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

by *Emanuela Shaba*[*], *Marco Guerci*[**], *Silvia Gilardi*[***] and *Emilio Bartezzaghi*[****]

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 a employee control-oriented or following a 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.

Keywords: Industry 4.0 technologies, organizational design, control, commitment

*Essay proposed to the editorial board on 31 January 2019 and accepted on 3 April 2019

* Università degli Studi di Milano. E-mail: emanuela.shaba@unimi.it
**** Università degli Studi di Milano. E-mail: marco.guerci@unimi.it
****** Università degli Studi di Milano. E-mail: silvia.gilardi@unimi.it
******** Politecnico di Milano. E-mail: emilio.bartezzaghi@polimi.it

Abstract. Le tecnologie dell'industria 4.0 e il design organizzativo: evidenze da 15 casi italiani

La letteratura manageriale sulle tecnologie Industry 4.0 ha principalmente esplorato la loro relazione con le dinamiche occupazionali, con le competenze richieste ai lavoratori e con i ruoli emergenti all'interno delle imprese. Questo studio si propone di arricchire tale letteratura adottando un approccio centrato sulla progettazione organizzativa, esplorando cioè quali configurazioni organizzative siano implementate dalle imprese che hanno adottato le tecnologie Industry 4.0.

Il lavoro si basa su 15 *case study* realizzati in aziende manifatturiere italiane che hanno adottato le tecnologie Industry 4.0. I casi sono stati realizzati tramite 70 interviste semi-strutturate ad attori coinvolti nell'implementazione delle tecnologie Industry 4.0 nelle imprese analizzate. I risultati mostrano che: (i) quando le tecnologie di Industry 4.0 vengono adottate, l'organizzazione viene riprogettata; (ii) tale riprogettazione ha come esiti alternativi l'adozione di configurazioni organizzative orientate al controllo dei lavoratori, oppure l'adozione di configurazioni organizzative orientate alla partecipazione dei lavoratori. I risultati mostrano quindi che tali configurazioni organizzative non sono determinate dalla tecnologie dato che, pur avendo implementato tecnologie simili, le imprese analizzate hanno adottato configurazioni organizzative diverse. Le implicazioni per la teoria e la pratica dei risultati sono presentate e discusse.

Parole chiave: Tecnologie Industry 4.0, progettazione organizzativa, controllo, commitment

Acknowledgement: the authors thank Annalisa Magone, Tatiana Mazali, Salvatore Cominu, Antonio Sansone and Giuseppe Della Rocca for their valuable feedback.

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 and 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, aimed only at identifying patterns in the evolution of organizational design when Industry 4.0 technologies are adopted, and not at testing or tracking their diffusion 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 companies analyzed, the adoption of Industry 4.0 technologies is associated with two main models of organizational design: (i) control oriented design, and (ii) 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. The second group, called *Operational Technologies*, is composed of three other main families. First family, *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 family, *Advanced human-machine interface,* relates to recent developments in wearable devices and human-machine interfaces, such as touch display and augmented reality. Last family, *Additive manufacturing* 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).

It can be deduced from the above, that the interconnection and the synergetic cooperation between information and communication technologies on one side and operational technologies on the other is 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 and 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, in order to support 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 and 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 and 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 the 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 reduced 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 and 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 *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 and 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 and 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 and 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 and 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 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 and Humphrey 2008). 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).

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 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 control-oriented or commitment-oriented organization design is adopted. For example, control-oriented design leads to lower employee job autonomy whereas the commitment-oriented design leads to more employee job autonomy; or, the control-oriented design leads to higher formalization whereas the 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 control-oriented or the 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 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'[1].

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 and 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 seventy interviews were conducted, with the individuals that – in each organizations – were involved in the implementation of Industry 4.0 technologies and related organizational design. Professional roles interviewed included operators, technicians, engineers, unit heads, HR representatives, administrative assistants, and top management. Table 1 shows the number and roles of interviewees by company.

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 while simultaneously allowing the conduct of a personalized discussion (Mayring and 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 and Humphrey, 2006). Based on the above, we identified those organizational variables which

1 A comprehensive report of the evidence from the 20 cases is available in: Magone A., and Mazali T. (2018). Il lavoro che serve, Guerini e Associati. The interview protocol is available from the authors upon request.

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 and Humphrey, 2008). Cognitive demands reflect the person's general level of cognitive processes required for the job (Hunter and Hunter 1984).

Job Variety relates to the extent to which employees are required to execute a large variety of tasks on the job (Morgeson and 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 and 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 and 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.

Tab 1- Sample of companies

Companies	*Sector*	*Size*	*Technologies implemented*	*Nr Interviews*	*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	7	VP Operations, Production

			solution pieces; Automated finishing systems; Collaborative robots; Real time production; Automated warehouse; Augmented reality; Virtual reality; Digitalization of the distribution network		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

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 and 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.

2.3 Data Analysis

Data analysis was carried out in three stages. During the first stage, the authors independently selected the parts of the interview 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), and subsequent database testing by each author was performed. 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 refers 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, while in the second section uncommon ones. 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. In terms of *physical demands* results show that work has become less labor intensive; machines substitute for heavy physical tasks, and by so doing they facilitate processes that before were extensively manual. In terms of *cognitive demands,* there seems to be a positive relationship between them and the 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. 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 are associated with 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 increased teamwork. In order to transform technological innovation into plant processes, there emerges the need for more 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 grew together with the simplification of the structure of organization, which 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 Industry 4.0 technologies are associated with an increase of managerial control over workers and reduction of employee autonomy. The property of control seems to either be located in the machine, or to be more centralized under the manager. 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 set up from the electronically equipped 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 obtain every result in all its phases…*

On the other side, in other companies advanced technologies are related with increased employee autonomy. For instance, Company 11 that operates in a dynamic and unpredictable context has adopted a management model that places more importance in the greater participation of workers. The implementation of technological instruments such as predictive maintenance empowers employees to be more proactive, involved and more autonomous in maintaining the equipment, while the implementation of digital technologies of communication has facilitated access to codified knowledge that limits the need for hierarchy and subsequently empowers worker's autonomy. Moreover the implementation of smart working has placed more emphasis on the degree of freedom that an employee has in scheduling work. 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 technological 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 is reported. The digital technologies of communication (like for example the intranet which reports data collection from connected machineries used in the production processes) 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 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 digital communication tools:

> *…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. This digital communication tool 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. 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, intermediate levels and the organization has a better structure to manage the changes…*

In other companies results show a middle management drained of its powers. More elements of the managing process are now being executed by the machinery, something clearly shown in Company 7. Company 7 is a medium company operating in the metal mechanic sector that 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. These technological innovations have turned out to provide remote assistance to the process of control and supervision performed by middle management. Here is how the quality manager describes the above:

> *…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 them 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. In some organizations interviewees report evidence of deskilling after the adoption of Industry 4.0 technologies. In Company 1, for example, due to high level of automation, machines operate in a continuous cycle and independently, and for particular tasks automation has acquired full control of production that now do not need to be manned. 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...*

Data 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 increased 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 discussion

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.

Tab. 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 organizational structure (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

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 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).

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 over employees, 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 *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 *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 opt 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 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, albeit a flatter organizational structure.

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.

Tab. 3 - Uncommon design findings

Variables	*Results/Choices*	*Control oriented companies*	*Results/Choices*	*Commitment oriented companies*
	Less autonomy	6,7	More autonomy	
Autonomy	Control as property of the machine; or still on the manager		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. A common result is: less need for human communication	1, 2, 4, 6, 9	Technology provides more data used by employees and teams for better coordination; Technology creates the need for more human communication (more meetings, etc.)	3, 8, 11
Role of middle management	Role of middle management emphasized (in a traditional way)	2, 3, 6, 7, 9	Middle management has stake in the decision making of the company; playing a more supporting, and guiding role	8, 11
	Middle management drained of its role (more elements of the process are executed by the machinery)			
Level of formalization	Higher	1, 2, 4, 6, 9, 12, 13, 14, 15	Lower	8, 11

Skills and Competencies	Deskilling	1, 2, 4, 6, 9, 12, 14, 15	More technical plus transversal skills	8, 11
	Acquirement of only technical skills			

*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 fall in one outcome category

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 shares the concern that organizational actors need to act with caution (i.e., the "de-mythologized" view) when implementing Industry 4.0 technologies. The assumption that technology is neutral and that it will automatically generate positive outcomes for all actors involved is not supported, and thus efforts should be made to rather co-design a socio-technical system that is inclusive of all interested stakeholders.

In addition, our results yield implications for policy makers, in raising awareness that supporting financially the implementation of Industry 4.0 technologies might mean supporting organizations in becoming more control-oriented. In other words, public policies aimed at increasing economic performance of manufacturing companies (at shareholders' benefit) might do so at employee's expense. Thus, public policy makers should be receptive not only to the implementation of Industry 4.0 technologies, but also to *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

We have identified a few important limitations and directions for future research in our study. A first limitation is that our sampling strategy has been centered on a single variable (i.e. Industry 4.0 technologies implemented), therefore future studies employing different sampling strategies may help make our findings more generalizable. Second, the data has been gathered through 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.

Our third 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' (Edwards, 1979) 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 have gained awareness of the value of different perspectives as useful in illuminating the rich texture of actual organizations. Hence, it becomes important to further investigate the phenomenon employing other relevant concepts

Lastly, particular attention should also be placed on how the emerging design choices are individually and collectively interpreted by employees and other relevant actors (e.g. unions). It could be interesting to explore the effects of design choices on work intensification, different dimensions of employee well-being, and on employee and organizational performance.

References

Acemoglu, D. (2002), "Technical change, inequality and the labor market", *Journal of Economic Literature*, 40(1): 7–72.

Acemoglu, D. (2007), "Equilibrium Bias of Technology", *Econometric Society*, 75(5): 1371-1409.

Anand, N., Daft, R. L. (2007), "What is the right organization design?", *Organizational Dynamics, 36*(4): 329-344.

Basaglia, S., Caporarello, L., Magni, M., Pennarola, F. (2010), "IT knowledge integration capability and team performance: The role of team climate", *International Journal of Information Management*, 30: 542–551.

Bayo-Moriones, A., Margarita, B., Fernando, L. (2015), "Are new work practices applied together with ICT and AMT?", The *International Journal of Human Resource Management*, 28(4): 553-580.

Berger, P.L. (1974), *Pyramids of sacrifice,* New York, Basic Books.

Bonomi, A.(2018), " Innovazione, digitalizzazione e lavoro emergente nella smart city di Milano. Inchiesta sul lavoro nella neofabbrica finanziaria", in Cipriani, A., Gramolati, A., G., Mari, G. (eds.), *Il lavoro 4.0. La Quarta Rivoluzione industriale e le trasformazioni delle attività lavorative*, Firenze, Firenze University Press.

Brennan, L., Ferdows, K., Godsell, J., Golini, R., Keegan, R., Kinkel, S., Taylor, M. (2015), "Manufacturing in the world: where next?", *International Journal of Operations and Production Management*, 35(9): 1253–1274.

Brynjolfsson, E., McAfee, A. (2017), *The second machine age: Progress and prosperity in a time of brilliant technologies*, New York, Norton.

Butera, F.(2018), "Industria 4.0. come progettazione partecipata di sistemi socio-tecnici in rete", in Cipriani, A., Gramolati, A., G., Mari, G. (eds.), *Il lavoro 4.0. La Quarta Rivoluzione industriale e le trasformazioni delle attività lavorative*, Firenze, Firenze University Press.

Caruso, L. (2017), "Digital innovation and the fourth industrial revolution: epochal social changes?", *AI & SOCIETY,* 1-14.

Daft, L.R., Murphy, J., Willmott H. (2017), *Organization Theory & Design: An international Perspective*, 3rd edition, Andover, Hampshire, Cengage Learning Emea.

Dewet, T., Jones, G. R. (2001),"The role of information technology in organization: A review, a model, and assessment", *Journal of Management*, 27: 313–346.

Dworschak, B., Zaiser, H. (2014), "Competences for cyber-physical systems in manufacturing", *Procedia CIRP*, 25: 345-350.

Edwards, R. (1979), *Contested Terrain: The Transformation of the Workplace in the Twentieth Century*, New York, Basic Books.

Eisenhardt, K.M. (1989), "Building theory from case study research", *The Academy of Management Review.*

Fondazione Claudio Sabattini & Associazione Punto Rosso. (2018), *Industry 4.0— Position paper,* http://www.fondazionesabattini.it/ricerche-1/ricerca-europea-industria-4-0

Fried, Y., Hollenbeck, J. R., Slowik, L. H., Tiegs, R. B., Ben-David, H. A. (1999), "Changes in job decision latitude: The influence of personality and interpersonal satisfaction", *Journal of Vocational Behavior*, 54: 233-243.

Gorecky, D., Schmitt, M., Loskyll, M., Zuehlke, D. (2014), "Human-machine-interaction in the industry 4.0 era", *In Proceedings – 2014 12th IEEE international conference on industrial informatics*, 289–294.

Guest, G., MacQueen, K. M., Namey, E. E. (2012), *Applied thematic analysis*, California, Thousand Oaks.

Hirsch-Kreinsen, H. (2016), "Digitization of industrial work: development paths and prospects", *Journal for Labour Market Research*, 49(1): 1-14.

Hunter, J. E., Hunter, R. F. (1984), "Validity and Utility of alternative predictors of job performance", *Psychological Bulletin*, 96: 72-98.

Kelly, E. (2015), *Introduction: Business ecosystems come of age*, Deloitte University Press.

King, N. (2004), "Using templates in the qualitative analysis of text", in Cassell, C., Symon, G. (eds.), *Essential Guide to Qualitative Methods in Organizational Research:* 256-270, London, England: Sage.

Kozlowski, S. W. J., Ilgen, D. R. (2006), "Enhancing the effectiveness of work groups and teams", *Psychological Science in the Public Interest*, 7: 77-124.

Laboratorio Cisl Industria 4.0. (2017), *Le Tecnologie e il Lavoro che Cambia,* Uno studio della Cisl, https://www.researchgate.net/publication/322899113

Lawler, E. E. (1969), "Job design and employee motivation", *Personnel Psychology*, 22: 426-435.

Malone, T. W., Crowston, K. (1994), "The interdisciplinary study of coordination", ACM Computing Surveys, 26: 87-119

Masino, G. (2005), *Le imprese oltre il fordismo***.** *Retorica, illusioni,realtà,* Roma, Carocci.

Mayring P., Brunner E. (2007), "Qualitative Inhaltsanalyse", in Buber R., Holzmüller H.H. (eds), *Qualitative marktforschung. Konzepte, methoden, analysen*: 669-680, Wiesbaden, Gabler.

Morgeson F. P., Humphrey, S. E. (2006), "The Work Design Questionnaire (WDQ): Developing and Validating a Comprehensive Measure for Assessing Job Design and the Nature of Work", *Journal of applied psychology*, 91: 1321-1339.

Morgeson F. P., Humphrey, S. E. (2008), "Job and team design: Toward a more integrative conceptualization of work design", *Research in Personnel and Human Resources Management,* 39-91.

Negrelli, S., Pacetti, V. (2018), "Tecnologie, lavoro, organizzazione nell'Industria 4.0", in Cipriani, A., Gramolati, A., G., Mari, G. (eds.), *Il lavoro 4.0. La Quarta Rivoluzione industriale e le trasformazioni delle attività lavorative*, Firenze, Firenze University Press.

Nemeth, C., O'Connor, M., Klock, P., Cook, R. (2006), "Discovering healthcare cognition: The use of cognitive artifacts to reveal cognitive work", *Organization Studies*, 27: 1011–1035.

Osservatorio SM. (2015), Osservatorio Smart Manufacturing, Politecnico di Milano, School of Management, www.osservatori.net

Parker, S.K., Wall, T.D., Cordery, J.L. (2001), "Future work design research and practice: Towards an elaborated model of work design", *Journal of Occupational and Organizational Psychology*, 74: 413–440.

Parker, S.K., Van der Browck, A., Holman, D. (2017), "Work Design Influences: A synthesis of multilevel factors that affect the design of jobs", *The Academy of Management Annals,* 11(1): 267–308.

Romero, D., Bernus, P., Noran, O., Stahre, J., Fast-Berglund, Å. (2016), "The Operator 4.0: human cyber-physical systems & adaptive automation towards human-automation symbiosis work systems", in *IFIP International Conference on Advances in Production Management Systems*: 677-686

Salento, A. (2018), "Industria 4.0 e determinismo tecnologico", *Industria 4.0: Oltre il determinismo tecnologico*, Bologna, TAO Digital Library

Sims, H. P., Szilagyi, A. D., Keller, R. T. (1976), "Job Characteristics Inventory", *Academy of management Journal*, 19: 195-212.

Stock, T., Seliger, G. (2016), "Opportunities of Sustainable Manufacturing in Industry 4.0", *Procedia CIRP*, 40: 536–541.

Strauss, A., Corbin, J. (1998), *Basics of qualitative research: Techniques and procedures for developing grounded theory,* Thousand Oaks, Sage Publications.

Trist, E.L. (1981), "The sociotechnical perspective", in. A.H. Van de Ven, W.F. Joyce (eds.), *Perspectives on organization design and behavior*, New York, Wiley.

Venkatesh, V., Bala, H., Sykes, T. A. (2010), "Impacts of information and communications technology implementation on employee's jobs in service organizations in India: A multimethod longitudinal field study", *Production and Operations Management*, 19:591–613.

Vitali, G.(2016), " La via italiana nell'applicazione di industria 4.0", in Torino Nord ovest, rapporto di ricerca, *Factory of the future, Tecnologia, competenze e fattore umano nella fabbrica digitale,* Guerini e Associati

Wall, T. D., Corbett, J. M., Clegg, C. W., Jackson, P. R., Martin, R. (1990), "Advanced manufacturing technology and work design: Towards a theoretical framework", *Journal of Organizational Behavior, 11: 201– 219.*

Waschull, S., Bokhorst, J.A., Wortmann, J.C. (2017), "Impact of technology on work: technical functionalities that give rise to new job designs", *IFIP International Conference on Advances in Production Management Systems,* 274-281.

Zhou, L., Chong, A. Y. L., Ngai, E. W. T. (2015), "Supply chain management in the era of the internet of things", *International Journal of Production Economics*, 159: 1–3.