Sociotechnical perspectives on digitalisation and Industry 4.0

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Abstract: The sociotechnical systems approach and theory (STS) helps to deal with today's rapid digital transformations in designing best suitable work, organisations and jobs. Not surprisingly, related approaches based on STS assumptions, such as modern sociotechnical thinking (MST) and workplace innovation (WPI) theory, are rapidly developing in Europe. Yet, research and (theoretical) analyses that place STS in today's digital industry challenges and WPI are sparse. The basics of sociotechnical concepts and new research, needs and perspectives for further development of STS in today's context need to be explored. Therefore, against the background of empirical experiences in logistics and process industry and in context of Industry 4.0, this article discusses firstly the model of classical STS approach and the skill orientated work design. Secondly, MST and its derived concept of WPI is positioned. Furthermore, a complementary 'practice theory' perspective is introduced, illustrated by an example design project. Finally, some future recommendations for research are made.

Keywords: digitalisation; Industry 4.0; workplace innovation; WPI; sociotechnical system approach; STS; skill-orientated work design; practice theory; material/skills/meaning.

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1 Introduction

The sociotechnical system approach (STS) is grounded on many approaches of analysis and design in work and industrial sociology. The STS approach has found application far beyond the community of social science. It has found acceptance within practice, in engineering and human resource communities as well as in policy making. The approach is useful to formulate requirements for digitalised work, as is now promoted with Industry 4.0 (Kopp, 2016; Howaldt et al., 2017). In light of the predicted serious transitions of the world of work within the digital transformation, it seems to be appropriate to check the basics of sociotechnical concepts and to explore (related) visions as well as needs and perspectives for further development. This was also one of the conclusions from the 'Innovationlab Hybrid Services in Logistics'[1] interdisciplinary expert workshop with representatives from social, work and engineering sciences on 15 February 2018 at TU Dortmund University (Kopp and Ittermann, 2018). For this paper, selected results of the workshop are used.

First, shall be sketched out shortly the model of classical STS in context of Industry 4.0 like it is used in logistic research in Germany. Within this STS-tradition, the concept of workplace innovation (WPI) has also been positioned as a new organisational concept for which the requirements are based on the Dutch (modern) approach (modern sociotechnical thinking, MST) (Oeij et al., 2017; Oeij and Dhondt, 2017) and will be discussed and compared to STS. There are many different sociotechnical approaches available for example like the cognitive work analysis (CWA) approach with a promising toolbox for designing and evaluating complex sociotechnical systems (e.g., Vicente, 1999; Burns and Hajdukiewicz, 2004; Jenkins et al., 2009; Naikar, 2017). We focus on WPI as an important reference for MST because of its practical and political significance on the European level and the collaboration in the mentioned workshop.

Next, a practice-theoretical perspective will be introduced, which direct itself to what happens in the direct relationship between technology and work. This perspective can be a further development for the STS-perspective. The result of this both practice-theoretical and sociotechnical inspired approach will be illustrated with an example out of the project 'Coordinating Optimisation of Complex Industrial Processes' (COCOP).[2] The perspectives will be illustrated with empirical experiences from the area of logistics and the process industry. It will be shown that the STS perspectives allow different accesses to practice with stronger or weaker normative implications.[3]

2 Industry 4.0 in perspective of a sociotechnical system perspective

2.1 Sociotechnical system approach

The way that industrial work evolves in response to the diffusion of digital technologies will strongly depend on how organisations and their stakeholders shape work design. An important direction in the debate is how to encourage the implementation of a skill-oriented work design model with the digital transformation (Forschungsunion and Acatech, 2013). Industry 4.0 is the summarising concept for the current trend of automation, digitalisation and data exchange in manufacturing technologies. “The widespread opinion is that the keyword Industry 4.0 stands for a technology-induced and centred vision of future automation and virtualisation of industrial production systems” [Ittermann and Niehaus, (2018), p.35]. In the opinion of many experts, “the highly flexible connection and synchronisation of the data network linked to the Internet with real factory processes opens up a fundamentally new potential for the planning, control and organisation of production and value creation processes” [Ittermann and Niehaus, (2018), p.35; Neugebauer et al., 2016]. In Germany, ‘Industry 4.0’ is strongly connected with ‘Work 4.0’ focusing in a broader perspective (also preferred by us) on digital transformation as enabler for people-centred new work designs. This requires a proactive vision from company managers, worker councils and unions. An analytical starting point for a skill-oriented design concept in the context of Industry 4.0 is the ‘sociotechnical system’ – an approach to work design that emphasises the interactions and interdependencies between technology, humans and the organisation as a whole. Although authors have not always been consistent in their definitions, a sociotechnical system can be understood as a production unit consisting of interdependent technology, organisation and personnel subsystems (Trist and Bamforth, 1951; Rice, 1963). Although the technological partial system can limit the design possibilities of the two other partial systems, these two systems determine to a high degree social and psychological workplace demands, that in turn affect the functioning of the technological partial system. If Industry 4.0 is understood as balanced sociotechnical systems, the separate partial systems should abide by the following requirements:

- In Industry 4.0 systems, it is not a question of ‘either technology or the individual’, but rather how a ‘complementary’ design should be realised. Complementarity means that, depending on the situation, the specific strengths and weaknesses of the technology and humans are equally considered and a functional division between humans and machines is developed that makes possible a disturbance-free and efficient functional capability of the total system. In the complementary design of the total system, the leading criterion should of course always be to take advantage of a skill-oriented work design (Grote, 2012) and furthermore to utilise new opportunities to design work structures that enhance learning (Böhle, 2017).
- The key design spaces are therefore less functional modes of the single partial systems, but rather ‘interdependencies’ between the technology, the personnel dimension and organisational aspects. In particular, it is a matter of designing the

functional relations or intersections between the technical, human and organisational systems. For the concrete configuration, besides functional and economic requirements, normative guidelines for skill-oriented work as well as diverse social and labour-policy interests play an important role.

Starting from these requirements, present research and our own analysis, the next section will focus on the key design spaces and the intersections between personnel, technology and organisation, to find the options for work design (cf. Hirsch-Kreinsen et al., 2016).

2.2 Options for skill-orientated work design

2.2.1 Intersection: technology/personnel

To understand what is needed for bridging the intersection technology and personnel in an Industry 4.0-perspective, the design criteria should not be limited to criteria of the ergonomically-oriented dialogue design, but rather fundamentally take into account new patterns of man-machine-interaction. Digital technologies allow for new forms of 'function-distribution and interaction between machine and the human worker'. Next, a key question is what new options arise in the application of intelligent robotic and assistance systems in digitised manufacturing processes. Solutions such as augmented reality, data glasses, tablets, devices, etc. change production and logistic processes profoundly. Future innovations in logistics require the application of drones, new concepts in robotics and autonomous pallet trucks/automated guided vehicles (AGV).

Alternative design solutions for the human-machine intersection need to specify how tasks and activities will be substituted by automated systems, but also need to address alternative ways to distribute tasks and control between workers and machines. Assistance systems for example help to support a greater variety in work and help support on-the-job learning processes, but can also limit the space of action of workers through strict process guidelines.

A complementary system design requires thinking from a total systems perspective. This requires a holistic and collaborative view of the human-machine interaction that identifies the specific strengths and weaknesses of human work and technological automation (Grote, 2012). A central point here is that human work should attain and conserve transparency and control possibilities over production processes, gain and develop the often indispensable practical knowledge, and, be supported in this by intelligent assistance systems.

This form of intersection design leads to a broadening of the employees' task spectrum, fulfilling the need for challenging, learning-friendly work, and opening new possibilities for workers' involvement in design and decision making. The work situation becomes digitally widened, requiring new qualifications. Single workers should be able to contextually and locally adjust assistance systems to their individual needs and performance capabilities. It must, above all else, allow employees to have sufficient and continuous educational and training opportunities in order to be able to consolidate and extend their experiential knowledge and 'on-the-job learning' processes.

2.2.2 Intersection: personnel/organisation

Looking at the intersection of personnel and organisations, digitisation brings 'new challenges for the design of work organisations'. Digitisation changes the scope of actions, work-time models, as well as leads to new demands on training and qualifications standards. A key question in this respect is how resources in the form of available competences, labour capacity and experiential knowledge of employees can be used for the design of Industry 4.0 systems. Furthermore, the organisational design of digitised work is decisive for the completeness of operational tasks, as well as for the development of the scopes of action, and learning and qualification opportunities.

In a skill-oriented perspective, the given design spaces can be used to achieve a sustainable revaluation of activities and qualifications. This could enable efficient forms of work organisation as well as work situations with particular qualification demands and in certain circumstances a high degree of behavioural scope, the polyvalent deployment of workers, and a multitude of opportunities for 'learning on the job'. Relevant competences are self-acquired in the process, or in the form of job-related and -integrated approaches: this means individual learning, e.g., through job-rotation, as well as forms of 'learning islands' or 'learning factories'. If work organisation and qualification strategies are supportive of learning, then they should take account of the heterogeneous levels of experience and different competence-bundles of the various employee groups. A central characteristic is that the tasks will rarely be addressed to single workers; rather, to a 'work collective' acting in a self-organising way, highly flexible and situationally determined according to the problems to be solved in the technological system.

Such organisational design can be referred to as a 'holistic work organisation', or metaphorically, the 'swarm organisation': a loose network of qualified and differently specialised employees (Hirsch-Kreinsen, 2016). The central feature of this organisational model – which is already reflected in practices in the German automotive industry (FAZ 2016) – is the absence of defined tasks for individual employees. Rather, the 'work collective' functions in a highly flexible, self-organised, and situationally determined way, adapting its behaviour to the problems that need to be solved around the technological system. The German automotive industry was previously characterised by very low-skilled and repetitive assembly jobs. Today, 'smart' robots substitute many of the low-skilled highly routinised assembly tasks. The remaining jobs focus on tasks like maintenance, quality assurance, and personal planning, which are pursued in a highly informal and flexible way.

2.2.3 Intersection: organisation/technology

When looking at the intersection between organisation and technology, new design options are emerging taking into account the overarching process and organisation of the whole company. The topics here are the function and hierarchy in direct value chain processes, as well as the structuring and the link between the core processes of the production and the associated management and support processes. New digital systems allow for networked intelligence, leaving the world of centralised 'computer systems' behind, leading to new design options for organisation and technology. Decentralisation and de-hierarchisation are now real options – often within already relatively 'flatly' structured company organisations. The previous forms of factory organisation, in particular also the classical organisation and personnel deployment structures are not only being decentralised, but also permanently flexible. Manufacturing, administrative and logistics processes are profoundly changed. Social media leads to different communication practices that also affect indirect areas such as planning, control, engineering and management. Management functions, for example in production and business managements, see shifts of decision making competences and in responsibilities to subordinate levels. Additionally, the flexibility of the new technological systems suggests a highly individualised production, in some cases a 'minimum batch size 1'. Therefore, an organisational structure based on autonomous, self-controlling systems with a 'decentralised control and intelligence' should be taken into account.

Finally, networked planning and control systems, and the application of data mining methods will enable new forms of value-chain structures and 'new business models'. In the 'smart networked factory', industrial value-creation is no longer limited to what takes place within the traditional boundaries, departments and company structures. Rather, a decentralised control and intelligence is required that requires new control dimensions. In consequence of this digitisation process, new business models come into use to meet the technology- and organisation-related challenges and their interrelations. Changes to the entire value-chains are now conceivable that may significantly transcend previous forms of inter- company division of labour and outsourcing. Braking through company barriers helps to deliver intensified service and customer orientation as well as change in business models.

2.3 Two additional conditions for successful implementation

To sum up, it must be stressed that a successful diffusion and implementation of the described design guidelines depend on a number of additional conditions. Here two aspects should be especially emphasised.

First, Industry 4.0 systems and work design possibilities need to be accepted by both the workforce and their representatives, and the management side. The current Industry 4.0 debate shows that this acceptance is important. Employees are rightfully concerned with consequences of new features of work design – for example possible job losses, new sources of stress with increased demands for flexibility, problems resulting from data protection, as well as an intensified surveillance-capacity of work performance. These concerns need to be addressed and eliminated. The expected reorganisation processes may conceal multiple, new and in part also contradictory demands on workers for flexibility and self-organisation. Effective approaches to solve these problems could lie in methods of participative processes for employees and their interest representatives during the introductory and design and implementation process of Industry 4.0 systems.

Second, there are challenges resulting from change in management functions and leadership styles. It has to be assumed that, in the face of the general challenges of the new technologies and in particular the implementation of skill-oriented forms of work, previous, hierarchically established management practices and structures will become dysfunctional and obsolete. The direction of necessary change points to the growing importance of 'soft skills' as well as high communication and teamwork capabilities: instead of control, it's now leadership and 'motivation at a distance'; instead of hierarchic direction, it's now 'orchestration' of co- workers and 'peer-to-peer' communication and encouragement of worker participation that are becoming the key features of management success. Generally, company management must, through a changed status-consciousness, take into account the tendency that, through digitisation and transformed forms of work, the functional and social boundaries between management and co-workers will erode, and under some circumstances even be reversed. We admit that this breakup of past management models and the emphasis on bottom-up processes may result in contradictions: sustainable and successful digital transformation in companies may be emerging at the same time through functioning top-down processes.

3 Modern sociotechnical thinking – WPI

STS has given social scientists a possibility to participate in the debate with technologists. Yet, both sides do not really seem to get any closer together (Hopp and Spearman, 2011). Technological requirements seem to be in conflict with most of the social criteria advanced by social scientists. MST brings an integrative contribution and design approach to STS that may help to bridge this gap. In this section, firstly, STS is compared to MST and WPI. Specifically, we will look into how MST positions itself as a next step in allowing human-friendly organisations to be built. After this, we will show what is meant with WPI and how it fits within the MST-framework. With this context, possible outcomes of disruptive technological change to the logistics sector will then be discussed. One example will be used to show the strength of MST reasoning.

3.1 Comparing sociotechnical system approach and modern sociotechnology

In the previous section about STS, a lot of attention was directed at the progress sociotechnical systems thinking has brought. The core idea of STS is that the social system and the technical systems are separate design universes. The social system does not follow the technological change. Both of these systems need to be in balance, and STS assumes that human-friendly criteria may be used to design the social system of organisations. The approach to deal with requirements coming from the assessment of the relationship between technology and organisation, organisation and people, and from people and technology is a logical approach. Social scientists should have a role in assessing and formulating these criteria for designing organisations.

However, organisational choice exists, whichever the technology it is that is being implemented. For Industry 4.0, this requires that management and workers need to be aware that technology does not dictate the tasks and work procedures. Skill changes are also the consequence of choices made in the social system. STS advocates creating simple organisations with as complex possible jobs, rather than simple jobs within complex organisations. Technology itself does not lead to upskilling, but upskilling is a requirement from the social system.

In comparison, MST also starts from the position that organisations need to be simple and jobs complex. The way to achieve this goal is however more complex than STS assumes. MST does not start to balance technological and social systems to one another. Organisations are designed to fit their market requirements. Because these market requirements have become volatile, unpredictable, complex and ambiguous (VUCA), organisations need to be able to fit this environment (Bolwijn and Kumpe, 1991). This means that in principle there is no balance possible between technology and social systems. Technology is just one of the means to react to this environment. MST starts from the market requirements to define the requirements for the organisation. With this reasoning, it is not the digital transformation that generates new requirements for organisations to respond to. If digital transformation is in line with market changes, then organisational design needs to follow.

It is also not so much a necessity to reshape workplaces because there is an abundance of highly skilled workers, nor is it a necessity for companies to offer good workplaces because it is 'good' for employees. The analysis made from a MST-perspective is that workplaces need to take into account human criteria, mainly because it is in the interest of managers and companies to do so. Skill orientation is therefore not so much needed because higher skills are more valued than lower skills. And lastly, participation is not a bow from management towards employees, but a necessary approach because management is not able to control the major changes within organisations.

What does MST then advocate for designing organisations that are able to survive in VUCA-environments? When designing organisations, technology is only seen as an aspect system, which may have impact on design criteria for organising. The main starting point in MST is that organisations basically need to be seen as having a production organisation and a control system (Kuipers et al., 2010). In designing organisations, the production organisation needs to be aligned with the market requirements. If the market requires organisations to be able to deal with VUCA, then the production units need to be aligned to the changing requirements. Over the past decades, we have learnt that smaller (team-like) production units allow better responses to changing market demands. Technology needs to be fitted into the requirements of the production organisation. The control system needs to be fitted to the resulting production organisation. MST advocates allowing decisions to be made at the organisational level close to the production units connected to the market. Decision making on the operational, tactical and strategic levels need to be in lign with how the organisation is going to function. Centralised or decentralised decision making is not so much the result of technology requirements, but need to be aligned with how the production structure functions. If the production structure allows decentralised decision making, then organisations should allow this. Decision making follows labour division.

MST also differs from STS by its more integral approach (Benders et al., 2009). Whereas classic STS provides a set of static and partial design principles, MST offers more detailed structural principles in terms of design content, while at the same time specifying a theory of change by means of worker participation and training (Van Eijnatten, 1993). MST has formulated clear design criteria for organisations to follow. Bottom-up decision making needs to be fitted in the design process linked to production and control structure. It is not the other way round. The following principles are central:

- Start with a strategic orientation phase.
- First design the production structure, then the control structure.
- Develop the production structure top-down.
- Develop the control structure bottom-up.
- Design the information and communication structure, and other supporting structures in last instance (Cox, 2000).

Maybe not surprisingly, the number of MST-designed organisations is not at all that great (Volberda et al., 2011; Oeij et al., 2012). In practice, many managers start designing organisations from the control structure. Certainly in organisations in which finance departments have a great role in aligning operations, decision making is shaped according to the needs of finances and not of what market requires production to do. Major inefficiencies are a result. This is also the case when looking at another organisational concept such as new ways of working. With this insistence on the control structure, efficient operations are not facilitated (Blok et al., 2017).

3.2 WPI: the translation of modern sociotechnical system approach to the workplace

WPI is an organisational concept that is advocated by MST and stimulates innovation adoption and capacity of companies (Dhondt et al., 2015). The aim of WPI-driven organisations is to enhance organisational performance and the innovation capacity in general (Oeij et al., 2017), but foremost by the engagement at the lowest levels within organisations. Engagement of employees is not so much seen as helpful for these employees, but as a necessary instrument to deliver improvements at all levels in organisations. Innovation should not be a centralised decision topic. The reasoning behind this approach is that within the VUCA-world, those connected to the market have the best insight into what is needed to adapt the organisation quickly and adept to the market demands. In this sense, WPI is fully an outcome of the MST-design philosophy. WPI-advocates prescribe that organisational designers take into account four dimensions within organisations:

1 structure and systems

2 learning and reflection

3 work organisation

4 workplace partnership (Dhondt et al., 2017).

These are in line with the two major dimensions MST focuses on, but WPI adds the HR-dimension to the design elements. It is not so much because that HR should be leading in design, but that with having minimal labour division and a high degree of decentralised decision making, it is necessary to have HR-measures fitted to this organisational environment. WPI has been promoted as a solution in itself; however the advocates of WPI have always had the design sequence of MST clearly in mind. One of the HR-goals WPI has in mind is that workplaces that fit the VUCA-world, need to show a balance between job demands and autonomy. Job demands relates back to the production organisation, autonomy to the control structure. Workplaces that simultaneously have high job demands and high autonomy are defined as better places to work in. High job demands deliver change and sufficient challenges which lead to growth (e.g., the progress principle: Amabile and Kramer, 2011). High autonomy gives the employee the possibility to deal with all the changes during work. In this sense, changes induced by markets can be quickly dealt with by employees working in these active job situation (Karasek and Theorell, 1990).

Workplace partnership is therefore core for WPI-designed organisations. The participation is not so much oriented at the design of the workplace, even though the requirements of MST still remain in place. Participation is focused on helping companies innovate their processes and products. Companies need to create environments in which the ideas and proposals of lower levels within organisations are channelled fast to the right decisions. It is therefore not so much the technology that allows for participative decision making, but rather that technologies need to be adapted so information flows and decision making are faster from bottom-up. To paraphrase Bloom et al. (2014) managers need not so much deploy search engines and information technology (IT) to reduce information costs, nor do they need to apply communication technologies (CT) to stream ideas to the top, rather, managers need to be aware that IT and CT need to be arranged in such a fashion that ideas and information from employees is channeled properly. An example from a Dutch logistics company helps to clarify this point (Policy Research Corporation, 2010). One of the major Dutch transport companies experienced major difficulties in planning of activities of truckers for the ever changing market. Planners could rely on state-of-the-art technologies to help them out, but even this investment didn’t help them to achieve stable manning of the trucks to serve the markets in the right way. It was only after engaging with a WPI-experiment that managers and employees understood that to let planners get grip on the VUCA-world, they needed to rely on the experience of all transport personnel to design better working rosters. Employees shared their experience with unexpected events and what in practice would work. Bottom-up implication and participation of transport personnel was needed for making the production structure work.

Again, from our research, we understand that the number of WPI-workplaces still remains limited (Oeij et al., 2015). Companies have too little of an evidence base to make the required changes, as it would seem. The use of standardised improvement systems such as Lean Production seems still very popular (e.g., Lodgaard et al., 2016). Yet, the use of these systems may not always be the best way for allowing innovation as it is not directly focused on innovation. It is foremost focused on process optimisation, waste and error minimisation and cost reductions.

3.3 Industry 4.0 and Logistics 4.0 in need for MST and WPI

The Industry 4.0 and technological change in many sectors, such as the logistics sector will require a systematic treatment within a MST-framework. Just the statement that new technologies may be disruptive or that Artificial Intelligence (AI) and robotics will lead to mass unemployment is insufficient from a MST-perspective to understand what will happen within organisations. It needs to be shown how these technologies can change the relationship between markets and the organisations. Platform technologies for example, have shown that they can change the relationship between a company and its market demand. Once platform companies such as Amazon nestle themselves between producers and customers, the market demand function of companies can change. For companies, the expectation is that because much of the market is channelled via the platforms, the VUCA-dimension may be drastically reduced. On the other side, the dependency on the platforms leads to new demands and measures. This situation is made possible by internet technologies, but the strategic action of companies such as Amazon and the ability to develop network effects is more organisational in nature than it is technological. AI and robotics in practice only have impacts on certain tasks and activities. For these two technologies to engender major changes in organisations, it requires strategic action from companies. In logistics, voice or light control of order picking speeds up activity. These technologies have been around some time now, so the impact will mainly be continuous and gradual. Major shocks are not really envisionable. AI can help to improve planning procedures, but even here, it requires finding out how AI can use the knowledge and engagement of all employees within a production setting. One example may show what we can expect from the introduction of new technologies in the logistics of the future.

In one company, we were engaged to support the introduction of a social media based application for truck drivers. The idea was that the new system could help employees change their driving behaviour to the principles of 'new ways of driving'. Main elements were limiting the speed of trucks and driving behaviours that lead to extra wear and tear and to higher gas consumption of trucks. The social media application developed, monitored a set of parameters of each of the trucks over time and provided feedback to the drivers. They could see how their performance was. The company also developed incentives to stimulate drivers to change their behaviours. A competition and extra tokens were devised to achieve this goal. From the calculation, the investment could be earned back in a very short period of time. Next to the behavioural change, the goal was also to guide the drivers in the operation much more quickly to new clients and to ensure that trucks always had a paid load to transport. The development of this clearly profitable technology however had to be stopped early in its implementation phase. Having developed the technology top-down, the truck drivers, when confronted with the innovation, clearly pointed out the design flaws in the whole approach. One example was that the whole idea was linked to the use of the mobile phones the drivers used. Drivers needed to be prepared to use the technology as provided, but also, the company overlooked the fact that trucks already were monitored by the on-board computers. Not using the existing technologies seemed quite superfluous for drivers. The extra measurement was seen with great suspicion because drivers wanted to know what the company would do with the collected material and how it would help them. The example shows that current new technologies require more implication of employees to get a successful implementation. In the new environments, management does not have a full overview of how social technologies such as social media applications and control systems will work out. A WPI approach would have shown how to direct the development and implementation of the new, possibly disruptive, technology.

3.4 Modern sociotechnology and WPI as useful concepts

MST provides tools to organisational designers and engineers to develop organisational structures that are rightly fitted to the environmental constraints the organisations currently are confronted with. WPI provides a concept that helps to engage the employees in the right way to support the innovation change companies need. Technologies alone will not lead to changes, nor provide themselves the solutions required from organisations. The new disruptive technologies will offer many possibilities for companies to change markets as needed, but it in introducing these technologies the knowledge and engagement of employees is of central importance. This requirement sets the current disruptive technological change apart from previous technological revolutions.

4 Adding a practice-theoretical perspective

Sociotechnical approaches like WPI and MST are successful in practice and have strong heuristic values. Joint-optimisation of human-technology-organisation also requires the perspective of the actor in the workplace. The risk remains that technology is still beating the drum in changing Industry 4.0 organisations (Rammert, 1997; Howaldt and Schwarz, 2010). Also, it would be helpful to add to the STS, a perspective on the dynamics of transformation. MST and STS need to integrate perspectives on economic and political behaviour. To add such perspectives, one should look for practice theories. These theories use a more social theoretical approach to understanding the relationship between actors and between actors their environment. The goal is more guidance for practice, but it requires a deeper understanding of the actor and technology.

4.1 Practice theory

There are a lot of different practice theories (Reckwitz, 1999). "Depending on the perspective, certain aspects come to the fore: the reproduction of structures through habitualised corporeality, conventions and routines of action beyond conscious action, the significance of materiality, etc. The commonality of the approaches lies in the stated basic assumptions or can be more abstract in the claim see the imposition of the dichotomy of action and structure and dissolve it in a procedural perspective of the current practical 'action'." [Wilz and von Groddeck, (2017), p.2]

Latours actor-network-theory (ANT) belongs to the most prominent approaches of practice theory in technology research (Howaldt and Schwarz, 2016, pp. 37). As all processes of change are processes of the connection of heterogeneous elements, human sociality, nature and technology are mixed and it is not possible to understand one side without considering the other. The social-theoretical relevance of the ANT in the form of a 'new sociology for a new society' (Latour, 2010) is – from the perspective of 'reassembling the social' [Latour, (2010) p. 22] – "the pursuit of new associations and the recording of their structures, her assemblages" [Latour, (2010), p.19] and to analyse all societal interconnections as a co-evolutionary result of society, technology and nature and thereby avoiding every reductionism (Schulz-Schaeffer, 2011). Social change is thereby the micro founded result of linking heterogeneous elements to new or changed associations, networks and practices. It follows – to put it in a methodologically perspective: "Whenever one aims to understand a network, one has to look around for the actors, and if one wants to understand an actor, one has to look on the network he pioneers" [Latour, (2009), p.55]. If it is not about explaining the social through the social and an absolute reference framework, but about following the actors, then it requires at the same time to "come after their sometimes wild innovations" [Latour, (2010) p.28].

Practice-theory make it possible to recognise the dynamic relationship between producers and users while developing and stabilising new arrangements as well as the embedding of innovations in social practices (Schwarz et al., 2015). As forms of life and practice are given and made at the same time, are condition and product of social practices at the same time, they prove themselves to be shapeable. Existing practices are altered by their stakeholders. Thereby, the social practice is always reshaped and transformed. The reflection on practice-building elements, of bundles and complexes of practices, of ways of life (understood as ensemble of social practices) (Jaeggi, 2014) enables the recognition of processes of transformation [Shove et al., (2012), p.121]. By describing both the stability and the dynamic of the practice-building elements, it can be shown how the configuration of practices develop and change. Every new combination of elements and practices is in a certain sense an emergent result of the previous. The change of forms of practices and the socially created ability to create something new in the course of the practice is an active social mechanism with structure-forming effects, and the participation in practices and forms of practices first enables agency [Shove et al., (2012), p.126]. Transformative change refers to the topic of reconfiguration of the practices, from which society arises, this mean on social innovations. Against this background, Shove et al. (2012) worked out a perspective on transformative change, which focuses on changes of 'attitudes, behaviour and choices' by external interventions and on technological innovations as a universal remedy. It is about intended changes of social practices and social innovations directed upon, about a steady readjustment anchored in social practices, thus about real world experiments under involvement of heterogeneous actors, understood as carrier of social practices, and in the frame of a self-organised co-evolutionary process (Shove, 2010).

Shove et al. (2012) developed an approach of changing social practices that is helpful to act in dynamical transformation processes. This dynamic perspective is based on the understanding that social practices are consisting of three elements that are changing over time. According to the authors, an intended change of social practices is based on new configurations of three elements of practices: material (incl. technology), skills and meaning (incl. motivation). Particularly, the 'meaning' of an innovation for people who are using it might have an important role on the diffusion of a new practice. Will the new practice lead to more or less job security, more or less work load, more or less attractiveness of the job, more or less appreciation of the skills of people exercising this practice? So, practice theory may contribute to explain and influence the acceptance of a new technology embedded in a social practice. Although the approach of Shove et al. (2012) is related to social practices of every-day life (such as driving a car, practicing a sport), it is also suitable to explain and design social practices in organisations. For business, this means to change working practices (such as new work content or scope of decision) and organisational practices (e.g., changing ways of collaboration and communication). This moves the focus from new technologies as isolated solutions to new habits of people and organisation (that will be using digital technologies), i.e., people will be performing their tasks somewhat differently. For instance, smart phones have not spread by reason of their technological features – in fact, people have fundamentally changed their way of communication as a new social practice using this technology. This has emerged in society, but meanwhile smartphones are increasingly being utilised for internal communication within companies. The next chapter uses the example of the process industry to show how this theoretical approach could be used for innovation projects.

4.2 Sociotechnical and practice theoretical instructed empirical example in process industry

In the project Coordinating Optimisation of Complex Industrial Processes (COCOP), technological and social innovations are being combined, integrating a new software system for plant-wide optimisation in process industries into a process of social innovation. This latter part is based on the STS, but supplemented by a practice theoretical view introducing a dynamic perspective on emerging new social practices.

Within COCOP (and other similar projects), a social innovation process means to get (future) users and stakeholders involved in the development process (of technology as part of a sociotechnical system) – not only as feedback to assess the impact of a new technology on working conditions etc., but as co-creators using the ideas and requirements of users/stakeholders for designing the new system. A survey was conducted in two pilot cases, a steel case in Spain and a copper case in Finland. It is a mixed methods approach including a questionnaire and an interview based survey. Based on the structured and standardised questionnaire, data was collected to define a baseline for social key performance indicators (KPI), such as user acceptance, job satisfaction, understanding of plant-wide processes, skills development and extent of participation. The interviews provided more detailed background information on current work, tasks, goals of (future) users and stakeholders and of experience with currently used computer/optimisation system as well. Furthermore, surveyed persons were asked to describe their requirements related to a sociotechnical system in terms of requirements to technology, skills development and organisational measures. The interview results showed quite clearly a picture of current and possible future working practices needed in changed sociotechnical systems including a software system to support plant-wide optimisation. Beyond the sociotechnical perspective, the interviewees described the meaning of the new technology within new practices. The software system that is being developed to support plant-wide optimisation will help operators and (installation/quality) managers to perform their tasks and to reach their objectives. Both groups are supporters of the idea of a plant-wide optimisation instead of isolated, sub-process related optimisation. All in all, the surveyed (future) users and stakeholders expressed a positive attitude towards the new system that will really get in use if expectations of users/stakeholders will not be disappointed.

However, to define users and stakeholders' requirements – the so-called human factors or social requirements in COCOP – is not sufficient for them to have a real influence on software development processes, because the social and technological disciplines seem to be using 'different languages', a translation process has to take place. Starting from a sample of preliminary requirements that were described by surveyed (future) users and stakeholders as questions, general statements etc., they were transformed in clear and measurable requirements that can be validated. For example, one of the requirements expressed by (future) end users of a new system was 'people need more reliable data'. However, interviewed people are actually telling about situations when data were not reliable and problems emerged. But such a description does not provide a process how to validate data. Therefore this user requirement has been redefined as followed: "The COCOP system could be improved with practical knowledge of end users during the development, e.g., by excluding non-realistic solutions (and also during its operation)." As shown in Table 1, this requirement is connected to a clearly defined process that includes activities how to fulfil the requirement. To make a real impact on the software development process, three conditions have been fulfilled – the 'who', 'when' and 'what' of human factors requirements:

- Who: 'which party' will fulfil the requirement and which one will validate the fulfilment (responsibility)?
- What: which human factors related 'activities' have to be carried out to fulfil and to validate the defined requirements. This includes conducting surveys, running workshops, measuring KPIs etc.

- When: how human factors related activities are connected to the project 'timeline'. Assigning requirements to milestones of the project makes clear when requirements have to be fulfilled.

After defining requirements in this way, they got the shape as shown on Table 1.

To really have an impact on the development of technology (as part of the sociotechnical system), it proved to be helpful to make a distinction between person-to-person and person-to- systems requirements. These different types of requirements have to be treated differently in the innovation process. This is rarely the case when looking at how technical designers work. Technical designers are mainly familiar with person-to-systems requirements, they will mainly focus on the relationship between software systems and persons. Therefore, generating awareness for the importance of person-to-person requirements is needed. Person-to-person requirements are not features of the software system, but features of the persons themselves and the organisation in which these persons function. This has been a main stress of the whole sociotechnical system thinking. Most of the human factors requirements are linked to the development 'process', others to the 'result' of a final software solution. This is a challenge that software developers need to further understand. The following matrix shows some examples of requirements that emanate from the distinctions made.

Table 1 Clarification of human factors requirements

Requirement	*Activity*	*Milestones to execute activity*	*Benefit*
The COCOP system could be improved with practical knowledge during the development, e.g., by excluding non-realistic solutions	Regular meetings with developers, process experts and a subset of end users will take place. They will evaluate whether the COCOP system is appropriate from a practical point of view. Developers will implement the new features that are agreed upon.	3, 4, 5	Ensures that plant-wide optimisation brings the envisioned benefits

Table 2 Matrix of human factors requirements

	Person-to-person requirements	*Person-to-system requirements*
Process-oriented requirements	The COCOP system should be supplemented by further communication channels (e.g., face-to-face) that are needed by the (future) users.	The system should support the best possible interaction of using data and practical knowledge of users.
Result-oriented requirements	The project should measure plant-wide processes as part of operator training ratio relative to baseline.	The system should measure the acceptance ratio of how often the plant personnel follow the advice given by the system.

This matrix builds on how working and organisational practices influence practice: future users/stakeholders are expecting a closer communication and collaboration with operators/managers of other sub-processes – not only mediated by the distributed control systems, but also face-to-face meetings to learn more about how to reach a plant-wide optimisation. Currently, some of the interviewed people are mainly using data for decision making; others are using practical knowledge for decision making. Working practices may expect to change in such a way that both sources for assessing the process status in practice and for making interventions (data and practical knowledge) will interact more closely in the future.

The next step that is currently taking place includes the defining of an action plan. Human factors related activities are being bundled into interventions that include interviews, questionnaires and workshops in the pilot cases of the project. This step is about finding synergies between interventions, prioritising interventions and defining expected benefits of each intervention for the implementing company.

All in all, an intensive communication process between technological designers and human factors experts (scientists) is going on, providing results that are integrating design features for the sociotechnical system. These features will support new working and organisational practices for the future that aim at optimising the quantity and quality of final products, the consumption of raw materials and energy, emission of pollutants and safe-guarding working conditions plant-wide. This process of integrating human factors requirements into the innovation process will be applied in other process industries, such as chemical and water treatment industries. Two pilot cases (steel and copper) are planned for this.

5 Conclusions

There are many sociotechnical approaches at EU level. They are challenged by the digital transformation and Industry 4.0. Against the background of empirical experiences in logistics and process industry and in context of Industry 4.0, this article has discussed the model of classical STS approach and the skill orientated work design. After this MST and its derived concept of WPI were showcased and positioned next to STS. Finally, we explored ‘practice theory’ as delivering a deeper understanding of change at the level of the individual in the practice setting. The aim of the article was to showcase, compare and discuss the usefulness of these approaches for today’s challenges in Industry 4.0.

These approaches each provide both common and unique insights and allow access paths to practice and designs that are useful for organisational decision makers and designers. All three approaches have in common their intention to improve organisational performance and quality of working life at the same time. MST and WPI are systemic approaches that acknowledge that the whole of an organisation is more than the sum of its parts. They also imply taking an integral design approach to change as organisations consist of parts that influence one another. Combined together with the knowledge from practice theory they may reinforce and complement each other and can help to address today’s challenges in Industry 4.0.

Although these approaches are helpful, and we do not want to make conclusive statements about the quality or practicality of one of the approaches, some future recommendations for STS-related research are made. To increase the impact in practice, it is helpful to intensify the discussion between different sociotechnical approaches and to work out a common framework, especially in context of Industry 4.0. This contributes to better integration of these approaches into, possibly, an applicable, unified MST-WPI-ANT-theory. Since a couple of years the European Workplace Innovation Network (EUWIN)[4] is doing this successfully. In addition, more hands-on tools, practical interventions and business cases need to be further (co-)developed and examined. Future research could support this by including practice theory, MST and WPI-elements in empirical studies (Oeij and Dhondt, 2017) and work closely together with organisations. Organisations should stimulate and facilitate such research. Nevertheless, a lot of work is to be done. The dynamic of digital transformation and new empirical research insights require to continuously discuss, integrate and improve the theoretical, conceptual, methodological and practical bases of STS.

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Notes

1 Find more information under: http://www.innovationslabor-logistik.de.

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3 Dutch or German original sources are translated into English by the authors for this article.

4 As part of that strategy, the Commission has launched EUWIN, a learning network that promotes EU-wide knowledge-sharing on workplace innovation. The network is open to organisations, social partners, policymakers and researchers. [online] https://www.tno.nl/en/focus-areas/healthy-living/roadmaps/work/healthy-safe-and-productive-working/euwin-the-european-workplace-innovation-network/ (accessed 16 January 2019).