Joint Organizational Design 4.0: Revisiting the Socio Technical Principles

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ABSTRACT

The adoption of 4.0 technologies for many companies implies the activation of organizational redesign processes. To reflect the changing nature of work and design practices when faced by new technology, the socio-technical systems theory has proposed a set of design principles to guide system design capable of ensuring the joint optimization of organizational performance and at the same time preserving or developing the quality of the operators' work. Through the analysis of three companies that have largely invested in digital technologies and at the same time redesigned their organizational structures, this study provides evidence on how the design principles developed by socio-technical theory are nowadays adopted, thereby indicating the possibility that the STS theory can (re) become central in both theory and managerial practices.

Keywords
Socio-Technical Systems, Digitalization, Participation, Agile Design

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1. Introduction

The 4.0 technologies are nowadays considered a remarkable opportunity for many industrial sectors in the advanced economies, especially those related to manufacturing. By enabling new forms of production, capable of reducing time and costs, and by increasing product personalization and quality[1], they increase competitiveness on a global level. For these reasons, and also thanks to supportive public policies, in many advanced economies there is massive utilization of them. Being that their introduction prompts companies to redesign their organization, a broad debate is underway today regarding the opportunities (mainly related to the optimization of organizational performance) and the risks (mainly related to the possibility of reduced quality of operators' work) that come along with the process of reorganization.

This paper explores the process of organizational design in three large Italian manufacturing companies that have adopted 4.0 technologies at large, aiming to determine whether the organizational design principles suggested by the socio technical theory are still valid to face the new challenges and whether they need to be adapted in light of the advent of the 4.0 technologies. Indeed, to that end, the socio technical theory has developed specific guidelines that provide direction to the system designer. However, after an initial diffusion, these guidelines have failed to proliferate in both research and managerial practices. Based on the idea that the design processes must be set up so as to define an organizational solution that considers both the technical and social aspects that characterize the organizational system, object of the design, these principles guide the design processes thus aiming the optimization of both the organizational performance and the quality of the operators' work.

Therefore, the STS principles are thus considered particularly suitable for approaching design challenges associated with the introduction of 4.0 technologies. This study thus focuses on the contents that characterize these processes, the actors that are involved in them, the design and deployment methodologies that are used. The results allow to show (i) how today these principles are incorporated by companies, through examples that enrich our understanding of the practical implementation of each of them, and thereby useful for organization designers and for their training; and (ii) develop some considerations regarding the possibility that this theory can today (re) become central in the design of organizations today

2. Theoretical review and research questions

2.1. Organizational design Process: the contribution of the Socio Technical System theory

The socio-technical theory, dating back to the middle of the last century, was first coined by researchers at the Tavistock Institute of Human Relations, and inspired by a holistic vision of the organization and people at work, very different from the Scientific Organization of Work, at the time the most dominant approach (for a historical overview, see for example [1]). The preliminary studies towards this theory began over a period, very different from the present, which followed the nationalization of the British coal industry, showing that despite substantial investments in new technologies, the newly nationalized industry was not doing well. Productivity failed to increase in step with increases in mechanization. Strikes and high absenteeism were keeping performance levels below expectations.

This research showed that the organizational model introduced to incorporate the new machinery into coal mines, developed according to the Scientific Management, ie considering the "task" as the basic organizational unit, dividing the production process into a sequence of individual tasks and designing work characterized by low

[1] In addition, recently, it has been recognized that digital technologies can enable a radical redesign of work processes and organization by allowing social distancing and smart working also useful for the preservation of the workforce during the Covid-19 pandemic.

variety of tasks, low autonomy, and limited team work - was not suitable for the characteristics of work in the mines [1], [2], [3], [4].

This model in fact was accompanied by an increasingly mechanistic and bureaucratic style of work organization, that had adverse human, social and organizational consequences. Starting from the comparative study of different companies, Trist and colleagues advocated that a different organizational model, one that considers both the technical aspects and the configuration of the relationships among operators, characterized by broader jobs, greater autonomy and increased teamwork, leads to greater work satisfaction, improved management of unexpected events and thus increase of both productivity and quality of work.

Based on such research, the socio-technical systems theorists argue that a complex organizational system can better adapt and survive when it integrates the technical component (for example the technologies used) with the social one (that is, the characteristics of the relational structure among the components of an organizational unit, their perceptions of the roles, the differences in status, coordination methods, their social and individual needs and the informal strategies adopted). Therefore, the heart of every organizational design process should be the so-called, primary work system, consisting of all the activities that pertain to technical and human resources necessary to carry out the tasks [5].

Starting from this assumption, the STS researchers [6], [7] have proposed three main highly interrelated sets of principles, to guide system design capable of ensuring the joint optimization of the technical and social systems. These principles focus respectively on the content and the process of design such as (i) design process field of action, (ii) stakeholder participation and (iii) the design and implementation methodologies.

Companies that have adhered to the socio technical organizational design have performed very differently. Initially, i.e. in the decades following the 1950s, these principles were applied in various sectors, initially in manufacturing industries and later the emphasis has shifted to the service sector. The heyday of socio-technical system ("STS") was, perhaps, the 1970s, when its principles were imported to the field of information systems. Thereafter the socio-technical systems theory has been gradually neglected by management and scholars alike [8]. In fact, during the 1990s, world economic, business, and technological arenas witnessed dramatic changes, the consequences of which turned out to be frustrating for advocates of socio-technical design [9]. In the harsh competitive environment, STS interventions became widely regarded as too complex, difficult or politically dangerous to pursue, when other methods (such as Business Process Reengineering) appeared to be simpler and less risky [10]. The philosophy that underpins these methods ostensibly runs counter to many of the humanistic ideas behind STS design [11]. Additionally, in the late 1980s many STS design approaches failed to take account of the work in HCI (Human Computer Interaction) and hence had little to say about interaction design in organizations [12]. Furthermore, at the time there were no attempts to try and adapt the STS design methods to the changing business management methods [10]. In addressing the dynamics of technological change, [13] highlighted how the turbulent or volatile, uncertain, complex, and ambiguous environment called for STS designing, because neither the purely "soft" approaches of behavioral science or the "hard" approach of industrial engineering could engender and sustain organizational learning and change as did the unique approach of STS. In fact, the 21st century has seen a revival of interest in socio-technical approaches. Pasmore et al., [14] for example, argue that as organizations face an increasingly unpredictable and even chaotic world, socio technical theory and design can provide a holographic view of the organization, though it should prove to be flexible enough to incorporate a continuous process of learning, constant redesign and incorporate concerns about human development. As a matter of fact, the 21st century has seen a revival of interest in socio-technical approaches. Many scholars argue that the system designer of the future will need to pay an ongoing, equal, and simultaneous attention to the joint optimization of both the social and the technical system, moving from a 'design for users' paradigm to 'design with users' [14], [15].

Recently, it is being recognized that the key features of 4.0 technologies, such as their versatility and therefore pervasiveness, their ability to leverage vast troves of data, ability to continuously acquire knowledge and skills, possibly operating autonomously, increasingly automation of complex cognitive tasks (thereby enabling new approaches to coordination and control), and other current development such as machine learning systems ("learning by doing"), are likely to open up space for a more organizationally oriented sociotechnical design intervention [16].

2.2. Designing an organization that adopts 4.0 technologies: what do we know jet?

Interconnectivity and cooperation are the most visible manifestations of 4.0 technologies, alias Industry 4.0, or Smart Manufacturing, that pertain throughout the manufacturing and supply chain enterprise [17]. Through these key features 4.0 technologies enable a flexible and intelligent production system that adapts in real time to the changing conditions [18]. Through these characteristics 4.0 technologies open up brand new opportunities for organizational design. In fact, they can posit a radical change in the typical dimensions of the organization, such as, for example, autonomy in carrying out the tasks, the cognitive demand, or social interaction. That is because constant real time access to process performance and the ability of the technical system to adapt to unexpected context events can potentially reshape the decision-making structure and the boundaries of problem-solving for operators and managers [1], [19].

Studies that have addressed the organizational design processes of companies that have adopted the 4.0 technologies are scarce and characterized by contradictory results, which have led scholars to develop two opposing scenarios [20]. The first scenario assumes that 4.0 technologies will enable organizational configurations that will enhance the role of operators and offer meaningful and rewarding work contexts for workers. This scenario sees a growing centrality of the cognitive contents of the operators' tasks, increased job autonomy both at the individual and team level, enhancement of individual skills, and fostered social interaction and team working [21].

A second scenario, instead, predict that 4.0 technologies will replace a substantial part of human work with machines, or they will activate processes of depletion of human work. In fact, this second scenario predicts in-work poverty, new jobs are likely to become more insecure and less rewarding, careers more fragmented whilst workplaces become more exploitative, unequal and with increasingly pervasive surveillance and disciplinary systems [22]. Both scenarios have been elaborated in most cases in a theoretical way, providing no effective empirical evidence and insights.

2.3. Critical review of available knowledge and research questions

Available literature on digital technologies and organizational design shows two main limitations [23], [16]. The first relates to the fact that both scenarios, one approaching from the side of human empowerment and the other from the side of replenishment/ impoverishment of human work adopt a deterministic reading of the relationship between technology and organization. Both scenarios, in fact, assume that technology determines the emerging organizational model, a typically techno-centric approach that underestimates the importance of the choices that individual organizations will take. The second limitation, which derives from the first, is related to the fact that available studies consider the process of organizational redesign as substantially irrelevant, precisely because it is believed that it will be the technologies (and not the choices that the actors will take within this process) to determine the organizational configurations. Both limitations stem from the fact that the dominant literature on these issues neglects (i) the social aspect of the organization, in which technological change is embedded [23] and (ii) the strategic and organizational factors that impact the organizational choice, among them the process design actors.

In this context, given that the objective of the socio-technical systems theory is to offer indications on how to design the organization so as to optimize both the organizational performance and the quality of the operators' work, this study aims to empirically analyze the organizational design process in companies that have redesigned their organizations accordingly, when implementing digital technologies. This type of analysis will allow us to understand (i) to what degree and in what way the adopted design process is being informed by the three sets of design principles suggested by the socio-technical systems theory; implying a focus on the design process content, actors involved, design and deployment methodologies used, and (2) to develop preliminary considerations regarding the possibility that STS theory and design principles can nowadays (re) become central in the contemporary organization design theory and practice.

3. Method

Given its exploratory nature, this study adopts a qualitative research design based on case studies. The three cases analyzed here include a company with headquarters in Germany and operating in the electromechanical sector (aka Mechanic), a company with headquarters in Germany and operating in the chemical/pharmaceutical sector (aka Pharma) and a company with headquarters in Italy operating in the energy sector (aka Energy).

All three companies have met the following selection criteria: (i) extensive use of Industry 4.0 technologies, accompanied by substantial organizational design. This redesign effort is therefore intended as a precondition for analyzing the implementation process. and (ii) established high level of job quality measured by a) excellence in human resource management (for example, selected companies are awarded in the 'great place to work' ranking and / or have achieved the 'Top Employer' accreditation) ; and b) excellence in industrial and employment relations (i.e., selected companies have received high recognition in their respective industries for their company agreements). The job quality dimension is regarded as a proxy measure for the fact that the organizations have been redesigned according to the main objective of the STS theory, and thus they have pursued the optimization of both the organizational performance and the quality of the operators' work.

Data collection took place immediately after the start of organizational redesign process. The timing was deemed appropriate, as all three organizations had completed multiple cycles/phases of the design and implementation process. The primary data source consists of 14 semi-structured interviews. Respondents, who hold various roles within the organization, have been part of the design process.

Each interview guide built according to the theoretical framework, lasted between thirty minutes and two and a half hours and all were recorded and transcribed. To supplement the information obtained, the research team made use of written data that included both primary sources (organizational charts pertaining to before and after reorganization), documents and presentations regarding the organizational design, and secondary sources (i.e.relevant Internet publications).

Data analysis involved three distinct phases. The first phase involved the creation of a case write-up. During the second phase the research team engaged in comparing the individual cases, while identifying similarities and differences. The last phase of the process involved further triangulation of the data, made possible through a workshop organized with key professional roles of all three companies observed. In general, the research team has followed a systematic abductive approach [24], which for us meant going back and forth the empirical material and the literature, having theoretical framework and data analysis evolving simultaneously while influencing each other.

4. Findings

4.1. Overview of observed companies and the innovation projects

Mechanic, operating in the electromechanical sector, is a global provider of technologies and services. It has invested in 4.0 technologies to both improve performance of the production processes of its products and to meet ever-changing customer demands. At the plant of Mechanic, chosen as the subject of this study, the introduction of digital technologies takes place within a more general framework of continuous process of innovation (technological and organizational), that enables the company to immediately identify both the technical and social objectives of any technological intervention. For the identification of innovation projects, every month all departments conduct information sharing sessions on the results achieved and select the areas where production costs are high, thus aiming for process optimization. Afterwards, leveraging on dedicated teams, the company initiated the digital innovation project. The teams involved a broad range of actors, among them technology users (such as floor operators) invited to provide their input as process experts. Applying the above approach, the company has implemented different digital technologies, such as, the installation of flexible sensor solution in the assembly department, launched the Monitoring and Data Analytics applications that show the overall equipment effectiveness (OEE) and allow open and transparent performance data (KPI) shared on interactive dashboards installed throughout the department, etc.

Pharma operating in the chemical/pharmaceutical sector has introduced the so-called 'Innovation 4-0' program, which objective is the identification of potential digital use cases. The plant, chosen as object of our study, was in fact selected as pilot for digital plant manufacturing. Examples of use cases, at the time this study took place, include: implementation of sensor network system (augmented reality glasses) that enable the operator to make use of fewer own resources, reduce downtime and increase accuracy, implementation of the SNS (Sensor Network System) that communicate with an interactive dashboard monitoring the progress of tasks, installation of the laboratory digital twin (digital work planning system) that facilitates the optimal allocation of resources. To achieve alignment of technology to organization needs, the 'innovation 4.0' program was structured to cover the following three macro streams (i) strategic skills (ii) technological skills and (iii) organizational skills. Operators from various organizational levels and units have been broadly involved. Such involvement ranged from purely "informative", or consultative, to an upward progression in later design stages, where operators are playing "real designers" i.e. being part of the solution definition during use case implementation.

Energy, operating in the energy sector, introduced digital technologies as part of its high-tech initiative that aimed the digitization of all the main phases of corporate asset management. The introduction of such technologies was accompanied by a complete redesign of the process chain (from the design, construction, management, and asset maintenance) and the implementation of support systems, other than those traditionally adopted in the company. For example, Energy launched a tablet-based approach to manage the technical activities associated with urban gas distribution. The benefits of the new Application have changed the work habits and daily routines of technicians, simplifying, among other things, the reporting of interventions, all but eliminating the use of paper, reducing the risk of error and increasing interaction among colleagues through the "FaceTime" application. The digital innovation project, governed by the Steering Committee established by the board of directors, consists of two macro phases. The first macro-phase, called feasibility studies, is divided into the following four sub-phases: (i) definition of the project vision (implying objectives related to technological innovation, to process management and work organization); (ii) development of project management intervention guidelines; (iii) definition of a new techno-organizational model, leveraging on 11 teams that included employees operating in different levels and functions; (iv) definition of an operational program based on clear guidelines for suppliers and precise functional requirements. The second macro-phase, related to technological implementation, consists of the following three sub-phases: (i) design of the solution defined in the feasibility phase; in this phase selected suppliers were also involved, which effort was facilitated/moderated by team leaders that coordinated team activities; (ii) implementation of pilot projects; (iii) project roll out

4.2. Key characteristics of the organizational design process

In this section, we describe key findings related to the main characteristics of the process through which the three observed companies have redesigned their organizations. Most specifically in this section we will describe the contents that characterize these processes, the actors that are involved in them, and the design and deployment methodologies used.

4.2.1. Field of action and contents of organizational process

The anticipation of socio organizational issues for Pharma and Energy has taken place both at program and at local intervention level. For example, in Energy organizational issues are anticipated in the very early stages of the design process. Indeed, the definition of the vision includes technological, process and organizational guidelines. In parallel to the indications related to the integration of asset management lifecycle, such as the definition of integrated asset database, maintenance engineering and maintenance field activities, vision guidelines offer indications related to organizational issues such as changing organizational roles that correspond to new processes. Thereby, the new organizational model has delineated the increased need for multiskilling and the future need for personnel (for example, the project team envisions a significant change for maintenance personnel).

During the organizational design, all three companies have paid equal attention to both aspects, technical and social, addressed from the early stages of the design process. Indeed, from the ideation phase, the 4.0 innovation

project has envisioned the presence of three basic interrelated domains: (i) the strategic domain, related to the choice of motivational and competitive advantages that drive the company to adopt 4.0 technologies and on the criteria with which to identify the organizational units in which to incorporate these technologies; (ii) the social domain, that will attend to choices about the re-design the redesign of the socio-organizational systems where I4.0 technologies are incorporated, and on the working conditions that characterize them, on the skills and the necessary coordination mechanisms; (iii) the technological domain, related to the choice of the specific I 4.0 technological solution

To this end, the observed companies differ in how they have operationalized the above strategy: Pharma and Energy have initiated a dedicated program with the following objectives: identification of organizational units most likely to be impacted by digital technologies (units with emerged critical aspects, potentially addressable by applying digital technologies), and the coordination of the implementation process composed of interventions dedicated to specific use cases. (Pharma and Energy companies); in both cases there is no specific/special program devoted to 4.0 technologies, instead 4.0 technologies are incorporated into preexisting programs, related to technological and / or organizational innovation. Both companies have addressed the socio-organizational aspects right at the start of the implementation process of 4.0 technologies. In fact the anticipation of socio organizational issues has taken place both at program level and at local intervention level.

Consistently with the key concepts of extended scope of the projects, in all three companies the design process involves actors from different disciplinary perspectives and competences. Indeed, the combination of different disciplines allows the generation of alternative solutions, which are then tested to consolidate the most effective one.

In Pharma, for the implementation of the innovation program, three streams of work, coordinated by the program leader, have been created. All three teams were composed of members with different skills. The first team, with a focus on technological issues, has been tasked with the identification of technologies to be adopted; the second team, with a more managerial focus, is responsible for the identification of specific use cases; the third team, focuses on organizational issues, and is responsible for the redefinition of processes, and its corresponding roles and skills. Each of the teams, supported by management consultants, initially proceeded to share perspectives (at times conflicting) on digital technologies "synthesized" through a continuous and structured ‘consensus building’ process. Each team, then, proceeded to interview a wide range of organizational actors (from different units and different organizational levels, also including technology users) deemed to be bearers of subject matter knowledge.

4.2.2. Actors involved in the organizational design process

In all the companies observed, the design process is characterized by a broad participation of actors, that make possible the multidisciplinary approach presented above. Evidence shows that participation has in all cases been horizontally and vertically extended. Participation is extended horizontally, that is, people working in all the main organizational units have been involved. Representatives of all functions and of the main processes have been involved in the project teams, with a special focus on representatives from the unit that addresses technological aspects (in some cases, the global information technology team is involved) and, the one that manages human resources (both at the company and plant levels, although not in all cases and on all use cases) for addressing social aspects.

Participation is vertically extended, i.e. involvement of people from different hierarchical layers. The technology executors (such as operators) have been involved during the local micro-design, in other words at the level of the specific intervention. In Pharma, for example, in the units where a use case was developed and tested, representatives from all organizational levels, even the most operational, were involved in the micro-design process.

In particular, in Pharma and Mechanic, participation is structured as follows: (I) in the early stage involvement of: department /process leaders, functional (line) managers, IT personnel; (ii) in intermediate stages involvement of: middle-management, technicians; shift leaders and lower level employees (shift operators); (iii) in final stages (micro-design of the local solution) involvement of: managers, technicians, shift leaders, operators. However, in Energy, employees from different hierarchical levels, including technicians and operators, have been in all stages

of the process engaged. It is important to emphasize that in all the studied cases, technology users are involved in different stages of the design process, depending on the intervention or context. In Pharma, for example, operators are being interviewed to show their preferences on the display characteristics of the digital dashboard.

Another observation relates to the degree to which the actors have been involved in decision-making. The escalator of participation- placed on a continuum- indicates the extent to which actors are able to influence decisions about various aspects of management—whether they are simply informed of changes, consulted (i.e. participants merely provide information about the problems/opportunities, that can be resolved/afforded by digital technologies), actually participate in decision making (i.e. participants choose between alternative predefined options), or their participation is creative (i.e. participants become designers, and are called upon to generate possible solutions).

Studied companies implement all three degrees of participation, depending on the specific phase and /of on the specific intervention. For example, in Pharma, first-level operators and their supervisors are involved as informants in the early stages of the innovation project, when the goal is the identification of the use cases. They are called again the final stages of the process to provide feedback on solution prototyping.

Finally, a third observation relates to the fact how all three organizations have activated participation processes of different nature. On one hand, the so-called direct participation is related to the individual involvement in the design process, while organizational participation refers to the involvement of workers' representatives in the design process. In all three companies there is a combination of direct participation with organizational participation, on the basis of the assumptions that trade union delegates represent the entire workforce, and that individual participation can never engage all the impacted workforce (especially in large-scale interventions). Thereby, all three companies have sought union endorsement, following two alternative strategies. On the one hand, Mechanic and Pharma have developed an informing/consulting relationship with the unions. Both companies have in fact constantly informed unions about the progress of the digital technology design and implementation programs and specific interventions, mostly on issues related to employee control and impact on workforce size. On the other hand, Energy has created dedicated communication channels with unions, parallel to the pre-existing ones. Through a framework agreement, both parties commit to the management of organizational changes and the evolution of professional roles related to the 4.0 project.

4.2.3. Methodologies adopted in the organizational design process

In all three cases, design effort is intended as a continuous, participatory, learning process, where planning and doing are contemporaneous to such learning process. In other words, the approach to design is not defined according to a traditional perspective, i.e project releases are not defined in advance, the phases are not sequentially connected, the project is not tied to a specific team that is ‘dismantled’ at end of each phase. Contrary to the traditional sequential way of organizing, the Digital project phases, the corresponding releases and final deliverables are defined in broad terms. They are not managed assuming sequential interdependencies, but instead through mutual interdependencies and broad participation.

In all three cases, the methodologies adopted ensure that the design choices pertaining to different domains (strategic domain, social domain, and technological domain) are managed simultaneously. As already mentioned, the scope of the projects has been intentionally defined in a broad and multidisciplinary way and this has led to the coexistence of different domains within the design process. Although different issues from different domains have been addressed in a systemic way, they are not approached single-handedly, but are instead understood as different nodes of one project, rather than sequential separate steps.

A second observation relates to the extensive use of design methods based on continuous experimentation and iterative cycles. These methods are typically defined as agile, referring to the ‘agile’ way the phases and the respective teams have been structured. Consistent with the agile perspective, the project phases are outlined in a non-sequential logic predicting constant temporal overlapping. Moreover, in all three companies the design process assumes that recycling and thus altering or refining decisions is seen as a necessity or rather an opportunity for reaching the best solution.

Finally, a third evidence relates to the fact that, in choosing the design methodology, the companies have given consideration to the fact that the approach to design should actively involve a broad set of stakeholders during

problem definition and identification of solution. In fact, evidence shows that new incorporated approaches to organizational design solutions foster broader stakeholder participation, by emphasizing/encouraging their coordinated interaction for the generation of creative design solutions, regardless of what has been done thus far, and the current existing constraints.

The set of evidence shown above indicate that the analyzed companies have mainly adopted two specific design methodologies, which originate outside the organization design field. Firstly, we refer here to agile design methodologies. All three observed companies have approached the design process of the techno-organizational system, by adopting, formally or not, agile methodologies, originally developed within the software engineering discipline. Within this discipline, albeit characterized by a strong technological focus, in fact, in recent years, design methodologies have been developed such that they foresee potential problems in good time and simplify decision-making, enabling, if necessary, corrective action even during project later stages. Secondly, companies have applied design thinking methodologies, initially developed in the product / service innovation process area, and that now are expanding to organizational innovation and change management areas.

5. Discussion and Implications

This study starts from the consideration that, in many cases, the planning of interventions when organizations are faced with 4.0 technological implementation is facing important limitations/constraints. In fact, by neglecting the importance of organizational redesign process, it is assumed that technologies will determine the emergent organizational configuration. Some predict that such configuration is aimed at the enhancement of human labor and others at its replenishment or impoverishment. In order to overcome this contrast, understood as the outcome of a techno-centric vision of the relationship between technology and organization, the present study - starting from the socio-technical systems theory premises- has analyzed the design process in three companies. The reason for this choice is the assumption that starting from the same technologies, different organizational configurations can be designed, and that the resulting organizational configuration depends on the design choices taken by different actors involved in the process.

The results of this study have revealed two important findings. First, they show that three design principles of the socio technical theory are today still informing the design processes in the observed companies. In fact, observing the emerged evidence regarding the content and the process of design, actors involved and the design and implementation methodologies, it is possible to recognize the three principles proposed by the theory of socio-technical systems, that are, respectively (i) the adoption of a broad field of action that includes social and technical aspects, (ii) broad participation and (iii) the experimental nature of the process.

Secondly, for each one of the principles we have enriched our understanding through the practical implementation of each of them. In consideration of such elements, assigning each project an extended scope and adopting a multidisciplinary methodology have resulted as the emerging operational concepts of the principle of 'joint optimization of technical and social aspects' implemented today by organizations. The second principle 'participation' is incorporated through the following actions (i) Vertical and horizontal participation. (ii) Informative and deliberative participation (iii) direct and indirect participation. Probably it is the actual application of the principle of 'adoption of a design process based on continued experimentation' that demonstrates the most fundamental break with the past. This third principle is today applied in two ways. First, through the adoption of 'Agile design' methodologies, that allow an interactive process with short and continuous experimentation cycles and address the various project areas in an iterative and simultaneous way. Second, through the adoption of design methodologies pertaining to 'Design Thinking', that thanks to the coordinated interaction among a large set of actors, allow the generation of particularly creative/novel design solutions.

The contributions of this study are twofold, as we contribute both to management theory and practice, as well as for organizational design training. First, the study shows how the principles elaborated by the socio-technical systems theory represent still today a framework capable of grasping and explaining many of the ongoing organizational dynamics. As already mentioned in the theoretical section, the STS theory has had a period of discontinuity in research and managerial practice

By showing that its principles still inform the design processes in the observed companies, this study highlights the fact that this theory - when "actualized", as shown by the (also very innovative) operational variations

implemented by the companies analyzed – can be used as a framework for understanding today's techno-organizational dynamics. Therefore, this work calls for a 'coming back' of the socio-technical theory, when contemporarily adept to reflect today's challenges and resources.

In addition, the study also provides interesting implications for managerial practices. In fact, it offers professionals guidelines and operational deployment examples on how to build the, what we in the title of this paper call the "digital socio-technical design". The pervasiveness of digital technologies makes these findings of particular interest for a potentially very large set of businesses and professionals. They present original and interesting implications for practitioners responsible in training the organizational designers of the future. From this point of view, the results offer the following two suggestions to management education. First, they suggest that the STS theory and design be provided an ample space in organizational design courses; secondly, they suggest an updated reading of this theory. From this point of view, for example, it emerges that the typical content of the socio technical teaching be integrated with novel, multidisciplinary knowledge, such as agile design and design thinking methodologies.

Finally, starting from the limitations of this study, it is important to address the new dimensions for future research these results open. First of all, despite the fact that this study is based on interviews carried out mainly with management-level of the companies, it is however important to understand if the resulting design process as described in the findings, would be positively perceived also by lower level employees (i.e., the operators) directly affected by new technologies. To that end, the investigation of the implemented control systems, intentional or emerging, formal or informal, that aim the mapping of the results achieved to desirable objectives allows to the analysis of whether – in addition to the traditional performance indicators related to impact of innovation interventions - companies have developed new systems for controlling the effects of digital interventions on the quality of work of operators and with what actual effects. Embracing these two research areas would allow to better qualify and quantify the positive, simultaneous and synergistic impact that the design process inspired by the STS theory, as presented in this contribution, has on the productivity and quality of work.

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