. The optimistic outlook emphasizes that a general improvement in qualifications in the future is not only possible, but inevitable. In view of this, the pattern of work in manufacturing industries can evolve towards a model that can be characterized by a very limited division of labor, high flexibility, and increasing levels of competence. Therefore, this scenario can be characterized as the "upgrading" of jobs, qualifications and skills.

4. Industry 4.0 as a Design Project

To sum up, while there are no direct consequences of new technologies for work, alternative development perspectives on work in Industry 4.0 should not be overlooked. Of course, the pessimistic outlook presents a possible scenario. Still, our research provides good reasons for optimism, particularly about skills upgrading. The argument is that collaborative work processes, especially characterized by a high degree of autonomy at work, can help skilled workers effectively harness digitized systems to their advantage. However, there are opposing perspectives on how the digitization of work will affect workers of different skill levels and the nature of the work. In other words, there is no linear relationship between new technology and work, but alternative perspectives for the development of work.

This argument can be linked to the common wisdom of labor research, that one cannot speak of "technological determinism", i.e., that technology influences directly the development of work. Rather, the development and design of work are clearly complex and reciprocal relationship shaped not only by technology, but also by multiple economic, social and labor-political factors. Especially, specific company conditions strongly influence the path taken by the technology deployment and work design in each case. The influence and the concrete constellation of these factors determine in what way the new technologies will actually be used and how work will be redesigned [17]. *Therefore, Industry 4.0 has to be regarded as a design project*.

5. Sociotechnical Systems Approach

On our analytical and theoretical considerations, this perspective can be concretized within the "sociotechnical systems" approach. The basic assumption of this approach is that, in any case, both efficient and human-oriented forms of digital work can be realized. Therefore, the "sociotechnical" approach brings together the interactions and interdependences between the technological, human, and organizational dimensions of a work process. Thus, a sociotechnical system can to be regarded as a work unit consisting of interdependent technology, personnel, and organization subsystems [18,19]. The subsystem technology includes the new digital technologies, the human subsystem refers to the employment structures and skill requirements, and the organizational subsystem comprises workplace structures, new management functions, and innovative business models. Furthermore, the sociotechnical system is embedded in strategic and normative framework conditions and societal context factors such as politically established regulations (Figure 1).

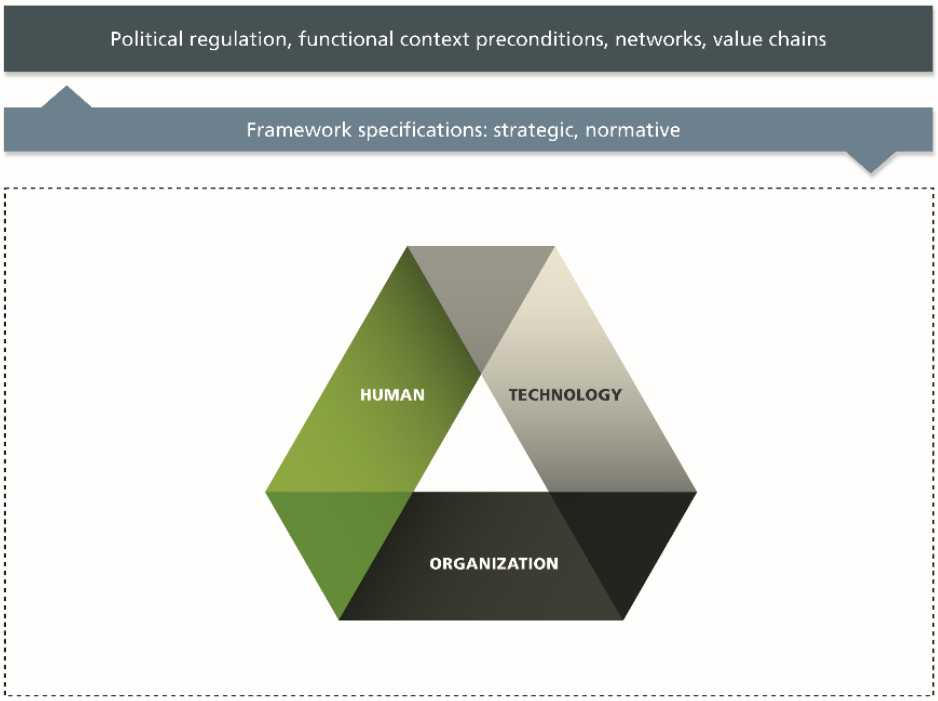

Figure 1. Conceptual representation of the sociotechnical systems approach (own source).

In the sociotechnical approach, it is not a question of *either* technology or work, but rather a *complementary* design of the three subsystems adjusted to one another in a total sociotechnical system. In other words, the specific strengths and weaknesses of the technology and human work should be equally considered to meet the concrete demands of production. Hence the basic principle of the sociotechnical system approach is the *joint optimization* of work, organization, and technology. However, the leading priority should be to exploit as well as possible the potential advantages of a human-oriented work design.

This aspect is also addressed in the catchy formula of the necessary *complementary innovation* (of the organization and personnel) that should be an element of the digital innovation. The argument goes as follows: "Organisations can only fully benefit from technological innovation if it is embedded in a proper work organisation" [20] (p. 138). This criticizes the technology-centered understanding of digital technologies observed among many decision-makers, which relies on the most far-reaching algorithmization of processes without taking into account the organizational and personnel context and necessary adjustments.

Criteria based on these considerations can be systematically deduced for the design and implementation of human-oriented forms of digitized work. The design criteria should

not focus on the single subsystems, but rather on the interdependencies between the technology, personnel, and organization, a matter of designing the *interfaces* between the technological, the human, and the organizational subsystems of the entire sociotechnical system. Design options for these interfaces may be highlighted as follows [3,4,21,22].

6. Design Options

6.1. Technology–Human Interface

The technology–human interface is, firstly, a well-known issue of the criteria for ergonomically oriented dialogue design, and secondly, a matter of new criteria for man–machine interfaces. This is because with Industry 4.0 systems, new patterns of *function-distribution* and *interaction between machine and man* are made possible. Their design must be assumed as one of the key issues in the implementation of digital technologies and Industry 4.0. There are currently two alternative solutions to the design of the technology–human interface: First, digital systems can provide strict instructions to workers in order to limit their space for action, and to reduce qualification requirements. This solution can be termed "technology-centered"; second, 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.

Of course, from a human-oriented perspective, the second design solution is desirable. In particular, this solution should be based on the following design criteria:

- *Context sensitivity and adaptivity*—These criteria include aspects of the ergonomic adaptation of digital systems to specific load and working conditions, which can be monitoring system loads or automating particularly difficult processes. In addition, it is a matter of optimally delivering situation-specific data and information to ensure uninterrupted workflow and avoid costly and stressful interruptions and delays. Intelligent ability is required to tailor information and support systems to individual, varying levels of competence on the part of workers, to ensure continued learning and enhanced process staff levels. Finally, the implementation of support systems must implicitly support the actual knowledge of employees.
- *Complementarity*—This criterion focuses on two central aspects of human–machine interaction: first, the flexible and situation-specific allocation of functions between humans and machines, and second a sufficiently transparent and controllable system. The relevant design aspects here are: ensuring human–computer interaction through intuitive and fast-learning hardware as well as targeted and situation-specific access to real-time digital information, to enable employees to make decisions and implement digitally supported behavioral preferences in a secure and editable manner.

Generally, an interface design must make possible, above all, a satisfactory functional and economic capability of the total system. This requires a holistic view of the human–machine interaction and the identification of the specific strengths and weaknesses of human work and digital technologies. Importantly, a central prerequisite here is that human work attain and secure control over production processes by gaining and building on the often indispensable practical experience and knowledge supported by smart assistant systems.

This form of interface design leads to broadening the scope of employees' tasks, meeting the demands of challenging and learning-friendly work, and opening up new possibilities for employee engagement in design and decision making. Therefore, the work situation is characterized by an expanding field of tasks and the need for new skills. The interaction between intelligent systems and worker behavior can generally be described as *hybrid*. Contrary to the traditional view of technology as a passive object, in digital technology the role of a behavioral agent is assigned, with the consequence that not only the division of labor but also the decision-making skills in a particular way must be constantly reinvented.

6.2. Human–Organization Interface

The human–organization interface deals with changes in the scope for actions, work-time models, and new demands on skills, qualifications and modes of training. A key issue is how the readily available skills, competencies and experiential knowledge of employees can be used for an optimal utilization of Industry 4.0 systems and a human-oriented work design. The current discourse on Industry 4.0 very often overlooks the organizational design of digitized work that is decisive for the completeness of operational tasks, as well as for the development of scope of action, learning, and qualification opportunities.

From a human-oriented perspective, the human–organization interface can be designed to achieve a sustainable revaluation of activities and skills. There are options for efficient patterns of work organization 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 competencies can be self-acquired. Individual as well as collective learning can take place through job rotation as well as in forms of "learning islands" or "learning factories". Learning-promotive work organization and training measures should take into account the various levels of (existing) experience and skills of the employees. An additional aspect is that the tasks will rarely address only individual workers, but rather teams. That means that "work collectives" should have the scope to act in a self-organizing 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 and organizational interface can be summarized in the following keywords:

- *Holism*—This criterion means all activities in a dual sense: on the one hand, an activity includes not only operational tasks, but also equipment tasks (organization, planning, and control). On the other hand, this criterion is geared towards a suitable and light mix of tasks that require more and less. For example, this design goal can be realized in the context of new forms of robotics or robot cooperation. Furthermore, the totality of activities is a central requirement for greater freedom of action as well as the ability to self-organize work.
- *Dynamics*—With this criterion, the following issues are addressed. First, the ability to organize work to exchange tasks systematically, in order to create workable learning processes and encourage them. Second, the new social media functions promote interdisciplinary communication and collaboration among employees with different expertise and thus increase creativity in work. Here, it is especially important to be able to "try it out in the workshop" to cope with the rapid development of technology. At the same time, in the context of loosely structured work patterns, it becomes possible to deploy employees with different capacities and production capacities, e.g., in mixed workgroups. Third, loosely structured and dynamic workflows are often a prerequisite for decisions and interventions to effectively deal with emerging unexpected disruptions.

Therefore, such an organizational structure can be described as a "holistic work organization" or metaphorically as a "swarm organization"—a loose network of employees with different qualifications and expertise. The central feature of this organizational model is that there are no defined tasks for each employee. In contrast, the "working collective" operates in a very flexible manner, self-organizing and deciding according to the situation, adjusting its behavior to suit the problems to be solved around the technological system.

6.3. Organization–Technology Interface

At the organization–technology interface, new design options are given due to re-designing the overall work process and even the re-organization of the whole company. This includes changes in the production chain in terms of function and hierarchy, as well as in the structuring and linkage between the direct processes and the indirect planning, engineering, management and support processes. Because of their decentralized and simul-

taneously networked intelligence, the new digital systems allow a far-reaching departure from the centralized IT systems of previous years.

Therefore, a general shift towards decentralization and de-hierarchization is possible—often in the framework of already relatively "flatly" structured company organizations. Furthermore, the company organization need not be only decentralized, since the digital technologies offer also the option of making the organization (even) more flexible. This suggests a highly individualized production, which is why an organizational structure based on autonomous, self-controlling systems with far-reaching *decentralized control and intelligence* should seriously be taken into account.

This concerns not only the manufacturing sector but also the hierarchical aspect of the company's entire organization, as well as logistics. The features of social media and with them, new forms of communication, also affect indirect areas such as planning, control, and engineering as well as leadership and management functions. In addition, there is a reorganization of management functions, such as in the production and business divisions, due to the change in decision-making power of these divisions and the transfer of responsibilities to subordinates.

Finally, new forms of value-chain structures and *new business models* become possible. In the "networked smart factory", industrial value creation is no longer limited to what happens within traditional organizational boundaries. In contrast, decentralized control is required, and the intelligence is—however—still controllable. As a result of this digitization, new business models are used to address technological and organizational challenges and their interrelationships. Therefore, changes are conceivable in entire value-chains that may significantly transcend previous forms of inter-company division of labor and outsourcing. With that are given the organizational prerequisites for overcoming company barriers to an extended service and customer orientation as well as to change in business models.

7. Conclusions

The findings show that there is no "one best way" or "one single way" in digital work. There are as yet no clear, deterministically derivable consequences for work as Industry 4.0 systems are implemented. Thus, the shape of a framework for the design of digital work becomes recognizable. Following the above-outlined criteria of human, technology and organization and their interdependencies under the requirements of Industry 4.0, forms of work that are characterized by the design of each of the interfaces are conceivable. To sum up, basic criteria for the development of a human-oriented design of work should include: far-reaching monitoring and regulation capabilities, intelligent assistance systems, complete and well-generalized tasks, learnability, high maneuverability, as well as new forms of self-organization with decentralized control. This framework can be applied to social and organizational requirements for high system transparency to human actors, controllability of complex system processes, and thus optimal functioning of the system as a whole. Of course, a successful diffusion and implementation of human-oriented digital work depends on additional conditions on the company level that support this process. Several aspects need to be emphasized here.

First, the acceptance of the new system and its work design capabilities, both on the workforce side as well as management side, must be ensured. The fact that this factor plays an important role has been confirmed many times in the course of our research. To alleviate workforce reticence towards new features of job design—e.g., the need to address concerns about job loss. New sources of stress with the requirements for flexibility are increasing, and the problems arising from data protection as well as the ability to monitor work performance are becoming crucial issues. Anticipated reorganization processes can mask many new and somewhat contradictory demands from workers for flexibility and self-organization. If there is a mismatch between current needs and resources, stressful behavioral dilemmas can arise for employees due to the need to manage immediate needs. Effective approaches to solving these problems can lie in process methods that involve employees and represent their interests in the introduction, design, and implementation of

Industry 4.0. On the management side, there can be frequent protests, especially against far-reaching measures that alter established practices within the hierarchical organization and the company. To overcome these limitations, targeted transfers of knowledge and experience should be introduced accordingly and further developed, presenting exemplary and successful good practice cases and communicating the success potential of human-oriented forms of work.

Second, there are challenges posed by changing management functions and leadership styles. It must be assumed that, in the face of the general challenges of new technology and especially the establishment of human-based forms of work, the traditional hierarchical structures and methods of management will become dysfunctional and outdated. The direction of change needed shows the increasing importance of "soft skills" as well as high ability to communicate and work in a team. Instead of control, now leadership and "motivation from afar", and instead of hierarchical leadership, "coordination" of colleagues and "peer-to-peer" communication and employee participation are now key features of successful management. In general, company leadership, through awareness of the new status quo, must account for trends through digitization and transformation of working forms, as functional and social boundaries between leadership and collaboration members will be eroded, or even reversed. In any case, the distinction between "blue collar" and "white collar" will become increasingly blurred. The aim is to establish new forms of self-organization and control, geared towards corporate goals, of course, but characterized by flexible and problem-oriented forms of management. Admittedly, this fragmentation of past management models and emphasis on bottom-up processes will lead to a certain contradiction: that digital transformation is successful and sustainable companies emerge simultaneously through top-down functional processes. However, because there are still many open questions, this issue needs more in-depth research in the future.

At the societal level, certain factors play a role in coping with change and further developments in regulatory forms of labor and social policies that at least indirectly influence the introduction of human-oriented digital forms of work. This includes, for example, the regulation of flexibility, working hours, co-determination and further training. These areas often require a new alignment of labor policy interests. This is the only way to avoid obstacles and reservations about work transformation arising from unresolved conflicts and objections. The importance of numerous further training measures as well as the development of skills for spreading human-centered forms of work in the context of Industry 4.0 cannot be overestimated.

A central goal of such measures should be to overcome multiple "digital divides". First, there is a need to balance skill differences between technology-intensive and non-technology-intensive firms. Second, differences in skills and performance between different employee groups (qualifications, age, etc.) must be balanced. Low-skilled jobs in particular must be taken into account so that these employees are not cut off from the general development of their qualifications. Overall, however, "capacity development" should be understood to mean the central means of education and social policy necessary to implement competence-oriented and people-oriented forms of work across a wide range of social levels.

All in all, a socially responsible development perspective on "Industry 4.0" is also the best way to ensure that future industrial work is suitable for an aging workforce. Furthermore, this design perspective can increase the attractiveness of industrial work and thus counteract the urgent demographic shortage of skilled workers in many industrialized countries. To overcome these pressing social challenges, key players in business, science and politics are investigating the social and organizational conditions necessary to realize the potential of people-oriented "Industry 4.0" designs and integrate them into comprehensive perspectives of sociotechnical integration. The EU's new Industry 5.0 concept [23] systematically addresses these requirements. In particular, it puts worker well-being at the center of the production process and uses new technologies to create wealth beyond work and growth.

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