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PH. D. THESIS

Beyond technological determinism and into the 4.0 joint, participatory and agile organization design

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Acknowledgements

In hearing the wisdom of Emery, Trist, Rice and Thorsrud (1960; 1968; 1969), whose work in designing new organizations I have drawn heavily in this research, I have sought intellectual enlightenment that has accompanied me during the entire PhD journey. I am mostly indebted to these sociotechnical scholars, well known for many different contributions and whose scholarship has had an immense impact on modern social science. Some time ago Lou Davis (1971), another prominent sociotechnical scholar, indicated that "the social and the technological forces can be seen working toward the same end, for 'job characteristics that develop commitment' and thus promote the economic goals of the highly automated enterprise are exactly those that

are beginning to emerge as demands for meaningfulness from the social environment participation and control, personal freedom and initiative." What had become visible in the '70s seems to be a well-established trend nowadays as digitalization pervades the industrial sector.

This journey would have not been possible without the untiring support of my supervisor, Professor Marco Guerci, who has provided invaluable insight and vision on this research project while adopting a coaching supervisory role. Our many conversations over the past few years have challenged the depth and breadth of my thinking and continuously pushed my boundaries. His intellectual vigor, work ethic, coupled with his patience, made this research journey fulfilling and enriching, not merely in academic terms.

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Abstract

The capability of Industry 4.0 technologies to interconnect, learn, and act autonomously are challenging organizations in their efforts in reshaping work and the organization of the workplace. Moving away from the deterministic academic debate, this PhD thesis integrates insights from the Socio Technical theory and design that places the social dynamics of the workplace back at the heart of the understanding of the interaction

between new technologies and organization. Through a multiple case study analysis, the first part of this research shows that organizational solutions are not determined simply by the technical context. In fact, this research shows that digital technologies are a factor that can enable opportunities or constraints for work and organization, but ultimately it is the choice made by the surveyed organizations that clearly has shaped the variant positions that they have taken, as in some cases 4.0 technologies enable an organizational design aimed at developing employee commitment, and in other cases they enable an organizational design aimed at increasing the control over employees.

In this context, given the specific environment and the multitude of objectives that a particular organization is to satisfy, it becomes important to explore an important dimension of agency in digitalization efforts, namely the role that the organization design process, activated during the adoption of new technologies plays. Through empirical analysis, the second part of this research, thus analyzes organizational design, through the Socio-Technical System (STS) theories and principles. The analysis that focused on the content of design process, actors involved and the deployment methodologies used, shows how and to what extent, the STS principles have been incorporated in the organizational design, and how they are operationalized by companies nowadays. This study demonstrates that STS theory - when 'actualized' to the contemporary context – can account for understanding today's techno-organizational dynamics in a non-deterministic way. In addition, findings reveal that the broad participation of employees in the design and implementation process is also a reflection of employees' opportunity for adjusting the pattern of technology use. Finally, results corroborate that "user-centric" STS informed design methods, such as Agile and Design Thinking, offer organizational designers the opportunity to embrace a broader multidisciplinary stakeholder base, including the technology users. Such methods shed light on the fact that a design system is never really finished, the components of the socio-technical system should be invented and reinvented, as organizations become open ended evolving systems.

This research, by providing a nondeterministic contribution to the understanding of the relationship between the digital change and work and organization, hopes to contribute in advancing the ongoing debate across research.

INTRODUCTION

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1. **Industry 4.0 and national initiatives**

Since its origins, industry[1] has experienced profound transformations driven by the emergence of novel technological paradigms. The first Industrial Revolution used water and steam power to mechanize production, the second used electric power to create mass production, the third one used electronics and information technology to automate production (Schwab, 2016). With the turn of the millennium, a fourth Industrial Revolution that is building on the third, the digital revolution (aka Industry 4.0), driven by the fusion of novel technologies (see Fig.1) such as sensors, smart robots and machines, and the huge computational power of advanced analytics, seems to have entered the *theatrum mundi* for good, "blurring the lines between the

[1] Industry globally accounts for 25% (2018) of the world total employment, with manufacturing in particular, contributing to GDP with 16% (World Bank, 2018). It is considered fundamental for ensuring good jobs, social and economic prosperity (European Commission 2017; National Economic Council 2016; The White House 2017).

physical, digital, and biological spheres" (Schwab, 2016). According to Schwab, velocity, scope, and systems impact are deeply changing the manufacturing systems connectivity, due to the integration of information and communication technologies (ICT), Internet of Things (IoT), and machines in the so-called Cyber-Physical Systems (CPS) (Kagermann et al., 2013; Schwab, 2016). Such distinct qualities make this technological transformation a breakthrough with no historical precedent, heralding a transformation of the entire systems of production, management, and governance, adding value to the whole product lifecycle (Dalenogare et al., 2018, Wang et al., 2016; Frank et al., 2019). In such a sense, Industry 4.0 can be understood as a result of the growing digitization of companies, especially regarding to manufacturing processes (Kagermann, 2015; Schumacher et al., 2016).

As a concept, Industry 4.0 was first coined in 2011, by the German government (Frank et al., 2019), as a strategic program to develop advanced production systems with the aim of increasing productivity and efficiency of its national industry (Kagermann et al., 2013). Since its advent, Industry 4.0 technologies are increasingly being recognized as a tool fundamental to increasing competitiveness (European Commission, 2017), bringing along significant social and economic opportunities and challenges that require governments to respond to timely and appropriately (Manda and Backhouse, 2017). Such response is meant to put in place regulative mechanisms that support the

Figure 1 Industry 4.0 technologies

- *Advanced Manufacturing Solutions*: Collaborative robots interconnected and rapidly programmable
- *Additive Manufacturing*: 3D printing connected to software used to make physical objects from digital models (
- *Advanced Human-Machine-Interfaces,* e.g., augmented reality and virtual reality
- *Simulation* through the Digital Twins – i.e., the dynamic digital representation of real objects, resources or systems
- *Internet of Things (IoT) and the Industrial Internet,* Multi directional communication between production processes and products
- *Cloud computing*, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services)
- *Big data and industrial analytics*– such as machine learning and semantic intelligence

facilitation and successful adoption of the digital transformation, as well as to address skills, education, infrastructure and other needs that arise due to new innovations (Manda and Backhouse, 2017).

To promote the success of the 4th industrial revolution in Europe, the European Commission, for example, has developed innovative policies that address regulation, infrastructure, skills infrastructure and funding (European Commission, 2015; 2017). To that end, most European countries and actually the most influential manufacturing countries worldwide (such as is the Smart Manufacturing in the United States, Made-in-China 2025 in China, etc.) have in fact launched national Industry 4.0 initiatives. Given the importance of industry for the Italian economy[2], the "Industry 4.0" National Plan, was launched in 2016. The Italian way to Industry 4.0 is represented by the need to adapt the technological and organizational innovations to the local context, which is characterized by productivity levels that are among the lowest in Europe, with an inadequate international positioning of companies, except for a limited number of leading companies in their respective sectors (Position Paper, Special Issue of Studi Organizzativi, 2020), by mainly small sized companies, with competitive advantage, where present, based on niche leadership, and family-led enterprises with insufficient financial resources allocation toward technological innovations. Thereby, the "Industry 4.0" national policy aimed at ensuring the foundation of an efficient framework for the support of the digitalization of industrial processes (for development of new process and new products and services) and for the improvement of workers' productivity[3] (including training the development of

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[2]Industry in Italy accounts for 21% of Italian GDP and manufacturing contributes to GDP with 15% (World Bank Data. 2018), the low-productivity firms (OECD Report, 2017)
[3] Labor productivity reflects several factors concerning the business and technology innovation, as well as skills and organizational know-how (OECD, 2015)

new skills). In fact, the Industry 4.0 national plan is built upon three foundational pillars: technology, organization and work, actively promoted through the cooperation of institutions, companies, public administration, research, schools, unions, and media (MISE, 2016). In 2019, the Italian Government relaunched and partially tailor-made this plan, renaming it 'Impresa 4.0'[4]. According to Butera et al., (2020), the limited use of digital technologies and the distress on the part of smaller companies have shown, however, that the widespread adoption of digital technologies does not take off if the three pillars of the Fourth Industrial Revolution are not designed and activated together, i.e. interventions on the strategic repositioning of companies, the redefinition of their internal organization, the reconfiguration of roles and professions, interventions on the training and retraining of workers with the redefinition and adaptation of their skills (Position Paper, Studi Organizzativi, 2020). The government recently, in a recent attempt to sharpen measures[5](European Commission, 2020) has addressed the importance of promoting skills as an important pillar for the success of the digital transition (European Commission, 2020).

Finally, although the 4th industrial revolution has become a prominent concept, its whole idea has not always been examined without critique. In fact, Morgan (2019) in her paper 'Will we work in twenty-first century capitalism?' pays a critical perspective to the 4th industrial revolution concept, arguing that the framing of such concept is not neutral. It is absorbed according to market conforming logics that allows a government to limit its responsibility for shaping the future, even as it continues to herald the potential. Morgan further argues that the future is being shaped now by

[4] Enterprise 4.0
[5] In fact, the previous plan Impresa 4.0 has been renamed to Transizione 4.0 (European Commission, 2020)

the way the fourth industrial revolution is being positioned, and that public policy is doing little to proactively shape the future in the interest of the workers of tomorrow 'if there are workers tomorrow' (Morgan, 2019).

2. **Visualizing Industry 4.0**

Industry 4.0 relies on the adoption of digital technologies to gather and analyze data in real time, providing useful information to the manufacturing system (Lee et al., 2015, Wang et al., 2016). Industry 4.0 can thus be visualized as a collection of devices, machines, production centers and products that can autonomously communicate with each other, exchange information, invoke actions and control each other independently (Wang et al., 2016). Such integration of the physical elements of the factory with the virtual dimension is supported by Internet of Things (Wang et al., 2016; Schuh et al., 2017; Tao et al., 2018) and it is known as the cyber-physical system (CPS).

To understand how industries see the potential contribution of the 4.0 technologies for industrial performance, Dalenegare et al (2018) separate Industry 4.0 technologies into two different layers according to their main objective. The first layer is called 'Front-end technologies' of Industry 4.0. It includes technologies concerned with the transformation of the manufacturing activities (Smart Manufacturing), those concerned with the way product are offered (Smart Products) (Dalenogare et al., 2018), how they are delivered (Smart Supply Chain) (Angeles, 2009), and how workers perform their activities (Smart Working) (Stock et al., 2018; Longo, Nicoletti and Padovano, 2017). The second layer is called 'Base technologies' and comprises technologies that provide connectivity and intelligence for front-end technologies

(Frank et al., 2019). In this way they allow front-end technologies to be connected in a complete integrated manufacturing system (Tao et al., 2018; Thoben et al., 2016; Wang et al., 2016). The "base technologies" of Industry 4.0 are composed by the so-called new Information and Communication Technologies (ICT), which include Internet of Things (IoT), cloud services, big data and analytics (Tao et al., 2018, Thoben et al., 2017, Wang et al., 2016). These technologies are considered base because they leverage the Industry 4.0 dimensions and make the interconnectivity possible, as well as providing intelligence to the new manufacturing systems. Frank et al. (2019), in their research, in identifying different patterns of adoption of the above two technological layers, show how Industry 4.0 technologies are interrelated. Such interrelation/integration of technologies is pushing companies beyond their spatial borders along the following three directions (see Fig.2) (Kagermann et al.,2013, Wang et al. 2016, Fantini, 2018):

- Horizontally, by expanding the boundaries of the organizations to reach customers and supply chains. Such horizontal integration is supported by digital platforms (Frank et al.,2019) that make sure the exchange of real-time information about production orders with suppliers, distribution centers (Pfohl et al., 2017), reach customers by tracking product delivery (Pfohl et al., 2017), and can also integrate different factories of the company by sharing real-time information on the operational activities (Simchi-Levi et al., 2004).
- Vertically, by integrating, through advanced ICT systems, all hierarchical levels of the company – from shop floor to middle and top-management levels (Schuh et al., 2017). To reach vertical integration, the first step at shop floor is the digitalization of all physical objects and parameters with sensors, actuators and Programmable Logic

Controllers (PLC) (Jeschke et al., 2017). The data is then gathered[6] at the shop floor. At the managerial information layers, other systems[7] obtain data from the shop floor, providing production status to the planning system[8]. When all systems are properly integrated, the information of production flows both ways (up-and-downstream), helping to deploy the vertical integration of the factory (Tao et al., 2018; Jeschke et al., 2017).

- End-to-end, for comprehensive engineering processes encompassing the whole product's lifecycle (Wang et al.,2016). This is achieved by aggregating the (i) "design and implementation" phase, that covers the identification, concept, requirement, design[9], implementation and build, and (ii) end-of-life phases, i.e. "operation and management" that cover the activity to operate the systems, run the processes and manage the resources (Fantini, 2018).

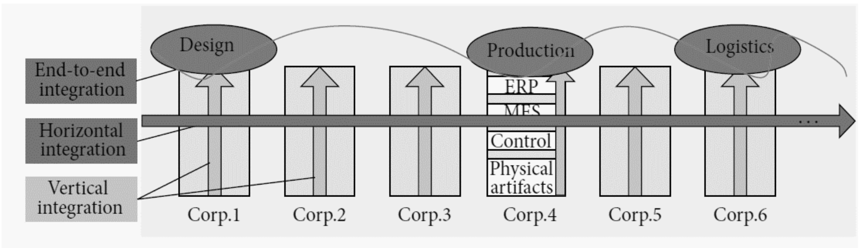

Fig.2 Integration along three directions (adopted from Wang et al., 2016)

2.1 Expected Benefits

The great variety of digital technologies lays out the conditions not only for the transformation of manufacturing production systems, but also for the development of new business models based on digital platforms (Dalenogare et al., 2018). It is

[6] Data is gathered with Supervisory Control and Data Acquisition (SCADA) (Frank et al., 2019)
[7] Such as: Manufacturing Execution Systems (MES) (Frank et al., 2019)
[8] Enterprise Resource Planning (ERP) (Frank et al., 2019)
[9] The effect of product design on production and service can be foreseen using the powerful software tool chain, so that customization of the product is enabled (Wang et al.,2016)

therefore essential for companies to define their own strategy on how to use the 4.0 technologies, if they aim at improving performance and growth, or creating and maintaining competitive advantage, etc. According to the selected business strategy companies can focus (as shown in Fig. 3):

(i) externally, for the creation of new/enhanced 'digital' product/service offerings. If externally focused, digitalization offers opportunities to pursue the creation of new services or to increase/enhance of the service components; increase customer centricity and provide for more flexible responses to customers' needs; provide rapid information, supplier integration and co-production with customers, etc. (Bartezzaghi, Della Rocca, 2019), or/and

(ii) internally, to digitally intervene in the production processes. If internally focused, new technologies open up opportunities by reducing time and costs of production processes thanks to simulation, virtual reality, 3D printers and Big Data; increasing various aspects of productivity such as: reduction of downtime and breakdowns through predictive maintenance; reduction of direct labor costs through robotics, remote control, etc., increasing quality through control and monitoring of operations; reducing problem solving times of system reconfiguration thanks to Big Data and simulation; reducing waste of raw materials and energy thanks to the IoT and continuous monitoring of the process and products; increasing safety, reducingf accidents, danger and fatigue (Bartezaghi, Della Rocca, 2019)

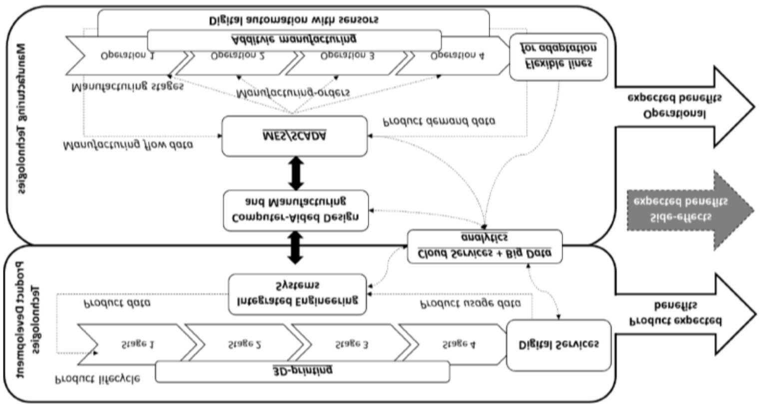

Fig. 3. Internal vs external focus (adopted from Dalenogare et al., 2018)

3. Main characteristics of 4.0 technologies and their implication for work organization

With digitalization, the classic conceptualization of technology, where physicality plays a central role, is being further challenged. Such conceptualization has 'spatial' limitations, and as Barley (2017) further claims, although 'digital tools lack physical form, their appropriation has engendered significant outcomes for work and organization'. To encompass the conceptual breadth, he defines technology as an artifact or a process whose qualities enable (and constrain) certain forms of organizational action. To that end, organization scholars have broadly analyzed digital implications for work and organizing, arguing that focusing on the kinds of behaviors that are typically afforded by new technologies across organizations (Treem and Leonardi, 2012) should allow us to understand when, why, and how they lead to changes in organizational practices (Plesner, 2019). To that end, two most visible characteristics of digital technologies, interconnectivity and intelligence (Cagliano et al, 2019), have drawn attention on many organizational practices.

Interconnectivity As many organizations today are still struggling to become fully integrated, because of limitations on interconnectedness of functional information systems that hinder the integration efforts (Waschull, 2019; Panetto and Cecil, 2013).

Industry 4.0 technologies are offering an opportunity to overcome these limitations and promote business integration, by facilitating integration across processes and from shop-floor to business process level (Atzori et al., 2010; Gubbi et al., 2013), thus facilitating the adoption of an integral and multi-disciplinary view towards the business, inside and outside the scope of employees' own work areas.

Intelligence New intelligent resources, such as big data and advanced analytics, have created new conditions for organizational practices. In fact, they are expected to possibly outperform humans in a wide variety of skilled and cognitive acts (Bailey et al., 2019, Faraj et al. 2018). Thereby, they have increased the capability of process elements not only toward collaboration, but also to take autonomous decisions. To that end, they are already automating administrative coordination by managing task decomposition and integration (Zammuto et al., 2007), thus enabling organizations to autonomously divide and allocate tasks as well as to integrate efforts in novel ways, reach individual and common goals without human intervention (Atzori et al., 2010; Gubbi et al., 2013).

As a result, emerging technologies are transforming how, when, and where work gets done, as well as by whom and for whom (Bailey et al., 2019). With the potential for such changes in scope, new questions arise about how work and its organization can and should happen in the future, including questions related to coordination, control, communication, hierarchy, professional roles and boundaries, socialization, practices, and much more (Bailey et al., 2019). For this reason, new 4.0 technologies challenge existing conceptualizations of technology in organizational theory and have invited a re-examination of technology's role in organizing by a wider spectrum of organizational scholars (von Krogh, 2018).

3.1 Academic Debate: 'Glorification' vs 'Demonization'

With the rise of digitalization, the academic debate over the instrumental role that technology plays in creating the modern organizations has gained further traction, with some critics 'glorifying' its ability to solve organizations' most pressing issues, whereas others 'demonizing' it (Elbanna, 2020).

Perspectives such as, for example, that of Ford (2015) voice concern about the "perfect storm" of digital technologies where the impacts from soaring inequality and technological unemployment in some ways amplify and reinforce each other (Spencer,2018; Brynjolfsson and McAlfee, 2014). The 'demonization' scenario (Elbanna, 2020) thus predicts that digital technologies will either deplete human work or make it redundant. Jobs are characterized by a low number of simple activities, with little or no room for maneuver, in a way that can be addressed to as "Neo Taylorism" (Schumpeter, 2015; Moore and Robinson, 2016.) This scenario predicts job polarization (Goos and Manning, 2007; Frey and Osborne, 2003), in-work poverty, in that 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 (Ford, 2015; Susskind and Susskind, 2015, Frey and Osborne, 2017), with workers subject to a more intrusive and intensive work environment (Dundon et al., 2017). By contrast to the above perspective, other authors tend to glorify the effects of new technological innovations. Authors, such as Srnicek and Williams (2015) and Mason (2015), focus more on the benefits of digital technologies (such as performance, or extension of human freedom), while some other argue that far from reducing work, technology is likely, as in the past, to augment it (Spencer, 2018; Huws, 2014) and others believing that new technology is yielding more liberating options for the meaning of work

(Bastani, 2019). 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 increased social interaction and team working (Bastani, 2019; Mason, 2015; Neufeind et al., 2018). In the same direction, while holding a 'bounded automation' perspective that argues that technological innovations do not simply unfurl according to their own endogenous potential, Fleming (2019) elucidates that a robot probably will not steal your job, but that's no cause for celebration because the jobs that do proliferate in the 'second machine age' are considerably poorer in terms of skill, responsibility and pay.

Both above views, one approaching from the side of the technological efficiency and one from the side of human empowerment, see organizational efficacy as hinged upon the technology. It is the idea that whenever technology changes, people change their ways of interacting and organizing. In fact, in their effort to understanding how current management practices came into being and how they evolved over time, neo-Schumpeterian authors such as Bodrožić and Adler (2018) have illuminated on the fact that separating organization from technology is increasingly difficult, and that the emergence of a technological revolution in leading industries generates radically new organizational and management problems, that in turn generate unintended consequences (often related to human problems), which in turn prompts a second cycle that generates another management model that rectifies those dysfunctions and thereby rebalances and stabilizes the new organizational paradigm. On the contrary, other authors, such as Volti (2006, 2020), Howcroft and Taylor (2014), Thompson and Briken (2017), etc., as opponents of technological determinism, have argued that the above-mentioned scenarios, one approaching from the side of human empowerment and the other from the side of replenishment/impoverishment of human work, neglect the fact that choices regarding technology development and adoption emerge in an environment where agency is an important determinant of technological change and its consequences.

4. Research Motivation and Objectives

> *"We are confronted with the "Digital Coal Mines" and with an urgent need for organizational theories and system design methods that will allow us to once again disobey the technological imperative"*
>
> Austrom and Ordowich, 2018

4.1. Objective 1

The motivation for this research has moved from the idea that while a turning point is taking place in the development of advanced technologies (and mainly information technologies), such a tremendous technological innovation is not being matched by the pace of transformation of organization and its people: technology is running ahead (Elbanna, 2020).

Current literature, thus far, has provided for limited considerations on the organizational choices that companies make when introducing Industry 4.0 technologies. In fact, not only empirical evidence is scarce on this aspect, but many authors (Plesner et al., 2018; Cagliano et al., 2019) recognize the fact that although a number of studies are facing the key questions of how 4.0 technologies will reshape the work environment, working activities and – eventually – the organization of work, they take a deterministic stance, according to which technology determines the social, and, by implication, pushes organizations in particular directions. As elaborated in part three of this introduction section, this techno-determinist perspective has two normative subsets – technological 'glorification' and/or 'demonization' that do not tell us much about how digitalization affects work practices at the everyday level.

Against this background, in a time when, academic views are polarized, and research is limited to theorization, when empirical work is scarce, it is the right time to empirically analyze how organizations are re-designed when Industry 4.0 technologies are implemented. To that end, it is thus legitimate to ask whether technology constitutes a factor independent from the organization, whether it confirms and accentuates traditional control models, or whether it gives rise to conditions for a more employee commitment organization. This contemplation has led toward the first objective of the research:

Objective 1:

Exploration and analysis of organizational configurations in companies that have implemented Industry 4.0 technologies.

4.2 Objective 2

Bartezzaghi (2020) argues that without a prior or parallel organizational change, the success of digital technology can however be considered limited. The risk of this approach would be nothing short of digitizing previous waste and inefficiencies and, as such, not increasing the productivity of the system (Bartezzaghi, 2020). The introduction of 4.0 technologies, thus, if not preceded or accompanied by the necessary organizational innovation (and managerial) interventions, runs the risk of nullifying, in whole or in part, the same advantages that it provides (Massone, 2017). To that end, along with the tremendous advancement in 4.0 technologies, substantial advancement should take place in the organization field as well, to fit with present and future technological, economic performance and social needs (human development). Therefore, it is not enough to incentivize the 4.0 innovations, if at the same time an overall path of organizational innovation is not activated, i.e., defining adept design principles, methods of action, standard indicators, etc. (Massone, 2017) In light of the above considerations, research is needed to not only understand the change process, namely how the organizations have (re)designed the work organization in light of digitalization, but also, given the specific environment and multitude of objectives that the particular organization is aiming to satisfy, it is important to identify the appropriate ways (the how's) of organization design in order to guide and accompany organizations in maximizing both, system performance and augmenting human capabilities. In this sense, it becomes important to looking in what way technology and organization design can become factors of joint optimization of both, performance and development of the quality of work. Building on the above considerations, the second objective of this thesis is deconstructed into two levels of analysis as also illustrated in Figure 3:

Objective 2:

- On a cognitive level, to understand the possible paths of organizational change related to the adoption of 4.0 technologies.
- On a normative/prescriptive level, to identify design approaches that support organizational performance and development of job quality

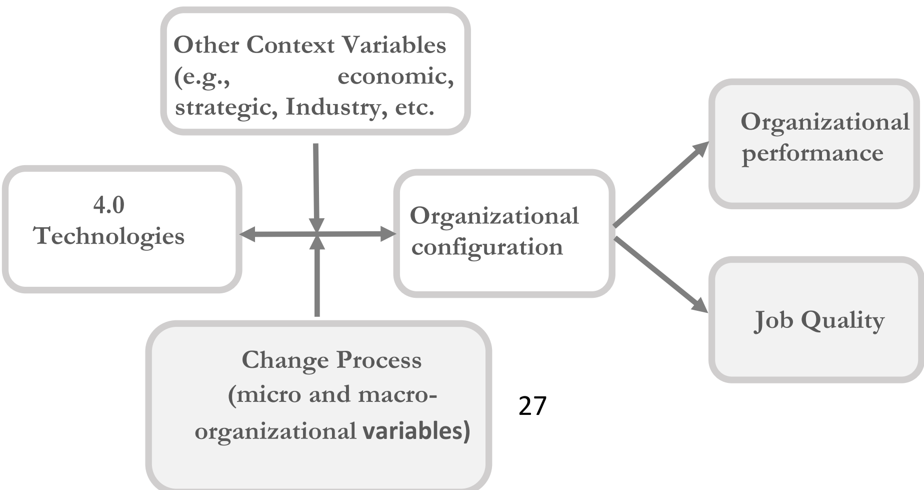

Fig. 4-Reference Framework

The following Figure 5 provides an overview of the overarching research goal and its decomposition in two main objectives, each of the which has been limited to more specific aspects (see specific papers), since their scope is too wide to be thoroughly addressed.

Fig. 5 Research Objectives

5. Research path: Transdisciplinary, Collaborative, Performative Research

In designing this research, in order to integrate the best available knowledge, we have adopted a transdisciplinary, collaborative research approach. Therefore, actors from different academic disciplines, such as the research unit of the Organization Studies

Department of Università degli Studi di Milano and the research unit of the School of Management of Politecnico di Milano, have been involved in the research process, bringing a wide array of knowledge base and perspectives, and allowing the integration of different skills, as Gibbons calls it 'integration of skills in a framework of actions' (Gibbons et al., 1994).

This research aimed at being meaningful not only in scientific terms but also in performative terms (Spicer et al., 2009; Spicer and Alvesson, 2009). Sharing the results of the research, by means of a workshop, with professional members of all interviewed companies, and making leverage of the involvement of other media representatives and other interest groups, the research team meant to promote the welfare of its constituents, making stakeholders understand the utility function (Banks et al., 2016) of the research. The common keyword of this workshop for both research and practice has been the integration between technology and organization; between roles (managerial, technicians, workers), but also, between companies, workers and actors outside the company. Showing that participation and involvement of technology users is a key factor in the new organizational models, and that such participation of the users represents one of the conditions for the continuous improvement of the digital implementation, the research team managed to involve practitioners in "our research conversations" and toward realignment of goals (Banks et al., 2016). This workshop and the follow-up conversations with company representatives have represented an effort into shortening the distance research-practice. Nevertheless, the research team has recognized its data sampling limitations that in turn open up avenues for considerable future extension of such data, to allay all possible concerns. To that end, taking further concrete actions such as, anticipating the practitioner awareness toward the utility function of the research

(Banks et al., 2016), providing practitioners with clear goals from the start of the project, involving their close interaction throughout the process of knowledge production, would contribute not only to lowering the collaboration costs, but also increase the two-way knowledge mobility (Dhanaraj and Parkhe, 2006). On the other side, the benefits of the research results should be further promulgated through workshops, educational events, publishing in existing practitioner journals, making use of social media tools (such as LinkedIn, University webpages), etc. These are important steps, as Banks et al., (2016) put it 'important to advance evidence-based management and help reduce the science–practice gap'.

The research team advocated for paper-format production of research output. Such an approach is in line with the 'progressive' form/attitude that reins over the organization studies field (Carollo, 2016). As a matter of fact, the research team was able to produce two research papers, highly connected in their focus on the interplay between the digitalization and its impact on work and future organizations. Both of these works have been published by the 'Studi Organizzativi' Journal. The first paper, entitled 'Industry 4.0 technologies and organizational design – Evidence from 15 Italian cases' was published March 2019, while the second, entitled '4.0 Organizational design: socio technical theory and design principles revisited' was published September 2020. Furthermore, this paper is being refined and modified to be submitted to the regular issue of the internationally peer-reviewed Journal for Organization Design.

Both abovementioned papers have been presented in international conferences, engaging in the ongoing debate within certain academic communities of inquiry, where they have drawn considerable interest. It is important to note that the contributions of both papers are intended to be two-fold. On the one hand, the primary contribution of the dissertation is directed to the existing debate within organization studies around the impact of digitalization on work and organizations. On the other hand, thanks to the qualitative research tools employed in my research activities, I have tried to inductively and abductively add to the growing strand of literature providing new concepts and opportunities for theorization (see Implications part of Conclusion Section).

Last but not least, both papers are not only the result of research interests developed in collaboration with the research team during my PhD career, but also of the research opportunities and challenges that I encountered in the past three years. Nonetheless, the knowledge exchanges I had in the last three years with members of both scientific communities, have enabled me to continuously enhance my learning experience and refine my thinking process, to engage in scholarly debates, a process that in turn has significantly contributed in my building up confidence, voice, and, above all, my identity as researcher in the field.

6. Structure of the thesis

This dissertation has been designed as a collection of two interrelated published papers which cover a research period from September 2018 to March 2020, a full technical account of which are presented in Chapters I and II that represent the main body of this PhD thesis. Each paper that represents a chapter of this dissertation can thus be read as an individual study with specific research questions, theoretical framework, methodological concerns and contributions. In this sense they are the 'heart and soul' of this dissertation, and what binds them is their focus on the mediating role that the 4.0 technologies have on work and organization design process. This dissertation is structured into thus, two main Chapters and the Conclusion Section. More in detail, it is organized as follows.

The first Chapter of the thesis starts by providing an overview of the digital revolution, its importance for the manufacturing industry and its particular relevance for the Italian economy. But why is 4.0 technology important for organization of work? To understand the interaction between technology and organization an overview of the current theoretical debate on the role that digital technology plays in organizations is presented. The theoretical section of the paper specifically concentrates on this vibrant debate that has emerged on the evolution of organizational design, i.e., the extent to which current organizations are designed following Tayloristic or post-Tayloristic principles (e.g., Masino, 2005), and on the main features of digitalization that enable/afford or constraint organizational change. Afterwards, arguing that there dominates a techno-centric vision among scholars that either 'demonize' or 'glorify' digitalization of the workplace, and not willing to commit to either side of the above deterministic debate, we explore a different perspective, the Socio technical Theory that relates to the interaction between organization of work and the introduction of new technologies in a balanced, non-deterministic way. Considering the above background there follows the main objective of this paper that conforms to the knowledge gaps, as an indication of the importance of this research. The presentation of the research method is an opportunity to reflect on the organizational variables that are most likely to be revisited with the introduction of new technology. Thereafter, the findings section is a detailed and accurate description of the trend of change of all identified variables. Finally delving into the discussion of results and implications of research, is an opportunity to remind the reader of the overall purpose of this research, an opportunity to wrap up the results, and a chance to delve upon further future research.

The second Chapter of the thesis represents a follow up study of the first Chapter. This study pays particular attention 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. While delving into the analytical background of the STS, its historical legacy, its successes and failures, the theoretical section lays out the foundation for this research particular research question. Through an inductive and abductive method, next sections of this Chapter present an analysis of three companies that have introduced digital technologies and have designed their organizations according to the criteria of organizational performance and human development. A discussion and implications of the findings not only for the STS theory, but also its implications for organizational design are discussed, along with limitations of this research.

Finally, the last part of the thesis relates to the Conclusions Section that summarizes the main findings and presents the main arguments that this research has advanced. I briefly summarize the two core chapters and examine how they together can make us better understand the interrelationship between digital technology and work and its organization. The general implications for both theory and practice are discussed, that pave the way in the end to reason on possible avenues for future research that can extend the lines of investigation initiated here.

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Chapter I.

Industry 4.0 technologies and organizational design–Evidence from 15 Italian cases[10]

[10] This paper has been published in March 2020 in the 'Studi Organizzativi' Journal, co-authored by Marco Guerci, Emilio Bartezzaghi and Silvia Gilardi

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Industry 4.0 technologies and organizational design–Evidence from 15 Italian cases

ABSTRACT

Current literature on Industry 4.0 technologies has mainly explored their relationship to the employment dynamics, or to the required competencies and emerging roles. This paper is complementing current literature with a perspective focused on organizational design. The aim of the paper is to explore how organizations are re-designed when Industry 4.0 technologies are implemented.

The paper is based on 15 case studies carried out in Italian manufacturing companies and data was collected from 70 semi-structured interviews to relevant roles involved in the implementation of digital technologies. Results show that, when Industry 4.0 technologies are implemented, organizations are redesigned following an employee control-oriented or following an employee commitment-oriented organizational design. These results show that organizational design is the result of decisions and is not determined by technology. The implications of our findings are presented and discussed.

KEY WORDS

Industry 4.0 technologies, organizational design, employee control, employee commitment

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INTRODUCTION

The latest advances of information and communication technologies in manufacturing have led towards what is considered as the fourth technological revolution, alias Industry 4.0, expected to facilitate fundamental shifts in how products are produced, by creating a transparent, integrated and intelligent manufacturing environment (Brennan et al., 2015).

Current literature has started exploring Industry 4.0 technologies, employing two alternative approaches. The first approach addresses the question: "Are Industry 4.0 technologies substituting work?" Studies have distinguished two possible scenarios on how technology is shaping employment dynamics (Romero et al., 2016). On one hand, a highly techno-centric scenario, with extensive automation of many work processes, in which human activities will be reduced to those tasks that cannot or should not be automatized. This scenario foresees a reduction of the low skilled workforce (e.g., Dworschak & Zaiser, 2014). On the other hand, the human-centric scenario that analyzes how technologies are changing the composition of (not reducing) jobs. The second approach addresses the question: "What are the competencies required by Industry 4.0 technologies?" focusing on skill requirements and on the way economic systems, organizations and individuals can build them (Waschull et. al, 2017). The above-cited approaches have provided limited considerations on the organizational choices that companies make when introducing Industry 4.0 technologies.

In order to fill this gap, we aim to analyze how organizations are re-designed when Industry 4.0 technologies are implemented. We argue that the design of an organization always requires choices, as in face of the same technologies we can potentially experience different organizational designs. Assuming a socio-technical perspective, we look at micro and macro variables most likely to be revisited when technology-driven change occurs. The choices made by organizations on those variables are expected to be radically different when different designs are adopted. This study has an explorative nature and is aimed at identifying patterns in the evolution of organizational design when Industry 4.0 technologies are adopted. However, the aim is not to test or track the diffusion of those patterns across organizations. In order to achieve our objective, we use data from 70 interviews carried out in 15 Italian manufacturing companies that have implemented Industry 4.0 technologies. Our results show that, in the analyzed companies, the adoption of Industry 4.0 technologies is associated with two main models of organizational design: (i) Employee control oriented design, and (ii) Employee commitment oriented design.

The paper is organized as follows. Section two, theoretical background, considers objectives and expected benefits of 4.0 technologies and introduces the reader to our socio technical perspective and to the vibrant debate on the evolution of organizational design. Section three focuses on methodological issues, followed by section four that makes an analysis of the main results obtained. Finally, section five, six and seven present some issues for discussion along with the main conclusions, limitations and implications of this study.

1. THEORETICAL BACKGROUND

1.1 Industry 4.0 objectives, technologies, benefits

Even if defining Industry 4.0 remains a challenge, an established definition that captures its main features is as follows: Industry 4.0 relates to the diffusion, implementation and application of networked information-based technologies to the manufacturing enterprise (Hirsch-Kreinsen, 2016). The concept, Industry 4.0, refers to a complex set of technologies, some already known for years, which are now mature to be applied on a large scale. To untangle the skein of technologies, the Smart Manufacturing (SM) Laboratory of Politecnico di Milano University has clustered the technologies in two main groups (Osservatorio SM, 2015).

The first group includes Information and Communication Technologies, composed of three main families. The first family is Internet of things through which each physical object becomes connected through standard communication protocols. The second family is Manufacturing big data and analytics and it refers to methods and tools dedicated to the processing of large amounts of data, such as Data Analytics & Visualization, Simulation and Forecasting. Last family, Cloud manufacturing, is a virtualized, shared and configurable set of IT resources in support of production processes and supply chain management. In the second group, called Operational Technologies, three other main families can be distinguished. First, Advanced automation, relates to systems with ability to interact with the environment (e.g., (Agv systems, drones), to use vision techniques and pattern recognition (e.g., manipulation systems, quality control), and to interact with operators (e.g., robots). Second, Advanced human-machine interface, that concerns recent developments in wearable devices and human-machine interfaces, such as touch display and augmented reality.

Last, Additive manufacturing that flips the approach of classical production processes by creating an object through its "printing" layer by layer (e.g., Rapid Prototyping, Rapid Manufacturing, Rapid Maintenance & Repair, and Rapid Tooling).

As it emerges from the above introduced technologies, there is on one hand the interconnection between communication and operation technologies, and on the other hand their synergetic cooperation that are expected to enhance results (Osservatorio SM, 2015). Not only the integration of technologies increases the quality, efficiency and productivity, but the ability to collect, analyze and share smart data enables the creation of new business models (Stock & Seliger, 2016). Moreover, real time information allows the reduction of overstock situations, and the facilitation and optimizing of processes such as inventory and warehousing management (Zhou et al., 2015).

Given the expected benefits, adopting Industry 4.0 technologies is therefore considered a key driver for the competitive advantage of European manufacturing industries (Kelly, 2015). Accordingly, for supporting manufacturing companies in the adoption of Industry 4.0 technologies, several public policies have been developed by European countries. The term "Industry 4.0" was first introduced by the German Industry-Science Research Alliance (Forschungsunion) in 2011, representing a politically established target for the production industry. The Italian approach to Industry 4.0 is based on the national plan, known as the 'Piano Calenda', launched by the Italian Ministry of Economic Development in 2016. This public policy views technological innovation not only as a tool to increase the contribution of manufacturing to the national GDP, but also as a tool for combining greater productivity with the renowned skills of the artisan manufacturing (Vitali, 2016).

The changes brought about by Industry 4.0 technologies have not only a great influence for industrial production, but they also have relevant organizational implications (e.g., Brynjolfsson & McAfee, 2017). In this context, this paper aims to provide empirical evidence on how businesses that have implemented Industry 4.0 technologies have redesigned their organizations. Prior to our analysis, we briefly recap on the current literature (scant and mostly theoretical) that has been exploring Industry 4.0 technologies and organizational design.

1.2 Industry 4.0 technologies and organizational design: a summary of the debate

In the last thirty years, a vibrant debate has emerged on the evolution of organizational design, i.e., the extent to which current organizations are designed following Tayloristic or post-Tayloristic principles (e.g., Masino, 2005). The literature on Industry 4.0 technologies and organizational design seems to be connected to this debate, as scholars claim that these technologies can be used either to design organizations still informed by the Tayloristic principles, or otherwise to design organizations informed by totally different principles (Negrelli & Pacetti, 2018). Hence, the debate seems sharply polarized into two alternative directions.

The first direction views Industry 4.0 technologies as enablers of an organization design which follows the Tayloristic model, that we label here as employee control-oriented organizational design. In consistence with this view, organizations are designed not only to "extend" the control function performed by Industry 4.0 technologies over the processes, but also over employees. The design of organizations is thus aimed at maximizing the control function, and is therefore considered to be informed by Tayloristic principles (Fondazione Sabattini & Associazione Punto Rosso, 2018). Such organizations present three key features. First feature is related to decreased employee autonomy. The capacity of Industry 4.0 technologies to make decisions autonomously results in less employee autonomy, as more and more decisions would be taken by a company's technical staff in the form of control algorithms (Dworschak & Zaiser, 2014). Since the decision-making rights are not diffused, but centralized on the technology and/or on few central decision makers, employees are provided with less decision rights. Second feature relates to the high formalization of jobs. In order to exploit the new controlling opportunities offered by Industry 4.0 technologies, jobs are designed to be highly formalized. Human work is being divided into simple and repetitive tasks, with a focus on individuals rather than on teams. Indeed, the fragmentation of jobs into a set of small, predictable, fragmented and repetitive tasks, often regulated by precise rules and procedures that the individual employee has to follow, results in an organization configuration that technologies can keep under strict control (Bonomi, 2018). The third feature relates to the de-skilling implication that Industry 4.0 technologies would have on employees. Indeed, the over-controlled employee, who is not required to make any decision but to strictly follow rules and procedures while performing fragmented and individual-based tasks, is also not required to possess specific competencies, as the machines already possess the necessary knowledge for making effective decisions (Acemoglu, 2002). Several empirical studies have supported this first view; for example, according to the investigation of Bonomi (2018) in the banking and finance sector, employees perceive that the use of Industry 4.0 technologies reinforces procedures and formalization, leading to more fragmented jobs, making knowledge less important, while intensifying control.

The second direction of the debate sees Industry 4.0 technologies as enablers of an organizational design informed by post-Tayloristic principles, that we label here as the employee commitment-oriented organizational design. Several factors (market, regulatory issues, technology, etc.,) have been pushing companies for years into organizational structures informed by post-tayloristic principles, and Industry 4.0 is seen as a speeding up this process (Anand & Daft, 2017). Interestingly, this view is dominant among institutional and corporate narratives (Caruso, 2017) that see Industry 4.0 technologies as enablers of an organizational design based on more employee autonomy, less standardization and fragmentation of work, and more employee development. In line with this view the organization is designed aiming to achieve employee commitment, a strategy characterized by three key features. The first feature consists in greater employee autonomy (Venkatesh et al., 2010). When using knowledge provided by technologies workers find it easier to decide on how to perform their tasks and how to find the best ways of performing their tasks (Dewet & Jones, 2001). Emphasizing the role of technology as a tool in supporting employee autonomy, Gorecky et al. (2014) argue that workers are expected to assume more and more the role of decision makers and problem solvers. The second key feature relates to the fact that employees are typically requested to perform significant (so, less fragmented), team-based (so, characterized by social interaction), and less formalized jobs. According to Basaglia et al. (2010), the greater volume of information and knowledge exchange provided by Industry 4.0 technologies increases job interdependencies. Organization of work that is now done around teams, whereby individual formal jobs do not exist, fosters stronger motivation and is thus expected to increase employee commitment (Bayo-Moriones et al., 2015). Last feature relates to greater employee development, as with new technologies employees have the chance to develop their competencies. Indeed, with regard to technical skills, increased automation and networking of machines is expected to develop employee competencies, which are supposed to include more in-depth combined knowledge in order to respond rapidly or initiate action in case of malfunctions (Dworschak & Zaiser, 2014). Moreover, as Industry 4.0 technologies foster integration between supply chain and product-related services, employees are given the chance to develop knowledge of value chains and production processes, and to increase their relational competences (Dworschak & Zaiser, 2014).

1.3 Assessing current knowledge, and moving forward

The polarization between the two above-presented alternative directions presents a risk, i.e. assuming that the Industry 4.0 technologies have deterministic effects on organizational design. A consequence of this assumption is that organizational design is seen as nothing but an adaptation to technological constraints. Therefore, choices, agency, designers, or the complex political processes which typically inform organizational design are not fully recognized.

Refusing this deterministic perspective, we argue that the design of the organization always requires choices, as in face of the same technologies we can potentially experience different organizational designs. Multiple choices, or work organization "solutions," exist for each situation (Parker et al., 2017). Therefore, we reject any kind of technological determinism, and hold a socio technical approach, that suggests that organizations are composed of people interacting with each other and a technical system to produce product and services. Butera (2018) rightly emphasizes that in order to face the complexity of the design and development of the Fourth Industrial Revolution, it is important to align it with the challenging needs and opportunities of the technological, economic and social context (Butera, 2018:101). Moreover, the socio technical system theory suggests that productivity and stakeholder satisfaction could be maximized via joint optimization based on stakeholder participation in the early stages of the design process (Trist, 1981 cited by Morgeson & Humphrey 2008). Assuming a socio-technical perspective, we look at how companies have re-designed their organization on the variables which literature suggests as most likely to be revisited when technology-driven change occurs. The variables cover both micro (i.e., nature of work, job variety, teamwork, skills and competences, level of formalization, autonomy) and macro (i.e., number of organizational layers, role of role of middle management, coordination mechanisms and collaboration) aspects of organizational design. The choices made by organizations on those variables are expected to be radically different when employee control-oriented or employee commitment-oriented design is adopted. For example, employee control-oriented design leads to lower autonomy whereas the employee commitment-oriented design leads to more autonomy; or the employee control-oriented design leads to higher formalization whereas the employee commitment-oriented design leads to lower formalization. Therefore, our study explores to what extent the organizational design of the companies that have implemented Industry 4.0 technologies is informed by the employee control-oriented or the employee commitment-oriented organizational design. As already mentioned in the introduction section the nature of this study is explorative, aiming to explore patterns in the evolution of organizational design, and not to test or track their empirical diffusion.

2 METHODOLOGY

2.1 Method and Sampling

Considering the novelty of the subject, the present paper was developed through 15 case studies, which are considered sufficient to obtain satisfactory results (Eisenhardt, 1989). The data used in the study are secondary source data, obtained from the collection of 20 case studies (five of which were deemed unsuitable) carried out from the association 'Torino Nordovest' .

Companies were selected based on the extent and types of the Industry 4.0 technologies implemented. Literature has been used to formulate and stimulate some initial questions, as well as to suggest suitable areas for theoretical sampling (Strauss & Corbin, 1998). Table 1 presents a sample of the 15 companies selected and a summary of their main characteristics.

The research method is based on semi-structured interviews. In total fifty-four interviews were conducted, with the individuals that – in each organization – were involved in the implementation of Industry 4.0 technologies and related organizational design. Professional roles that participated in the interviews include such positions like, operators, technicians, engineers, unit heads, HR, administrative assistants, and top management. Table 1 presents, for each company, the number and roles of interviewees.

Each interview, each lasting anywhere between fifty minutes and an hour and twenty minutes, was recorded and transcribed in its entirety (integral). The empirical data was collected between September 2017 and June 2018.

2.2 Interview guide and organizational variables considered

In most interviews information was collected using an interview guide with an initial open question aimed at inviting the interviewee to freely share about his/her experience. Thus, the framework of the interviews was constructed along a problem-focused approach and simultaneously allowing the conduct of a personalized discussion (Mayring & Brunner, 2007).

The interview guide has been developed to provide information related to the following three areas: (i) company key features, strategy and history; (ii) technological innovations introduced, and reasons for their introduction; (iii) the way the organization has been re-designed.

In order to develop a model that integrates different organizational variables, the third area of the interview guide was built following two theoretical pillars. The first pillar is based on the sociotechnical systems approach (e.g., Parker et al. 2001). The second pillar is based on contributions that focus on technology-driven work redesign (e.g., Morgeson & Humphrey, 2006). Based on the above, we identified those organizational variables which are the most likely to be redesigned when new technologies are implemented; their list and definitions are as follows.

Nature of work is divided in two dimensions: physical and cognitive demands. Physical demands reflect the level of physical activity or effort required for the job (Morgeson & Humphrey, 2008). Cognitive demands reflect the person's general level of cognitive processes required for the job (Hunter & Hunter 1984).

Job Variety relates to the extent to which employees are required to execute a large variety of tasks on the job (Morgeson & Humphrey, 2006). Essentially, job variety reflects the concept of task enlargement (Lawler, 1969), such that being able to perform numerous tasks on the job is expected to make a job more interesting and enjoyable (Sims et al., 1976).

Teamwork. A team can be defined as two or more individuals who socially interact (face to face or, increasingly, virtually) possess one or more common goal and are brought together to perform organizationally relevant tasks. They are together "embedded in an encompassing organizational system, with boundaries and linkages to the broader system context and task environment" (Kozlowski & Ilgen, 2006:79)

Level of formalization relates to the very nature of job bureaucracy, such as written rules, procedures, and instructions used by organizations to facilitate coordination and control of work (Nemeth et al, 2006).

Skills and competences include the variety of skills and competences required to complete the work (Morgeson & Humphrey, 2006)

Autonomy refers to the extent of discretion that employees have in order to make work related decisions and decide on work methods and scheduling (Fried et al., 1999).

Number of organizational layers pertains to the hierarchical structure of an organization, where each hierarchical level describes the span of control for each manager. When the span of control is wide, hierarchy is shorter (Daft et al., 2017).

Role of middle management. Middle management is the intermediate management of a hierarchical organization that is subordinate to the executive management and is responsible for the creation of an effective working environment and can be more control or development oriented (Daft et al., 2017).

Collaboration. The broad definition of this variable reflects the mechanism through which group members can help each other to learn and enhance performance. It has often been noted that Industry 4.0 technologies have important implications for interpersonal relationships at work (Wall et al., 1990). In this context (in light of exposure to new technological instruments) this variable most specifically relates to the collaboration between line operators and technical staff.

Coordination mechanisms are mechanisms that imply the use of strategies and behavior patterns directed toward the integration and alignment of actions, knowledge and objectives of interdependent members with the aim of achieving common goals (Malone & Crowston, 1994). Due to the fact that Industry 4.0 technologies introduce a host of complex coordination and information sharing tools, this variable gains particular relevance.

Table 1 Sample of companies

Companies	*Sector*	*Size*	*Technologies implemented*	*Nr Inter views*	*Role of Interviewees*
1	Design/furniture	Large	Automation; Personalized CAD and IT interface	5	President, Managing Director, Supply Manager, Operators
2	Metalmechanic	Large	IoT; Sensors; Tailor made machines; AI; Robots	5	President, General Director, HR Manager, IT Manager, Plant Manager
3	Metalmechanic	Large	Smart factory; Collaborative robotics; Virtual reality, big data; Digital twin specialist; Exoskeleton; Collaborative robot; Smartwatch	5	Corporate HR vice- President, HR Training Manager, Public and Media Relations, Innovations Manager, Other
4	Technological	Large	IoT	3	CEO, CTO, Chief Product and Marketing Officer
5	Technological	Large	Automated machines; Management systems software updates	3	General Manager, Engineering Director, Head of Process Engineering
6	Food	Medium	IS; Barcode reader; E-commerce; Warehouse automation system	3	CEO, Head of Special Projects, Promotion and Communication Executive
7	Metalmechanic	Medium	Automatization of machines; Online camera control of mechanical parts assembly; Electronically made assembly cards; Interacting displays; Robots; Automation of the management system of production and industrial accounting; WhatsApp communication	12	President, Sales Manager, Head of Technical Office, Head of Quality, Operators (production, quality, etc.), Unit Head
8	Metalmechanic (medical field)	Large	3D technology; Software with semi-predefined solution pieces; Automated finishing systems; Collaborative robots; Real time production; Automated warehouse; Augmented reality; Virtual reality; Digitalization of the distribution network	7	VP Operations, Production Director, Product Development Engineer, VP HR, HR Education Specialist, Operator
9	Elctromechanic	Large	Automated warehouse; Real time production and maintenance; Robots; Additive manufacturing	3	HR, I 4.0 Responsible, Simplification and Industrialization Officer
10	Metalmechanic	Large	Computer Interface with the machine; machine built-in video cameras; Built-in sensors; Cloud; IoT; 3D printing; Additive manufacturing	3	HR Business Partner, Product Manager, Special Innovation Projects
11	Technological	Large	Cloud; Digital twin; Predictive maintenance; Smart working; Office 365	4	SOA, Chief Digital Officer, Location Head, Technical Secretary

12	Metalmechanic	Medium	On the machine built-in electronic system; On the machine built-in cameras; Automatic warehouse; Dedicated computer for each printer; Wi-Fi connection	4	Managing Director, Operators
13	Technological	Small	CAD; Barcoding; On the machine built-in tablets; 3D printer; Automated warehouse	3	General Director, Export Manager, Administration Director
14	Food	Medium	Digital reporting line; IoT; Automated machines; Barcoding; E-commerce	4	CEO, Production Head, Junior Marketing Specialist, Administrative Assistant
15	Logistics	Large	Automated machines; Different IT instruments; Geo-localizing software; Digitalization of production chain management systems; Exoskeleton	6	General Director, Innovation Manager, Assistant to Direction, Unit Heads

2.3 Data Analysis

Data analysis was carried out in three stages. During the first stage, the authors first independently selected the parts of the interviews transcriptions related to organizational changes following the implementation of the Industry 4.0 technologies; the selected parts were then compared by the researchers, aggregated and used for the creation of a common database.

During the second stage, the authors worked towards a theory-informed thematic coding framework by comparing and contrasting each other's interpretations and categories and discussing similarities and differences (Guest et al., 2012). These discussions led to the creation of a first coding template (King, 2004), which was subsequently tested by each author on the common database. During this stage, whenever problems and inconsistencies arose within the research team, they were resolved by basing the interpretation on the identification of 'exemplar quotations' (Guest et al., 2012).

The third stage included the analysis by organization of the way each of the considered organizational variables has been redesigned when Industry 4.0 technologies were implemented. During the third stage, for each organizational variable, similarities and/or differences present among organizations were analyzed. Consequently, the variables were categorized into common and uncommon design choices. The first category refers to those variables on which the studied organizations present the same design patterns, i.e., made similar choices when they implemented Industry 4.0 technology. Diversely, uncommon design choices refer to those organizational variables on which the studied organizations present different design patterns, i.e. made different choices when they implemented Industry 4.0 technology.

3 RESULTS AND ANALYSIS

Following we will present the results in two sections. In the first section we discuss common design findings. In the second section we analyse the outcomes for the uncommon design choices. In each section we report exemplary cases from the 15 studied organizations.

3.1 Common design choices findings

In this section, we describe key findings for common design choices. Data shows that all the companies, for which we have information, present the same design pattern (i.e., no company made alternate choices) on the following variables: nature of work, job variety, teamwork, number of organizational layers and collaboration.

Nature of work. On physical demands results show that work has become less labor intensive because machines substitute for heavy physical tasks, and by doing so they facilitate processes that before were extensively manual. On cognitive demands, it emerged a positive relationship between cognitive demands and implementation of Industry 4.0 technologies. Intensive use of digital instruments has added to the job complexity by emphasizing the need for more information processing and problem solving that underlie the cognitive ability component of this variable.

This topic relates directly to Company 1, a large company that operates in the design/furniture sector which through a high level of automation and digitalization (extensive use of personalized CAD and IT interface) has highly standardized its production processes. The below excerpts affirm how work in Company 1 has become not only less manual, but also more cognitive:

> *Says a supply manager: …Now the work is easier. The workers use the software to make the machine do the manual work that they used to do…'*
> *Says an operator: and so we can say that the operators reason more compared to before, before they used to do things automatically, they had to do so, instead in front of the machine now they have to reason, use their heads more…*

Job Variety. Our evidence shows that Industry 4.0 technologies are associated with higher job variety. In order to integrate with the new technological processes, profiles of the workers involved have become more multitasking as employees are required to perform a number of different tasks. Company 9 is a large electro-mechanic company that produces water pumps in the submersible, and drainage and surface ranges for agricultural and industrial use. This company has not only automated production processes, but also has recognised a pressing need in the industry for a cost-effective solution for real-time reporting of production and maintenance data, and for that reason they make high usage of collaborative robotics and additive manufacturing. Due to high digitalization and automation, the tasks of the operator have been broadened. As one operator simply puts:

> *…The old operator was the one who put the mold, prepared the tools for the machine, today in addition to those skills and tasks, which have not been lost, there are more tasks related to automation, monitoring, which previously were tasks of the specialists office...*

Collaboration. There is an increase of collaboration between line and technical staff across most organizations. The need to transform the technological innovations into factory processes has stimulated the creation of cross-functional teams that involve line workers and IT engineers, leading to a more collaborative environment. Company 2 is a large metal mechanic company that makes extensive use Industry 4.0 instruments such as: IoT, built-in sensors, tailor made machines, AI, and robots. In this company there is a general consensus on the fact that digitalization and internet of things have resulted in a higher degree of complexity in work processes, which coincides with a growing demand for technical skills. In order to fill this gap, an IT manager explains the importance of collaboration between staff and line workers:

> *...It happened to me, which is a very positive thing, to be part of these inter-functional teams between IT and line workers that fill technical gaps automatically…*

Teamwork. Advanced technologies seem to be associated with more teamwork. In order to transform technological innovation into plant processes, there is the need to have an interaction between organization and the technological process. Therefore, in most organizations, there is more emphasis on teamwork, through which the most expert worker(s) transfer their knowledge. In Company 15, that operates in the logistics sector, new technological instruments such as: automated machines, different IT instruments, geo-localizing software, digitalization of production chain management systems, and the exoskeleton, have generated the need for more teamwork, where most skilled worker is transferring knowledge. Says one unit head:

...We have more teams, made of for example 5 workers, and for each team we try to have an experienced key person as point of reference. They are not team leaders or formal team-leaders …

Number of Organizational Layers. Interestingly it was found that most organizations report less hierarchical layers. New advanced technologies have optimized processes and accordingly simplified not only the cycles of production, but also the organizational structure. In Company 2, a large metal mechanic company that produces pumps, pistons and designs hydraulic system components, the advanced technologies like IoT, built-in sensors, tailor made machines, AI and collaborative robots have been related to the optimization and simplification of the cycles of production that before were complicated by regulatory systems. There is also better integration with the supply chain, the warehouse, etc. This crucial (integrative) aspect of smart factory went together with the simplification of the structure of organization. It has become leaner, flatter. In the words of the IT manager:

…we are quite innovative not only in production aspects, lean production, Industry 4.0, and IT aspects. This project is part of lean if you want, lean production that brings with itself a flatter organizational structure...

Taken together, above findings indicate that Industry 4.0 technologies are associated with an increase in cognitive work, decrease in physical demands, more job variety, more collaboration and teamwork, and less hierarchical layers.

3.2 Uncommon design choices findings

The variables that belong to the uncommon design choices are: employee autonomy, coordination mechanisms, role of middle management, level of formalization, and skills and competences. Following we present in details the results obtained.

Autonomy. Findings show that in some companies 4.0 technologies may help increase managerial control over workers and might reduce employee job autonomy. The property of control seems to be located either in the machine or is more centralized on the managers. For instance, Company 7, is a medium metal mechanic company that has implemented technological tools like automation of machines, online camera control of mechanical parts assembly, electronically made assembly cards, interacting displays and collaborative robots. The new machines can be electronically set up from the central technical office. Findings highlight the capacity of Industry 4.0 technologies to control the resulting productivity of the employee. Respondents placed more emphasis on the increased possibility of control on the individual behavior and performance, while there is no change at the level of workers' discretion (e.g., pace, method). Here is how the sales manager describes the effects of automation on controlling performance:

> *…For us automation is already incorporating all the data... Also, in the program HIPER there is an interaction between machine and man, in the sense that there is a continuous transmission of all the performed processes, so through the exchange of data we get every result in all its phases…*

In other companies advanced technologies emerged as associated with more employee autonomy, by, for example, providing the possibility to schedule tasks in the way that best suits the employee. For instance, in Company 11 advanced technology (like predictive maintenance) has enriched the traditional offer of services and made possible the "servitization of services". In such a dynamic and unpredictable operating context, the management model is placing more importance in the greater participation of workers, emphasizing greater discretion so that employees have to coordinate their actions and find the best ways of perform their tasks. The adoption of technological instruments has provided for greater responsibility and more autonomy to the employees. The story told by the SOA shows how the organization in order to meet its objectives is basing its philosophy in giving more trust and favouring the autonomy of its employees:

> *...The more fluid way of working implies, on the one hand, the acquiescence of a sense of responsibility from all employees which must be further reinforced, with new tools….from the managers perspective this is deprivation from some privileges and some tranquility that hierarchical control normally entitles, which now must be transformed into a capacity of government much more based on objectives and results, giving autonomy and trust to people...*

Coordination mechanisms. In some companies an increase in coordination mechanisms was found. The digital technologies of communication (like for example the intranet) facilitate the exchange of information and by doing so they improve collaboration, exchange of ideas and coordination of work, by simply creating new forms of interaction/coordination. In Company 4, a large technological company, that produces Industrial computers, and embedded software systems (IoT), the digital technologies of communication (like the intranet) have reduced the costs of processing and transmission of information which in turn facilitates the exchange of information. This fosters the creation of new forms of interaction/coordination. The chief information officer of this company describes the importance of intranet as a communication tool:

> *…As chief information officer I manage all the information systems, therefore all the support tools, also of communication, of internal company sharing information, i.e. the so-called intranet. The intranet is crucial for us as we have to extract the information from the mail of employees and put it in the repository and that everyone shares, the information must be live repositories.*

In other companies, technology has provided the tools to increase human interaction/collaboration (more meetings, etc.). For instance, Company 3 is a large metal mechanic company that is specialized in automation, in producing robots for welding, and designing technology solutions that enable digital manufacturing. The company places value on quickly adapting to market demands that in turn translates into the need for a flexible operating model. To achieve this production philosophy, the company has valuated that a flat organizational structure is paramount, a structure that places importance on horizontal networks, where human collaboration dominates. Industry 4.0 technologies implemented such as Intranet make more information available to frontline workers and offer workers more flexibility (they can now send their suggestions at any time), and by doing so, the technologies favor more human interaction. The narration of the following episode gives the innovation manager the opportunity to reaffirm the above:

…and then also at the level of internal coordination, at a higher level, surely there are many initiatives, as already said, the periodic coordination of the various centers of excellence and innovation, the monitors that are distributed throughout the company, where the initiatives are presented so that everyone is aware of what the initiatives are and what are the possible problems and who are the people to turn to. And that brings more human communication and interaction, which is fundamental in this context...

Role of middle management. The relationship between technology and the role of middle management seems to vary. In some organizations this role seems to be emphasized in a traditional way (i.e., more control and execution powers). Company 6, a medium range family-owned company is operating in the food sector. They have implemented Industry 4.0 instruments like IS, barcode reader, e-commerce, warehouse automation system, etc., and have realized that they need a better organizational structure to manage the company through the recent technological changes. To realize this, they have decided to emphasize the controlling role of middle management, by increasing hierarchical layers. In this regard the following image is introduced by the CEO of the company:

...The receivables have doubled, the growth of the personnel has made the restructuring of the company unavoidable, we have inserted an HR function, the intermediate levels and the organization has a more hierarchical structure…

In other companies results show that middle management seems to be drained of its powers because more elements of the managing process are executed by the machinery. For example, Company 7, a medium company operating in the metal mechanic sector, apart from advanced automation, has implemented technological innovations like online camera control of mechanical parts assembly, electronically made assembly cards, interacting displays, collaborative robots, etc. The whole technological developments turn out to provide remote assistance to the process of control and supervision that deplete middle management of its role. In such a case the quality manager says:

> *…From here we see the progress of all the machines, we see the causes of downtime from anyone of the PCs in the company I can see them. What the operator sees at the machine's monitor, we see it here too. We don't have to move. Here, for example, I see number of theoretical daily pieces, downtime, I see the causes, the next work steps, the times ... This program is linked to the quality control islands that are found in some production locations, close to some machines, that did not exist before. For me, all the programs that continue to be developed in this sector will be such that in this position man will be increasingly substituted by the machines...*

On the other side, findings show that some organizations point to the key role of middle management, as a more supporting, and guiding role. For example, company 8 is a large metal mechanic company which strengths lay in the innovation, quality, and the development of new products. To achieve growth goals, they have reshaped their technological structure by adopting Industry 4.0 technological tools such as additive manufacturing that has provided new customized solutions. Adopting Industry 4.0 technologies has also demanded an organizational and cultural approach that emphasizes an agile/proactive management model, so that decision-making authority is delegated to employees and managers are required to support those in making the right choices. Empowering the developmental role of middle management is one of the frontiers of their organizational redesign, as explained from VP of HR in the following extract:

> *...We have also worked on managerial skills in order to strengthen middle management by building a sort of toolbox of the boss, on the development of employees, motivation and conflict management, communication...*

Level of formalization. Results show a higher level of formalization for some organizations. Through advanced automation several companies have standardized many processes which have resulted in higher levels of formalization of work. For example, in Company 1, the passage from the crafting model to the digital model of production is reflected in the passage from the informal knowledge of the production line to the formalized knowledge. Through automation, personalized CAD and IT interface the company has standardized many processes and formalized work:

> *...While before we had an infinite quantity of flows, we have now managed to contain them, therefore there is more order in production; we know how to solve problems or how to approach production. The way how to work, is more defined than before, before there were several ways to get to the goal, while today everything is more standardized not so much the solution as the work process...*

At the same time findings indicate that in other organizations the level of formalization is lower, albeit the advanced technology. In Company 11, which strength lays in offering services with extremely distinctive skills, the advanced technology (like predictive maintenance) has enriched the traditional offer of services. This organization, which activities are diversified and not standard pushes toward a more personalized way of working. Says chief digital officer:

> *...The goal is to have a management able to predict even one week's work on activities that are not always standard and are in fact very diversified, it is much more about the soft aspects than on the quantitative ones. So, if at the end of the pilot phase, for example, we will also find an univocal way to give an extra tool to our middle management to work, we give it if they ask for it, if there is a need, it is not a standardization of the work…. On the contrary, we work more and more towards the personalization of work…*

Skills and Competences. For some organizations, interviewees highlighted a deskilling effect of the adoption of Industry 4.0 technologies. One explanation is that through high scale automation, for particular tasks automation has acquired full control of production which is achieved through machines that do not need to be manned. In Company 1, for example, due to high level of automation, machines work in a continuous cycle and independently. This process has resulted in deskilling. While discussing such phenomenon, an operator gives the following explanation:

> *...there is an increase in the technical skills, but looking at the factory side the skills decrease. The panel comes out already finished, ready and in the label there*

is written where they should bring it. The technician at the end does not even worry about what panel is going through. While before he used to take care of the panel and of the machine...

Evidence shows that in other organizations, Industry 4.0 technologies have been described as associated with the acquirement of new skills among employees. For instance, company 8, is a large metal mechanic company that has implemented many Industry 4.0 elements such as: 3D technology, software with semi-predefined solution pieces, automated finishing systems, collaborative robots, real time production, automated warehouse, augmented reality, virtual reality, and digitalization of the distribution network. The demand for integration with the new processes has transformed the profiles of all the figures involved, in particular it has been related to the enhancement of technical skills. The greater uncertainty produced by digital technologies, asked for more transversal skills in order to handle unpredictable job situations. This together with an open organizational vision that places importance on relationships has resulted in a shared perception of an increase need for more transversal set of skills. A relevant illustration is presented by the production director:

...I have had for two years, during the implementation of digital technologies, the goal of encouraging polyvalence and poly-competence; we have done many projects, now we can say that it is an acquired lifestyle. Even if it is not so trivial to move between tasks, this is made possible through a well done method that supports people in developing with new skills...

4 OVERALL INTERPRETATION AND DISUCSSION

The present work aimed to provide an analytical description of how organizations that implemented Industry 4.0 technologies have been redesigned. We focused our gaze on a wide set of organizational variables, trying to provide evidence to common and uncommon patterns.

Results presented in common design choices show that work has become more cognitive, less manual, and more various. Results also indicate that technology promotes more teamwork and collaboration, while some organizations opt for a simplified or flatter organizational structure (see Table 2). As such, these results imply that organizations that have implemented Industry 4.0 technologies are redesigned in continuity with post-Tayloristic principles, and in line with key features of lean organization. This leads us to the preliminary conclusion that the design choices made by all organizations are not enough to call for an organizational revolution, but instead the "organization 4.0" is facing an evolutionary phase of the post-Tayloristic organization. This finding reinforces the first objection to the techno-centric view, which employs a deterministic approach and submits to the technological imperative, as it calls into question the "disruptive" effect of current technological transformations (Salento, 2018:8).

Table 2 Common design findings

Variables		*Results/Choices*	*Companies*
Nature of work	*Cognitive demands*	More cognitive	1,2,3,5,6,7,8,9,10,11,12,13,14

	Physical demands	Less manual	1,3,5,6,7,8, 13,14,15
Job variety		More Variety	5,7,8,9
Collaboration (Line plus technical staff)		More Collaboration	1,2,3,4,8,10,11,15
Teamwork (among peers)		More teamwork	1,2,3,4,8,10,11,15
Nr of organizational layers		Flatter organization (less layers)	2,3,7,8,11

*All the companies, for which we have information on the choices made on the above-reported variables present the same patterns (i.e., no company made opposite choices);
**Companies not mentioned either do not present any change, or did not explicitly disclose data

On the other side, results presented in the uncommon trends category provide evidence that in some companies the implementation of Industry 4.0 technologies is associated with higher levels of control, higher levels of formalization of work, a de-skilling effect, and a depleted role of middle management. By contrast, in other companies, Industry 4.0 technologies are associated with the development of more technical and transversal skills, enhancement of employee autonomy, and a more engaged and supportive middle management. Taken together, these results seem to support the idea that Industry 4.0 allows for very diverse organizational designs. On one hand technologies seem to enable the above-mentioned employee control-oriented organizational design that refers to organizations which, in order to exploit the controlling opportunities that Industry 4.0 technologies present, show a higher level of formalization, less employee autonomy, deskilling, and a middle management drained of its role (see Table 3). On the other hand, they seem to enable the above-mentioned employee commitment-oriented organizational design, that refers to organizations which, in order to exploit the empowering opportunities that Industry 4.0 technologies present, show lower levels of formalization, more employee autonomy, more skills and competences, and an empowered role of middle management (see Table 3). The two organizational designs are mutually exclusive, as companies opted for choices that fall either in one or in the other (see Table 3).

Some of the findings appear to be contradictory; however, when looking at them closely, that is not the case. First, reporting that work has become more cognitive, but skills and competences have in some cases reduced seems to be contradictory, but with the new technologies nature of work has become not only more cognitive, but also less manual. In some cases, the lost manual skills are greater than the acquired cognitive skills which results in deskilling. Another apparent contradiction seems to be the finding that refers to the fact that as organizations become flatter, some companies report an empowered middle management. Although current research shows that flatter organizations are characterized by a lessened control-oriented supervision (i.e., supervisory management can control a larger number of employees, who in turn enjoy more autonomy), we realize that technologies can also be an effective tool in increasing control/supervision. In turn employees enjoy less autonomy, more control, albeit a flatter organizational structure.

Table 3 Uncommon design findings

Variables	*Results/Choices*	*Control oriented companies*	*Results/Choices*	*Commitment oriented companies*
Autonomy	Less autonomy Control as property of the machine. or still of the manager	6,7	More autonomy Control as property of the employee or of the team	3, 8, 11
Coordination mechanisms	Technology provides more data, used by the manager for more coordination Technology directly coordinates employees.	1, 2, 4, 6, 9	Technology provides more data used by employees and teams for better coordination	3, 8, 11

	A common result is: less need for human communication		Technology creates the need for more human communication (more meetings, etc)	
Role of middle management	Role of middle management emphasized (in a traditional way) Middle management drained of its role (more elements of the process are executed by the machinery)	2, 3, 6, 7, 9	Middle management has stake in the decision making of the company. a more supporting, and guiding role	8, 11
Level of formalization	Higher	1, 2, 4, 6, 9, 12, 13, 14, 15	Lower	8, 11
Skills and Competencies	Deskilling Acquirement of only technical skills	1, 2, 4, 6, 9, 12, 14, 15	More technical plus transversal skills	8, 11

*Companies seem to opt for choices that fall either in one or in the other outcome category.
**For e.g. company 6 makes choices that fall in one category, and all choices made by company 8 falls in one outcome category

5 IMPLICATIONS

Peter Berger (1974) has pointed out that technology is often presented in mythological forms, and this happens above all in times of crisis (Salento, 2018). However, in most situations, technology is not neutral: it benefits some factors of production, while directly or indirectly reducing the compensation of others (Acemoglu, 2007). Our findings present interesting theoretical and practical implications in this perspective.

5.1 Theoretical Implications

We consider that the results of our study are in line with the socio-technical perspective adopted in this paper which recognizes that technologies in themselves create possibilities and potential, but ultimately the future of organizations will depend on the choices they make. Therefore, the current theoretical debate about the two perspectives (i.e., Industry 4.0 technologies as enablers of control-oriented vs commitment-oriented organizational designs) seems to be oversimplified, since it is not taking into consideration the agency of the organization. Our results indeed confirm the existence of different organizational designs, as in some cases these technologies enable an organizational design aimed at developing employee commitment, and in other cases they enable an organizational design aimed at increasing control over employees.

5.2 Practical Implications

The main implication concerns the fact that organizational actors should show caution (i.e., the "de-mythologized" view) when implementing Industry 4.0 technologies Indeed, assuming that technology is neutral and that it will automatically generate positive outcomes for all actors involved poses risks. Therefore, efforts should be made to rather co-design a socio-technical system, while involving all interested stakeholders in order to prevent possible downsides.

In addition, our results yield implications for policy makers, in that supporting financially the implementation of Industry 4.0 technologies might mean supporting organizations in becoming more employee control oriented. In other words, if public policies should positively affect the economic performance of manufacturing companies (at shareholders' benefit), that might be achieved at employee's expense. Thus, public policy makers should take into consideration not only the implementation of Industry 4.0 technologies, but also the way these technologies will be incorporated in the organizational design. Strong modifications of the public policy in this direction would have an educational effect on organizations, as those would push managers to anticipate the organizational design (avoiding a techno-centric approach) and to involve stakeholders in its early stages.

6 LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

This paper presents some limitations. First, this study adopted a sampling strategy centered to a single variable (i.e. Industry 4.0 technologies implemented), and future studies could make our findings more generalizable by employing different sampling strategies. Second, the data have been based on interviews, so more observation is needed in order to be more conclusive. In addition, future research should consider differences in structural features of the organization (e.g., size, industry, specific technologies adopted) which might affect organizational design. Another limitation has to do with the theoretical perspective that we employ in this paper, i.e. the socio-technical perspective. The literature focused on how work comes to terms with the new technology is versatile and entails different theoretical perspectives. For example, some explicitly 'worker- centric' studies like Edward's 'Contested Terrain' emphasize how, in face of the tension between worker's and manager's interests, various technical relations of production generate particular forms of labor organization or help to maintain existing organizational forms. Thus, we are aware of the value of different perspectives as useful lenses for illuminating the rich texture of actual organizations. Hence it becomes important to further investigate the phenomenon employing other relevant concepts. Last, particular attention should also be placed on the matter of how the emerging design choices are individually and collectively interpreted by employees and other relevant actors (e.g. unions). Moreover, it could be interesting to explore the effects of design choices, and their interpretations on work intensification, different dimensions of employee well-being, employee and organizational performance.

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Chapter II.

JOINT ORGANISATIONAL DESIGN 4.0: THE SOCIO TECHNICAL PRINCIPLES REVISITED[11]

'A man who is made a prince by favor of the people must work to retain their friendship; and this is easy for him because the people ask only not to be oppressed. But a man who has become prince against the will of the people and by the favor of the nobles should, before anything else, try to win the people over'

By Machiavelli in Giddens 'The Structuration Theory'

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A preliminary version of the findings of this study has been presented to the WOA Conference, WOA 2020, held in Milan 6th-7th February 2020 with the theme 'Will employees dream of electric sheep? Impacts of digital technologies within and beyond the workplace'

Selected findings have been presented also at the workshop organized at the Politecnico of Milan University, November the 25th, 2019. Members of the surveyed organizations have taken place.

A preliminary version of findings has been presented and published at the STPIS, 6th international Workshop on the socio-technical perspective in IS development, June 2020
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Joint organization design 4.0: socio technical principles revisited

ABSTRACT

The analysis of three companies that have jointly considered the technical and the social systems while designing and implementing the new digital technologies shows how and to what extent the Socio-Technical Systems (STS) principles are nowadays adopted, thereby indicating the possibility that the STS theory can (re) become central in both theory and managerial practices. Thereby we propose an 'actualized' sociotechnical design approach, capable in aligning an organization to the rapid and radical change that come along with the digitalization and indicate that the application of STS-informed design methods, such as Agile and Design Thinking, oriented more to action and intervention, mirroring the actual act of designing in a dynamic way, but also offer organizations the opportunity to embrace a broader stakeholder base.

Keywords

4.0 technologies, Socio-Technical System Theory and Principles, Joint Design, Participation, Agile Design

INTRODUCTION

The digital revolution (aka Industry 4.0), driven by the fusion of novel technologies such as sensors, smart robots and machines and the huge computational power of advanced analytics, is reshaping the competitive landscape (Autor and Salomons, 2018) by bridging boundaries of time, distance, and function (Merali et al. 2012; Yoo et al. 2010; Zammuto et al. 2007). As an organization becomes increasingly interconnected by a common digital infrastructure (Tilson et al., 2010) the pervasive embeddedness of digital technologies in the very core of products, services and operations is changing the organizing logics of the firm (Raj and Seamans, 2019; Kirkman and Mathieu, 2005).

Current literature has paid a lot of attention to the instrumental role that digital technology is playing in shaping organizations. Authors, such as Brynjolfsson and McAlfee (2014) and Autor and Salomons (2018) argue that we might face the costs of automation, measured by higher unemployment (Pajarinen and Rouvinen, 2014; Autor and Salomons, 2018) and rising inequality. Other critics have shown anxiety regarding its potential for labor substitution (Mokyr et al. 2015; Acemoglu and Restrepo, 2018; Dauth et al. 2017), as more radical ones point to the creation of the 'digital Taylorism' (Schumpeter, 2015; Moore and Robinson, 2016). By contrast, perspectives linked to the work of Mandel (2017), Spencer (2018), Huws (2014), Neufeind et al. (2018), etc., see digital technologies as yielding more liberating options for the meaning of work (Bessen et al., 2018; Dauth et al. 2017), unlocking superior performance (Choudhury et al., 2018), or enabling more collaborative forms of work (Gratton, 2014; Graetz and Michaels, 2018).

In viewing technology as a deterministic, exogenous force on organizational properties (Howcroft and Taylor, 2014; Thompson and Briken, 2017), above perspectives furnish an incomplete account of technology and its interaction with organizations. To that end, there is an urgent need for organizational theories and system design methods that will allow us to 'disobey' such technological imperative (Austrom and Ordowich, 2018) and see organizations from a holographic perspective.

Moving away from technological determinism, the socio technical theory (Trist et al., 1963; Trist, 1981) has developed specific guidelines that pay close attention to both, the social and the technical system, and provide direction to the system designer. After an initial diffusion, such guidelines have failed to proliferate in both research and managerial practices. However, the capacity of digital technologies to facilitate the coordination and cooperation (Hirsch-Kreinsen, 2016; Kusiak, 2018; Kirkman and Mathieu, 2005) between the technical and the social systems offers nowadays a remarkable opportunity to see organizations with distinctive socio-technical lens. In such a context, the objective of this study is to contemplate on the possibility that in face of digitalization, an 'actualized' STS theory and its design principles can become (again) central to the design of contemporary organizations.

Holding such an objective, we begin this research by addressing the main contributions of the STS theory to the organizational design process and explain why this theory and its design principles may be particularly well-suited to address organization design issues as they implement digital technologies. After a critical review of available knowledge on organization design, we introduce our main objective. Thereafter, the contents that characterize the organization design process, actors involved, and the design and deployment methodologies used in the observed organizations are described. Lastly, conclusions of this work are unfolded, and we identify implications for an 'actualized' socio-technical organizational design. We also describe novel design methods as a reflection of the actual act of designing in a dynamic way.

1 THEORETICAL REVIEW AND RESEARCH QUESTION

1.1 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 Davis, 1988). The preliminary studies towards this theory began over a period, very different from the present, which followed the nationalization of the British coal industry. A series of field experiments and case studies showed 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, i.e considering the "task" as the basic organizational unit, dividing the production process into a sequence of individual tasks and designing work characterized by low variety of tasks, low autonomy, and limited team work - was not suitable to the characteristics of work in the mines (Trist et al., 1963; Trist, 1981; Trist et al., 1993). 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 the increase of both productivity and quality of work.

Based on these experiences, the socio-technical systems theorists state 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 (Chern, 1987).

Starting from this assumption, the STS researchers have proposed three main highly interrelated 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.

Regarding the first principle, field of action, STS suggests that it should be envisioned in such a way that it ought to be inclusive of both the technical and social factors. The scope, thus, extends to take into account, in the design process, of all the various elements that make up the primary work system, i.e. basic activities/tasks, related to technologies (tasks related to the technical aspects, typically taken into consideration by the Scientific Management), as well as the interdependent relationships between the various activities and the resulting need for coordination and integration among the operators (related to social aspects, often ignored by the Scientific Management). The second set of principles proposed by scholars pertains to stakeholder participation in the design process. Socio technical scholars suggest that any organizational redesign intervention should be based on a broad and anticipated involvement of a broad set of actors, starting from the technology users. In fact, the Tavistock researchers believed that technology users, directly impacted by technology (i.e., the operators and their direct supervisors) possess full knowledge (explicit and implicit) of the working context. They believe as well that exploring their local knowledge through the application of various methodologies, such as in-depth interviews, is not sufficient, since it does not capture the tacit knowledge (that is, implicit knowledge that is neither documented nor formalized, therefore un-transmissible).

Finally, the third principle suggests that the design process should adopt methodologies capable of generating continuous experimentation and proper tools for fostering dialogue and confrontation, in order to encourage shared acceptance of the different aspects of the problem, enhance the experience and contribution of those directly involved, and to find a satisfactory solution (a continuously improving and therefore a continuously "experimental" solution).

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. In Italy this was exemplified by projects such as those of the Olivetti assembly islands, the design of Dalmine's New Medium Train, Honeywell's Research & Development laboratories -Bull and many others, and international conventions such as the 1988 international conference of the Istituto IRSO on Joint Design of Technology, Organization and People Growth in Venice. The situation changed in the 90s for a wide variety of reasons extensively addressed in recent contributions (among all, Butera, 2020, chapters 2 and 3). As a matter of fact, during the 1990s, as world economic, business, and technological arenas witnessed dramatic changes, STS interventions became widely regarded as too complex, difficult or politically dangerous to pursue, when other methods (such as, lean production method, or Business Process Reengineering) appeared to be simpler and less risky (Winter et al., 2014). The philosophy that underpins these methods ostensibly runs counter to many of the humanistic ideas behind STS design (e.g., Niepce and Molleman, 1998). Additionally, many STS design approaches had failed to take account of the work in HCI (Human Computer Interaction) and hence had little to say about interaction design in organizations (Alter, 2015).

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 (Parker and Grote, 2019). To that end, as organizations of the 21st century are facing an increasingly unpredictable and even chaotic world, socio technical theory and design should be able to prove to be flexible enough to incorporate a continuous process of learning, constant redesign and incorporate concerns about human development. Pasmore et al. (2018), for example, argue that the socio-technical 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' (Kumar and Whitney, 2003).

1.2 Designing an organization that adopts 4.0 technologies: what do we know yet?

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 (Hirsch-Kreinsen, 2016). Through these key features 4.0 technologies enable a flexible and intelligent production system that adapts in real time to the changing conditions (Kusiak, 2018). 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 (eg Davis et al., 2012; Cagliano et al., 2019).

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 (Bailey et al., 2019). 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 (Brynjolfsson and McAfee, 2014).

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 (Frey and Osborne, 2017). Both scenarios have been elaborated in most cases in a theoretical way, providing no effective empirical evidence and insights.

1.3 Critical review of available knowledge and research questions

Available literature on digital technologies and organizational design shows two main limitations (Howcroft and Taylor, 2014, Parker et al., 2017). 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 (Howcroft and Taylor, 2014) and (ii) the strategic and organizational factors that impact the organizational choice, among them the process design actors.

Trist and Bamforth (e.g., in Trist et al., 1963), highlighting the problems of this determinism, showed that the mechanization of work relations often had adverse human, social and organizational consequences and that any particular technology could usually be used within the context of a variety of organizational forms. STS theorists have in fact demonstrated (Morgan, 1989) that in adopting and developing the implications of the technology, we do face a choice between approaches that reflect the traditional bureaucratic values, or more democratic, holographic values, where productivity and quality are not opposite ends of a continuum but are on two different scales; enhancing one does not necessarily diminish the other.

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.

2 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. In Mechanic, interviews were held with the VP Human Resources & Organization South Europe, HR manager, Head of HR of subsidiary plant, Head of industrialization of processes, Head of digital innovations, and Head of Maintenance; in Pharma, interviewees included the Project Leader, HR Manager, Talent and Change Manager, Head of Packaging Department, Head of Quality/Control (scheduling/planning), and Head of Production; and in Energy, interviews were held with Head of HR business Unit Asset Italia and Head of operation and maintenance optimization.

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 (Dubois and Gadde, 2002), 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.

Table 1 Company characteristics

	Mechanic	**Pharma**	**Energy**
Industry/sector	Metalmechanic	Healthcare and Agriculture	Infrastructure and services of the natural gas industry
Sector	Mobility Solutions, Industrial Technology, Consumer Goods and Energy and Building Technology.	Health, Agrochemistry and Innovative Materials	
Product/services	Mobility solutions, home appliances, software solutions, etc	Pharmaceuticals, Crop Science, Animal Health	Transportation and dispatching, storage and regasification of natural gas.
Headquarter location	Gerlingen, Germany	Leverkussen, Germany	Milan, Italy
Headcount	410000	116998	3016
Headcount in the studied plant/branch	400	280	1900

3 FINDINGS

3.1 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

3.2 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.

3.2.1 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.

For example, in Company C organizational issues are anticipated in the very early stages of the design process. Indeed, during the definition of the vision phase, there were guidelines developed based on the integration of the technological dimension to that of the process and the organizational one. Alongside the indications related to the integrated management of the asset lifecycle, the definition of a single company-level database for each asset, maintenance engineering, field operations of maintenance activities, through the guidelines the company immediately(anticipates) identified and outlined the topic of changing organizational roles, required by the 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).

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. Several operative practices are implemented by companies for operationalizing this key concept; a typical practice- strongly connected to the theme of broad stakeholder participation, which will be discussed later- is to create multi-disciplinary project teams, i.e., project teams characterized by members with a wide set of competencies and backgrounds.

The multidisciplinary teams have been established according to the following criteria (i) hierarchy-related criteria, (including in the team-s composition different actors at various levels in the organization), (ii) competence-related criteria (inserting in the team of actors who, beyond the hierarchical level on which they place their role, possess subject matter knowledge and experience considered important in the design process); (iii) personality-related criteria, members that possess social or personal characteristics which are considered important in the design process (e.g., including in the team new employees with base knowledge of digital technologies or those with limited tenure); (iv) impacted organization unit affiliation-criteria (inclusion of actors working in the organization unit most impacted by technologies, as they possess tacit knowledge, related to work processes and its corresponding social dimension).

From this perspective, the pre-existing innovation project, within which Mechanic introduced the Digital one, leveraging on a stable multidisciplinary team (composed of first level staff and line managers of all organizational units), aimed at sharing innovation objectives of different departments, measure their progress, and explore discrepancies. With the introduction of the Digital project, temporary multidisciplinary teams, whose goal was the local implementation of the new techno-organizational solutions, have been established. The teams were composed of different subject matter experts, among which technology users.

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.

In Energy, 11 teams have been established to respectively cover: integration of asset management and work methods (5 teams), facility maintenance (4 teams), roles, skills and training issues (2 teams). Each team is comprised of 6-7 participants, for a total of about 100 people, including managers, technicians, team leaders, and experienced or/and very young operators. The activity of each team is coordinated by a facilitator/team leader, not necessarily a subject matter expert, but rather acting as an integrator of different perspectives. In order to identify a solution 'with users' the technology team was involved from the beginning as a -listen- only participant.

3.2.2 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 extended vertically, 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.

The project's management team was acutely aware that in order to maximize the probability that innovations would end up being used by the end users continuously, they needed to take onboard the input of the end users of such technologies. In Pharma, in fact, in the production department, during the process of design and implementation of the augmented reality glasses, operators are involved to give their input during the 'usability testing' phase.

Finally, it is interesting to note that a key aspect of the project teams' task was to clearly define the end user of each technological innovation in order to activate target-appropriate participation tools. Engaging the end user does not necessarily mean involving the first-level operators, since some use cases do not expect those actors to be the end users of the solution; in many cases the solution was designed as a new tool to offer to the shift leader (i.e., the top-level supervisor), who was then involved in the design as an end user.

The participation of a wide set of actors can be assessed on a continuum which goes from a purely informative role (i.e., participants "just" provide information on the problems/opportunities which can be addressed through I 4.0 technologies), to participative decision-making role (i.e., participants choose between alternative options already predefined), up to a creative role (i.e. participants become designers and are asked to generate possible solutions as key members of the design team).

Studied companies implement all three degrees of participation, depending on the specific phase and/or 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. In Energy, the members of the 11 teams, dedicated to defining the new model, have been creatively participating during the phase of problem identification, as well as during the solution definition. For example, field operators have been directly involved to, select their working tools, such as tablets, among the preselected alternatives, a decision that impacts their work habits and daily routines.

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, based on 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 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. The monitoring of contractual clauses has been entrusted to a Joint Technical Commission, which addresses, among other things, issues such as privacy regulations and use of employee work-related information. The Joint Commission contributed to the definition of a training and development plan, which impacted approximately 550 employees based on the mapping of the necessary skills. This plan was considered to be a key change management intervention for supporting employees in recognizing opportunities for further professional development and has been made available to all stakeholders involved.

In all three cases, in fact, the participatory model (which often did not involve all those impacted by the change) has been broad. This model leverages on the formal organizational documents (e.g. organization charts or procedures), extensive internal communication efforts, and extensive training for operators. For example, to communicate the ongoing changes to all its employees, Pharma has on several occasions put the production process to a halt (the company works over a 24 hour production cycle). Moreover, more in-depth communication tools, such as personalized meetings with individual operators, to review the new techno-organizational model and the participatory process, have been used to reach a shared understanding.

3.2.3 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 (for example, the goal definition phase ends when a certain outcome has been achieved; the same should be true for the definition of specifications phase and the feasibility one, etc.), the phases are not sequentially connected (for example, the feasibility phase starts after, and only after, the definition of specifications phase, which in turn starts after and only after the goal definition phase), the project is not tied to a specific team that is 'dismantled' at end of each phase (for example, the team that works on the goal definition phase is 'dismantled' at the end of the phase, at which point the project is continued by the team that works on the specification definition phase, and so on). 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 (phase A precedes B, that is, phase A produces an output that is used as an input in phase B), but instead through mutual interdependencies (phase A and phase B produce outputs which in turn are used from both as necessary input, therefore team activities proceed in iterative cycles) 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.

In Energy, for example, this systemic approach is leveraged through the initiation of different project teams (operating in different domains), simultaneously active and constantly in contact with each other; for example, for each use case, the project steering committee (which strategic goals include the definition of project objectives and overview of work progress) interacts in a structured way with the teams responsible for the development of solution (related to issues pertaining to the technological domain), and the teams operating on the micro-design of the organizational solutions (related to issues of social domain) in order to ensure that local organizational choices have been aligned to the organization's vision.

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 (that is, the team in charge of phase A works, to then "leave room" for the team in charge of phase B) predicting constant temporal overlapping (the team in charge of phase A works while the team in charge of phase B works). 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.

All three companies have outlined a design process with a logical conclusion at quick user testing to preliminary solutions, to test their goodness of fit and introduce necessary modifications accordingly. To that end, a broad set of actors were involved in prototyping the solution, to visualize their ideas to life test the solutions, and give their feedback. This approach has been widely used for example in Pharma where, according to the project leader, the company has always preferred a solution-based approach, such as usability testing of "quick and dirty" solutions with operators, rather than planning in advance.

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. For example, in Energy the 11 teams dedicated to defining the new model have made use of design thinking methodology, a framework that triggers team members to think and act like a designer. Similarly, in Pharma, the leader of the 4.0 project, following design thinking methodologies, made use of guided brainstorming sessions, where participants were encouraged to emerge with ideas, thus help in the generation of new techno-organizational solutions.

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.

4 DISCUSSION AND IMPLICATIONS OF RESULTS

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. To overcome this contrast, understood as the outcome of a techno-centric vision of the relationship between technology and organization, the present study, and given the generative potential of digital technologies to see organization design through distinctive socio-technical lens, this study has analyzed the design process in three companies.

By observing the emerged evidence, it is possible to recognize the three principles proposed by the theory of socio-technical systems, as 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. Moreover, for each one of the principles we have enriched our understanding through the practical implementation of each of them (for a detailed representation see Table 2). Secondly (see Table 2), for each one of the principles we have enriched our understanding through the practical implementation of each of them. 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 principle is today applied through the adoption of 'Agile design' methodologies and of design methodologies pertaining to 'Design Thinking'. Such methods manage the design and implementation process upon short, iterative, and continuous experimentation cycles, something that in the past - and in many cases even today – has been considered in a sequential and separate way (such as the waterfall methods). It is thus a spiral shaped process that simultaneously co-optimizes both systems (the technical and the social), a process that is never really finished. This way they make room to maneuver, and the innovation initiative can start at any stage: during the pilot design, during the program of continuous improvement etc. Thereby these methods provide a skeleton that gives stability (structure) and at the same time generate the necessary dynamism, thanks to the ongoing creation and re-composition of multi-disciplinary teams and of work by process and by project.

Table 2 –Principles and actual operating applications that characterize the design process

PRINCIPLES	OPERATING APPLICATIONS	EXAMPLES FROM OBSERVED COMPANIES
Joint Design of Technical and Social aspects	Extended project scope	• Pharma-From the start, it is envisaged that the project scope be expanded to include issues pertaining to three areas: strategic, organizational and technological. For each of these aspects a dedicated team has been assigned. • In Energy the project's scope and vision have broadly defined the expected outcomes that include both technical and social elements
	Multidisciplinary project approach	• In Mechanic, dedicated teams, that meet monthly, have been assigned to the Digital project, as part of a more general framework of continuous innovation program. The teams consist of members with different disciplinary skills and backgrounds. • In Energy for the definition of the new techno-organizational model (of processes and systems), 11 teams have been set up, whose members have different disciplinary skills and backgrounds

Broad Participation	Horizontally and Vertically Extended Participation	• The 11 project teams in Energy are composed of individuals from different hierarchical levels (vertical participation) and different functions (horizontal participation) • In Mechanic, for the implementation of each use case. dedicated teams, composed of representatives from different functions (horizontal participation) and from different organizational levels (vertical participation), have been assigned.
	Informative, Consultative, Deliberative, and/or Creative Participation	• In Pharma, technology users and their supervisors have been involved from the start of the design process. Participation ranges from merely informative/consultative to having a more strategic role in later phases (deciding among different design solution alternatives) or generating ideas related to final solution specifications (creative participation) • In Energy, the members of 11 project teams have participated to the generation of solutions (creative participation), while technology users (field operators) have been involved in selecting their work tools (decision-making participation)
	Direct and indirect Participation	• In addition to the individual participation, Mechanic and Pharma have approached

		existing worker representatives, using the existing communication channels, regarding Digital program development and specific interventions, and on matters that relate to employee control and impact of digital technologies on workforce size (organizational participation) • In addition to the individual participation (direct participation), Energy entered into a company-union agreement related to the innovation project. A joint commission was set up for monitoring its progress (indirect participation).
Continuous experimentation	Design Process is Simultaneous and Systemic	• In Pharma three teams have worked simultaneously to identify possible techno-organizational solutions. Brainstorming sessions were held to encourage the generation of participatory creative solutions, regardless of past experience. • In Energy, the 11 teams, although working on different topics, have been simultaneously active. Members have been engaged in imagining new solutions, regardless of what has been done thus far and the existing constraints.

	Design Process is Iterative, based on Continuous Experimentation	• In Pharma, a solution-based approach was preferred, such as carrying out some form of prototyping, usability testing of "quick and dirty" solutions with operators, rather than waiting to test the complete product. • In Energy, the 11 project teams were constantly exchanging, and have been engaged in different cycles of prototyping and testing.

The contributions of this study are twofold, as it contributes both to management theory as well as to organizational design training. First, by showing that the STS principles still inform the design processes in the observed companies, this study shows that the STS 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. Secondly, the study shows that the integration of both systems (social and technical) should be considered by organization designers as the new area of collaboration for successful organizational development, highlighting the importance of anticipating the organizational design (avoiding a techno-centric approach). To that end, STS-informed design methods, such as Agile and Design Thinking, readily permit such co-optimization of resources along all the phases of design and implementation process. They reflect the fact that in light of digitalization there is a shift in focus. Such a focus is nowadays oriented more to action and intervention, mirroring the actual act of designing in a dynamic way and leaving behind the traditional sequential organization process. Thereby, the system components are not only integrated and jointly optimized with each other, but in many cases, they have been invented and reinvented again, reflecting the actual act of designing in a dynamic way, as it unfolds in the daily practice of the specialists, users and other stakeholders. These methodologies, originating from the Information System and Innovation domains, have initially found their application in the product/service innovation process area, linked to the "form" of products, and as accepted formal creative problem-solving method with the intent to foster innovation (Dell 'Era et al., 2020). Our findings show how the observed companies are expanding such methodologies to organizational innovation and change management areas.

In addition, the results 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 up. First, this study has adopted a purposeful sampling strategy centered around only a few case studies. Employing different sampling strategies, thus considering differences in structural features of organizations would enable a more dynamic view of the organizational design process and enable us to observe the extent to which the results of this study are relevant to other contexts/settings. Second, based on the fact that this study is based on interviews carried out mainly with management-level of the companies, it is important to expand data collection in terms of interested stakeholders, 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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CONCLUSIONS

1 Discussion and directions for future research

Starting off from the results of this thesis there is the realization that: (i) organizational solutions are not determined simply by the technical context that can provide opportunities or place constraints for work and organization, but ultimately it is the choices made by the surveyed organizations that have shaped the journeys/paths that they have taken. This is, in fact, what the socio-technicians call the organizational choice (Trist and Bamforth, 1951) (ii) in light of digitalization, joint, participatory and agile design are fundamental prerequisites that act as productivity boosters, enhancing the performance of the organization, and enablers of continuous improvement (contributing to the basis of organizational intelligence, that is, the capacity of the organization to learn, adapt to changes in the context, solve problems and innovate) and, on the other hand, enhancing the quality of work (in terms of participation and motivation of workers).

However, after taking a closer look at the results, it became apparent that there is the need to further delve upon two reflections. First, the interpretation of the results of the first study (see Chapter I) in some respects can appear contradictory. Opposing logics related to the uncommon design findings are realized through common practices (see common design findings). In fact, in time, as one firm begins using technology to empower employees, the second for surveillance, and the third to distribute information about managerial initiatives and so on, what would be missing would be an account of how all (most) studied organizations came to take for granted that 4.0 technology should be used to have more collaboration, or to socialize employees (as common design findings show) and why such adoption was accompanied by a (common) flatter organizational structure. How come heterogeneous uses of technologies in individual organizations produce homogeneous outcomes (as the common design pattern of organizational variables indicate), such that such outcomes become common across the observed organizations? To understand the kind of analysis required, we should continue the research where we stopped it, before the diffusion of technologies begins. In this research we engaged early in the process of implementation, that is, before a technology becomes fixed. More evidence is thus needed as the Industry 4.0 technologies become more pervasively diffused within and outside the boundaries of an organization. Thereby there is need to offer much more insight into how organizations arrive at relatively homogenous responses to technology (by highlighting their common design choices), to understand how deeply a technology affects an industry, and also how widely it affects other industries (Edwards and Ramirez, 2016). As Leonardi and Barley (2010) put it 'understanding the homogeneous response should help us recognize that technologies are more than tools: how they are adopted, implemented, and used shapes how organizations emerge, replicate, and change.

Furthermore, as mentioned above, as the perceived effects of 4.0 technologies are significant (as some firms experience more employee autonomy, more accentuated enhancement of skills, etc., and other firms experience deskilling, reduction of job autonomy, increase in the standardization of work, etc.) at the same time all these firms experience an increase in innovative work practices, such as greater collaboration, teamwork and participation facilitated by 4.0 technologies. How could it be that some of them experience "increased portion of more prescribed and standardized tasks" and at the same time they experience innovative work practices? In their milestone paper Edwards and Ramirez (2016) suggest that focusing on different dimensions of technologies, in terms of their intended and unintended effects; direct and indirect effects, etc., could help future research explain of how technology can be disempowering at the level of the specific task, while all along it increases the ability to shape the wider contours of the organizational system (as common design findings of this research show). Thereby paying closer attention to their different dimensions and subtle differences could demonstrate to be revelatory in understanding the above paradox.

The second observation relates to the second study that shows that leveraging on a broad set of 'knowhow' coming from those directly involved is a fundamental prerequisite for the success of the technological project. Such finding is an indication of the fact that during the technology design and implementation phase, the influence of different social actors on decisions regarding the technical characteristics of the technology and their intended effects tends to be significant. To realize the active involvement of a broad set of stakeholders (among which the end-users, the employees) throughout the various phases of the project - from the definition of the objectives, to the identification and evaluation of alternatives, to the development and testing of solutions two design methodologies, agile and design thinking, have contributed into lowering the threshold of the applicability of the concept of end-user, extending such a concept in time and space (see below Implication Section). Nevertheless, although we show that such participatory architectures and design methodologies facilitate the participation of diverse stakeholders, however the research predominantly engages with management perspective and analyzes managerial work as the driving force behind organizational design and redesign as organizations face digitalization. To that end the study is overlooking the perspective of the technology user. Not accounting for how employees have come to terms with new technology, and the whole process of implementation, undoubtedly affects the conceptualization of the above proposed framework: joint optimization of performance and job quality. Given the consideration that artifacts and systems are interpretively flexible (Ferraro et al., 2015), and thereby different audiences sustain different interpretations with different evaluative criteria, the future enquiry of the user experience becomes important. It is thus a matter of considering the interpretations of how employees make sense (Orlikowski and Scott, 2008) of technologies and of the process of organizational (re)design in the workplace, in order to understand of new ways of organizing that are acceptable to diverse participants. Secondly, this particular study carried out the implicit assumption that there are no distinctions between specific digital artifacts. As stated above, Edwards and Ramirez (2016), in classifying the dimensions of technological change that are crucial in understanding the implications of technology, argue that apart from the intended and direct effects that can be reformulated again at the stages of design, implementation and evaluation of new technology, it is important to investigate on the dimension of the unintended and the indirect effects. Adopting a narrower definition of properties of technology as 'specific features that provide opportunities for or constraints on action' (Leonardi and Barley, 2008: 162) could improve our understanding of 'what a technology lets users do, what it does not let them do'. The investigation of such dimensions together with the expansion of the data collection should contribute to have a wider view of the relationship between technology and organization, and to carefully consider how to respond to new technologies.

2 Implications

Given that both studies have emphasized the particular implications that they carry, in this subsection I would like to take the opportunity to extend my attention to the implication that the new design methodologies, agile and design thinking have for organization design, in particular their impact on the development of end-user concept. In addition, I would like to share new insights on the implications that this research has for public policies.

2.1 Implications for organization design (End-user concept)

The STS-informed design methods, Agile and Design Thinking, are used by the observed organizations (Chapter II) as design methodologies to build the socio technical organization in face of technological change. In aiming the generation and evaluation of different techno-organizational alternatives/solutions such methodologies provide for greater room to maneuver for the pursuit of the overall objectives of the project. They do this by allowing for the simultaneous interaction between the phases of the project (and at different levels of detail), a process that in the past used to be performed in a sequential and separate way, and also by leveraging on a broad set of knowhow coming from those directly involved throughout the various phases of the project - from the definition of the objectives, to the identification and evaluation of alternatives, as well as during the development and testing of solutions. In this way, these methods are more oriented to action and intervention, enabling the agile company to respond quickly and effectively to external and internal change, and to embrace a broader multidisciplinary stakeholder base, including the technology users. Thereby, they widen the application base of the end user concept, in that such a concept moves on to address the problem and to define/craft the solution along all the phases of the techno-organizational project. It is thus fair to say that that these design methodologies are lowering the threshold for creating 'joint and participative' solutions and expanding the user base both for professional and end user, as well as the field of action in time and space, hence contributing into renewing the vision/concept of end-user development (EUD) (Lieberman et al., 2006) for organization design.

2.2 Implications for public policies

Although the benefits of socio technical design appear quite obvious, however the difficulties encountered in activating them in a seamless manner are many. Butera (2020) rightly argues that one of the current dilemmas nowadays concerns the fact that managers and union representatives accept organizational designs (social systems) that are poorly suited, if not largely unsuited, to the requirements of sophisticated technology and/or of contemporary society and its members, and that this narrow worldview (the fear of the unknown, the concern about holding power, the outdated social values of management and union representatives) is inhibiting the development of organizational designs far more suitable to the present and future technological, economic and social needs.

It is thus important to guide organizations, provide them with the necessary tools toward organizational innovation, such as promoting flexible and agile organizations, providing methods of operationalization, indication of the necessary steps toward a participative organizational design, and other indicators of standards, that can be used as a benchmark to the results obtained (Bartezzaghi, della Rocca, 2020). In addition, it is necessary to act through incentive schemes, such as the activation of different forms of participation that should be seen as part of a broader change process. To that end, public official institutions should continuously support investment into, facilitate access to financing to instruments aimed at promoting participatory strategies/projects. Participatory planning should be carried out jointly by industry associations, official institutions, employee representatives, as well as educational system reps, discussing and sharing objectives of productivity, sustainability, and quality of life. Thereby industry associations can play an important part to incentivize employee participation schemes among its member companies through various initiatives funded by such industry associations. Individual companies, on the other side, can incentivize employee participation schemes by recognizing and rewarding (also monetarily) initiatives that excel in broad participation and joint design. Moreover, existing professional enhancement funds, established by the various market participants and recognized at a governmental level (e.g., FONDIR), should be used to promulgate the benefits of broad participation and joint design. In addition, holding small- and large-scale educational events that extend the network of the experts, aiming industry consultants in strategic, management and organization topics as target audience, can be another tool to align participation incentives with private sector utility goals. Furthermore, to support participatory design, regulation in the form of labor law can be emanated to expand the use of collective bargaining strategies. As is well known, in the German case (Bartezzaghi and della Rocca, 2019), there exists a regulation for companies with more than 5 employees that obliges the employer to consult the workers (or their representatives) and to listen to their possible observations or veto conditions. The introduction/expansion of such a collective process requires thus the support of adequate public policies able to encourage companies to equally involve workers in the organization of work.

3 Concluding Remarks

'The whole is greater than the sum of its parts' Aristotle

Edward Schreckling and Christoph Steiger (2017) claim that digitalization is no longer a choice but an imperative for all organizations, whereas Bartezzaghi (2020) rightly argues that the introduction of technologies, if not preceded, or accompanied by the necessary organizational interventions toward organizational (and managerial) innovation, is bound to undermine not only the risks, in whole or in part, but also the advantages that digitalization brings. In this research we have demonstrated that organizations can choose to "disobey the technological imperative" and moreover they can be designed, as expressed in Trist (1981) words, 'in ways that tap, enhance, performance and develop human potentialities'. In fact, the capacity of digital technologies to interconnect, informate and integrate (Bailey et al., 2019; Cagliano et al., 2019) across different organizational dimensions (horizontal, vertical, end to end (Frank et al., 2019) and organizational actors (facilitating the interaction between technology developers and technology users, etc. ((Winter et al., 2014)), provides a means for connecting parts of the organization, a means for developing relationships (between the social and technical). As such, they have the generative potential for an organization design with co-optimization as a major goal. Such capacity can undermine the traditional structure of the organization (organization as a sum of its parts) and facilitate the move towards a more holographic (Morgan, 1989), convergent organization. To that end, this PhD thesis provides implications for actors involved in organizational (re)design, by showing that the integration of both systems (social and technical) should be considered by organizations as the new area of collaboration for successful organizational development.

In a concluding note, in the original sociotechnical studies, back in the 1950s, Trist and Bamforth, as they ventured out of the mines and into the worker's village to understand why the reconfiguration of technologies in the mine had led to unexpectedly reduced production, developed an incredibly comprehensive multidisciplinary research, a research that was carried out on different levels of analysis, including a range of micro, meso (such as individual and team) and macro level (organizational) analyses to construct valuable scientific knowledge. Such empirical and detailed level of analysis, involving, thus, the psychological, the sociological and the organizational perspective, can generate a capacity to see the interconnections and the mutual shaping of the technical and the social system. Such approach and work should nowadays serve as an inspiration to us, young researchers, to not lose track of our empirical focus, because only close field study and a holographic vision, will help us unravel what it means to be accurate, reliable and accountable (Elbanna, 2020) not just from a philosophical but, more importantly, from an empirical perspective. Moreover, we should be proud of that, so that over the years we have the opportunity to improve technology, organizations, and improve lives.

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