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EMPOWERING ORGANIZATIONS IN THE INDUSTRY 4.0 ERA: LEVERAGING HUMAN AND DIGITAL RESOURCES IN SOCIO-TECHNICAL SYSTEMS

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1. EXECUTIVE SUMMARY

With the advent of the fourth industrial revolution, commonly referred to as "Industry 4.0" (I4.0), scholars and practitioners have reinvigorated their focus on digitalization topic. This revolution coined in 2011 in Germany brings with it new enabling technologies that stand as revolutionary not only for organizations, but for the whole society. Indeed, the fourth revolution is considered a sociotechnical phenomenon that affects both technological and social domains.

Considering the growing importance of digitalization, numerous research projects have been conducted in recent years to study the characteristics and implications of the fourth industrial revolution. However, despite extensive research on the topic, there are still some aspects of this phenomenon that have not been adequately addressed.

While there is considerable knowledge about the enabling technologies and their positive effects on operational performance, the understanding of the impacts on organizations is not yet complete. In other terms, although we know the effects on performance, there is a lack of impactful research regarding how organizations can evolve through digitalization 4.0 in terms of processes, organizational structure, and human resources.

Consequently, the aim of this research is to simultaneously investigate the technological and social dimensions that characterize the 4.0 revolution by examining the relationship between the two domains. Our goal is to understand how organizations evolve in this new context and how they can be empowered through the development of their human and digital resources. This objective serves as the common thread throughout the three essays presented in this dissertation. The collection of essays provides a comprehensive overview of the empowerment path, considering both technological and human resources in the organizational contexts most affected by digitalization (manufacturing and purchasing). The choice of these domains is primarily justified by the fact that both areas have been and are currently strongly affected by digitalization, a theme that will be explored in detail within the scope of this dissertation. Secondly, the choice is linked to theoretical positioning; indeed, the intention of the research aims to augment the body of knowledge within the field of operations management. Nonetheless, consistent with the objectives of a doctoral dissertation, this research attempts to delimit the investigation to a more specific context. Moreover, these two areas are central to manufacturing realities, and including them both allows for additional considerations arising from the comparison.

The first essay delves into the profound effects of digitalization on purchasing departments, focusing on the interplay between automation and augmentation. Its primary goal is to uncover how these technological advancements influence the evolution of purchasing processes and the associated social dimensions. Employing a qualitative research approach, the essay is based on interviews with purchasing professionals and managers. The results of the first essay show the dynamic and cumulative transformation process within purchasing departments. From a theoretical perspective, this study enriches our understanding of the intricate relationship between technology and social systems in purchasing. It emphasizes the necessity of a balanced approach that harmoniously integrates both dimensions. On a practitioner level, this research offers valuable guidance to managers embarking on digitalization initiatives.

The second essay aims to investigate the impact of Manufacturing Execution Systems (MES) implementation on job design, while exploring the relationship between MES and I4.0 investments, as well as. Employing a mixed-method research approach, combining quantitative survey data with qualitative case studies, this research delved into the nuances of the phenomenon.

To contextualize the MES technology in the I4.0 era, the study shows that MES technology can both benefit from and serve as an enabler for I4.0 technologies, particularly in manufacturing settings. This first result suggests that MES plays a pivotal role in accelerating the adoption of I4.0 technologies. Turning to the impact of MES implementation on job design, the results demonstrate that after MES implementation the decision-making autonomy increased for production operators, who gained the ability to make decisions related to the production process. MES implementation also impacted task variety and skill development. Even task significance is positively affected, with both operational and managerial levels experiencing greater significance in their roles. However, these effects are not universal and deterministic, as some companies opted not to grant further empowerment, and the willingness and readiness of operators to grow and undertake the professional development path played a crucial role and MES implementation also influences job outcomes, including motivation, satisfaction, and performance. The findings contribute both theoretically, by enriching the JCM with a technological perspective, and practically, by offering guidance to managers embarking on MES implementation projects. Recognizing the potential impact on job design and the moderating factors at play can help organizations navigate digital transformations more effectively till the organizational empowerment.

The third essay examines how the combination of human and digital resources empower the organizational effectiveness. Taking advantage of the particular historical period in which the research takes place, that is a time interval marked by the COVID-19 pandemic and the Russia-

Ukraine conflict, this essay focuses on the dimension of organizational effectiveness related to adaptation and flexibility. The research aims to enhance our understanding of organizational resilience, exaptation, and resource adaptation and absorption dynamics showing the role of human and digital resources. Methodologically, the study adopts a qualitative approach, analysing data from large global companies that effectively coped with the pandemic challenges. The analysis focuses on observing how these organizations dynamically reconfigured their human and digital resources to address the disruptions caused by COVID-19. One significant contribution of the study is the conceptualization of organizational resilience as a human and digital resource reconfiguration process that combines exaptation and absorption. The study also extends the concept of exaptation beyond innovation to organizational resilience, demonstrating how resource recombination plays a vital role in maintaining resilience during crises. This study contributes to both theoretical and practical knowledge in crisis management, emphasizing the importance of resource dynamics in fostering resilience.

This dissertation offers valuable practical and theoretical contributions in the context of technology adoption, job design, and crisis management, thereby advancing socio-technical systems theory in the Industry 4.0 era. In terms of practical contributions, the dissertation provides insights for managers overseeing digital and organizational transformation projects. The research uses case studies with field-collected data to offer concrete recommendations and practices. It emphasizes the importance of balancing automation and augmentation technologies for organizational empowerment and addresses employment-related issues and resistance to change. The theoretical contributions are equally significant. This collection of essay enriches socio-technical systems theory by demonstrating that automation and augmentation can complement each other, shedding light on how technology influences social systems in organizations. Then, it extends the understanding of the sociotechnical relationship and job design, identifying individual characteristics that moderate the effects of technological changes on job outcomes. Finally, the dissertation advances the literature on organizational effectiveness and resilience, describing it as a resource reconfiguration process that combines exaptation and absorption of human and digital resources over time, providing a dynamic view of resilience in unpredictable business landscape.

2. INTRODUCTION

2.1 Purpose

Industry 4.0 (I4.0) is a technological and socioeconomic phenomenon (Horváth and Szabó, 2019) that is transforming businesses and organisations through a process of digitalization. Thanks to new enabling technologies, methods and tools, a flexible and cost-efficient production becomes possible in the context of I4.0, thus improving the quality of products (Lu, 2017).

From a technological perspective, the impacts of I4.0 technologies on industrial processes have been widely treated and the extant literature suggests that the 4.0 revolution may allow companies to increase the performance of their processes and improve their products by means of a flexible manufacturing system (Kagermann et al., 2013). The main operational benefits identified concern the reduction of set-up times, labour and material costs and processing times resulting in higher productivity of production processes (Brettel et al., 2014; Jeschke et al., 2017). The digital transformation goes far beyond the improvement of processes and products through new technologies. It also covers business models, organizational and managerial aspects, as well as the entire Supply Chain, creating significant challenges for manufacturing companies (Bleicher and Stanley, 2016). Changes are so revolutionary since they also concern the labour market. Several research have been conducted to study possible impacts on employment, as well as the risks connected to job automation (Frey and Osborne, 2013). Similarly, studies have been made on possible emerging and disappearing jobs in the 4.0 revolution (Hirsch-Kreinsen, 2016).

However, I4.0 is a sociotechnical phenomenon, and the literature is not comprehensive about impacts on the social dimension, except from the above-mentioned implications for the labour market. In fact, little consideration has been given also to possible developments for existing roles and tasks in organisations affected by digitalization (Cagliano et al., 2019; Cimini et al., 2020). The literature has merely debated about the possible development paths of workers because of the digitalization of industrial work. This debate has led to speculation about possible increases in decision-making autonomy (Bayo-Moriones et al., 2017) and in tasks breadth (Morris et Venkatesh, 2010) of workers, however these considerations require further verification and investigation. This investigation should strive to further explore the attributes of this prospective professional development, offering a focused examination of aspects such as the assessment of employment structures, potential requirements for workforce reassignment, and the evaluation of necessary skill sets.

To fill this gap, the main purpose of this dissertation is to investigate the phenomenon of organizational empowerment in the context of I4.0, by evaluating the relationship between

digitalization and the social dimension of organizations. In doing so, emphasis is placed on the evolution of human and digital resources as a result of technological implementation. Considering the human resources evolution, the research is not limited to understanding whether professional evolution can occur, but also aims to define which job dimensions and characteristics are subject to potential developments and how organizations and managers can facilitate such transformation.

In addition to considering this perspective, the research also seeks to be consistent with studies investigating the effects of digitalization on performance by analysing how human and digital resources can jointly support the organizational empowerment. To differ from what has already been covered in the literature, with the purpose of complementing it, this research aims to show how human and digital resources can contribute to the development of organizational effectiveness through resilience, thus helping companies adapt and survive in increasingly turbulent and changing environments. The choice of this subtopic is partially due to the particular period in which this dissertation was conducted, that is during the Covid 19 pandemic. Without intending to go into the dynamics of this phenomenon, we believe that it was an event where important lessons can be learned, always consistent with respect to the topic of human and digital resources and their relationship and interaction. In addition, this choice also aims to consider the environmental element in the technology-organization relationship. In the theoretical background, studies will be presented that show how the operating environment can influence technical and social decisions, and how a complex and uncertain context can accelerate technological implementation. In summary, it will show how the existing literature, although dated, already shows how environment and context can influence the socio-technical dimension. In this dissertation, an attempt will be made to go beyond this concept, showing instead how the socio-technical dimension, here considered as the interaction of human and digital resources can help the organization manage precisely an uncertain and complex environment.

The need for deep exploration and the complex nature of the considered topic, even because of the multiple relationships studied, naturally leads to the adoption of case study methodology. This approach allows an investigation of the phenomenon in its natural context, providing comprehensive understanding and insights. Consequently, this research relies heavily on qualitative methodologies, consistent with the objectives of the thesis, seeking to answer the What and How they present. All information was collected personally through interviews, which were always augmented by secondary sources. Each essay consists of exclusive cases, which are not repeated in other research in the dissertation.

Before going into the details of the essays and discussing the research questions, the next section will present the theoretical background and the main contributions that currently exist related to the

phenomenon of I4.0, thus framing the topic and then coming to the presentation of the research design and its objectives.

2.2 Background and literature

Introducing a definition for an ever-evolving phenomenon subject to constant innovative pushes is not straightforward. The pace of change is growing exponentially, making it challenging to establish a common understanding of I4.0. In fact, literature offers various definitions stemming from different perspectives. One of the most intriguing definitions for the purposes of this dissertation is provided by Khan and Turowski (2016), who refer to I4.0 as "a revolution enabled by the application of advanced technologies at the production level to deliver new values and services for both customers and the organization itself." This definition is particularly relevant as it encompasses both the technological and social aspects. Despite the lack of clarity on the definition, a typical problem in reference to digital transformations, a common theme in the debate is that due to the number and potential of technologies, organizations are affected and experience a process of adaptation (Hanelt et al., 2021). The I4.0 phenomenon, like previous digital transformations, is therefore naturally linked to the theme of organizational change. Hence, the need emerges for a theoretical reference that can combine a social dimension such as organization and a technical dimension such as digital technologies.

The socio-technical systems theory, introduced by Trist and Murray (1993), has traditionally served as the foundation for examining the relationship between technology and organizations. This theory depicts the technological and social elements, such as organizations and the workforce, as deeply interconnected and mutually dependent. While technology has always been a focal point in organizational studies, it is through the socio-technical perspective that the profound and reciprocal relationship between organization and technology has come into focus. Within this framework, technology moves from a contingent factor to a fundamental dimension of organizational design. This theory is primarily grounded in the idea that the interaction between social and technical factors sets the stage for successful system performance. These interactions encompass not only cause-and-effect dynamics but also unforeseen consequences: the social dimension is shaped by human resources, which exhibit distinct behaviours compared to machines. Furthermore, even the technical dimension itself can exhibit non-linear behaviour under complex conditions, as observed by Walker et al. (2008).

From a technological perspective, the concept of advanced technologies is invoked, suggesting that I4.0 is not based on a single implementation, but rather embraces a wide range of enabling technologies, such as Cyber-Physical Systems (CPS), Internet of Things (IoT), cloud computing, big data analytics, machine learning, advanced manufacturing technologies with sensors, decentralized

agent-driven control, advanced robotics, Augmented Reality (AR), advanced tracking and tracing technologies, and additive manufacturing (3D printing) (Bigliardi et al., 2020) . This notion implies that I4.0 digital transformation relies on the adoption of new enabling technologies, which represent an adaptation and evolution of technologies that have been present in the industrial sector for decades. The study conducted by the Boston Consulting Group titled "Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries" (Rüßmann et al., 2015) confirms the foundational role of these enabling technologies in the digital and productive development of the fourth industrial revolution. The subsections 2.2.1 will delve deeper into this set of technologies.

From a social perspective, the definition implies potential positive impacts, as it alludes to the creation of new value for the organization, as well as for its resources. However, the definition does not delve into the specifics of this value, which will be further explored in subsections 2.2.2, which is primarily focused on examining the interplay between technology and organizational dynamics.

Table 2.1 presents the topics covered in the following sections of the theoretical background, in the order in which they are presented.

Table 2.1 – Literature background structure

Topic	I4.0 enabling technologies	Human and digital resources: the relationship	Human and digital resources: the role in building organizational effectiveness
Content	Definition of the enabling technologies and technological approaches considered in the research (automation vs augmentation)	Introduction to sociotechnical systems theory Implications of digitalization for human resources Influence of the social system in technology implementation choices	The relationship between organizational effectiveness and resilience Human and digital resources to support organizational effectiveness

The discussion presented in the following subsections begins by exclusively addressing the technological dimension, outlining the set of enabling technologies. This introduction on technological aspects allows to specify which technologies are considered for this research. However, as previously mentioned, the aim of this doctoral thesis is to consider the existing relationship and interaction between the technological dimension (represented by digital resources) and the social dimension (represented by the organization and its human resources). For this reason, the theoretical background will also encompass key current knowledge related to the relationship between human and digital resources. Finally, this relationship will be further explored in terms of interaction, examining how it can contribute to organizational empowerment in terms of effectiveness and resilience.

These following subsections provide a comprehensive overview of the theoretical background, aiming to contextualize the topic and promptly highlight the gaps. The specific literature concerning each research object, however, is delineated within the respective essays. Consequently, Chapters 3, 4, and 5 each encompass an exhaustive and detailed examination of the relevant literature, delving into the specifics of the variables and dimensions addressed in the paper characterizing the essay.

2.2.1 I4.0 enabling technologies

As a starting point for the background of the study, it is appropriate to delve into what these enabling technologies are. Industry 4.0 technologies can be categorized according to a set of 4 classes suggested by Freour et al. (2021):

- *Assisting technologies* may be characterized as technologies that give workers freedom of choice while assisting them in completing tasks;
- *Augmenting technologies* cannot duplicate human action sequences but they may create new ones and present them to the human agent. They have some degree of agency since they give active aid by providing suggestions, but they do not decide what should be done. They are known as "additional technologies" because they amplify one's abilities and senses;
- *Arresting technologies* select and implement pre-planned actions when preset conditions are met. They are prohibited from deviating from the exact processes and tasks specified by their program. In a partnership between people and technology, the job can be delegated by humans to the technology, which can then halt when the requirements for performing the program are not satisfied and hand off exception handling to humans;
- *Automating technologies* can choose an action but they are designed to carry out a series of acts automatically. By the collection and analysis of copious amounts of data, these technologies are able to create new methods of doing things. These technologies have learning capabilities that

allow them to improve work processes and rectify the analyses they do. So, it is feasible that as they learn, the action sequences they are able to accomplish may alter.

The Boston Consulting Group have identified nine key technological trends that form the foundation of Industry 4.0 and explores their potential technical and economic benefits, with a focus on case studies from Germany, a global leader in industrial automation (Rüßmann et al., 2015).

- *Big data and analytics:* Because Big Data and Analytics (BDA) is a fairly new and evolving concept, there is no uniform definition of Big Data and Analytics (Zakir et al., 2015). One of the most accepted characterizations comes from the Gartner report, which defines BDA through three Vs, namely volume, velocity and variety, later to become five by adding value and veracity as well. These additions emphasize how BDA must bring value to the business and must have a certain reliability and certainty. Manufacturers can gather and analyse data from various sources, including production equipment, enterprise systems, and customer management systems. In fact, this technology in the 4.0 era has considerable and relevant applications, especially in manufacturing. Such applications include information gathering, prediction of failures, data store of all operations, decision-making support, but also more particular activities such as fraud detection or controlling of the transportation system (Javaid et al., 2021).
- *Simulation*: simulation technology entails the utilization of software and hardware to assess the prospective result of a specific scenario, relying on established parameters and the incorporation of one or more variables that have the potential to impact the outcome of said scenario. These simulations will use real-time data to create a virtual representation of the physical environment, which may include machinery, goods, and people. Various simulation approaches are applied in Industry 4.0. Agent-based modelling and simulation (ABMS) involve autonomous agents representing different system elements, facilitating modelling of complex interactions. Discrete Event Simulation (DES) focuses on events that change a system's state over time, suitable for process-oriented analysis. System Dynamics (SD) employs continuous simulation to study dynamic systems using stock-flow diagrams.
- *Horizontal and vertical system integration*: I4.0 facilitates enhanced cohesiveness among companies, departments, functions, and capabilities. Due to the development of cross-company, universal data-integration networks and the creation of automated value chains, I4.0 will result in a significant increase in the coherence of businesses, departments, functions, and capabilities (Rüßmann et al., 2015).
- *Cybersecurity*: "cybersecurity is the collection of tools, policies, security concepts, security safeguards, guidelines, risk management approaches, actions, training, best practices, assurance

and technologies that can be used to protect the cyber environment and organization and assets." (Schatz et al., 2017) Critical industrial systems and production lines need to be protected from cyberattacks more than ever because of Industry 4.0 increasing connection and adoption of industry-standard communications protocols. Hence, comprehensive identification and access control of devices and users are crucial, as well as secure, dependable communications. Lezzi et al. (2018) investigated which assets would need Greater protection in the I4.0 era, suggesting a particular attention to Industrial Control Systems (ICS) and Cyber-Physical Systems (CPS). ICSs serve as a management and control system, automating technical facilities and monitoring business processes in various critical areas. CPSs, on the other hand, integrate computation, networking and physical processes, allowing the digital and physical worlds to interact. CPSs use sensors to monitor physical processes and decentralized intelligence to make real-time decisions, optimizing processes. Looking instead at the industry, manufacturing appears to be the most exposed to cyber security issues.

- *Additive manufacturing:* additive manufacturing (AM) is the manufacturing industrial name for 3D printing, a machine-controlled process that builds three-dimensional items by depositing materials, usually in layers. The use of additive manufacturing is widely employed in I4.0 to create small quantities of customized goods that have advantages for development, such as complicated, lightweight designs. Transport distances and inventory levels will be cut with the use of high-performance, decentralized additive manufacturing equipment (Rüßmann et al., 2015). AM and I4.0 have a beneficial reciprocity. On the one hand, I4.0 plays a key role in enhancing AM. On the other, AM aligns with I4.0 principles, optimizing the production of high-value, on-demand products by leveraging real-time market responses. Personalization is a key feature of AM, which synergizes with Industry 4.0, blockchain, and digital twins to transform customer preferences into customized products (Khorasani et al., 2022). AM adoption is driven by design innovation and product enhancement, but faces barriers like extended production times, high costs, and a lack of AM expertise, particularly with metals (Ronchini et al., 2023)
- *Internet of Things (IoT):* IoT is defines as "sensor(s) and/or actuator(s) carrying out a specific function and that are able to communicate with other equipment. It is part of an infrastructure allowing the transport, storage, processing and access to the generated data by users or other systems." An alternative definition is "group of infrastructures interconnecting connected objects and allowing their management, data mining and the access to the data they generate." (Dorsemaine et al., 2015). It offers Industry 4.0 technology foundation. IoT creates the digital infrastructure and makes it possible for physical things to communicate with one another by exchanging data, which facilitates decision-making coordination, enabling independent operation

without direct human intervention (Vereycken et al., 2021). IoT has numerous application contexts and domains, the most relevant of which include healthcare, environmental, commercial, smart city, industrial and general aspects (Asghari et al., 2019)

- *Augmented reality (AR):* AR is defined as "a real-time direct or indirect view of a physical real-world environment that has been enhanced/augmented by adding virtual computer-generated information to it" (Carmigniani et al., 2011). AR application enhance the user experience and turns the operative environment into an interactive learning environment (Rüßmann et al., 2015) and play a key role in Industry 4.0. AR enhances data visualization, improving the reliability, security, and maintenance of systems. However, data privacy is a crucial issue as large amounts of information are collected (De Pace et al., 2018). AR finds applications in various industrial sectors. It's utilized in maintenance for technicians to access information and instructions, assembly, human-robot collaboration for safety and efficiency, manufacturing for smart production, training to improve performance, and logistics for tasks like order-picking (Reljic et al., 2021)
- *Robotics*: a heterogeneous group of automated or semi-automated machines that can perform tasks without human supervision or in cooperation with human tasks (Margherita and Braccini, 2021). Collaborative robots (cobots) are mainly used to support physical activities or cognitive tasks. In physically demanding activities such as lifting heavy loads, they reduce the risk of musculoskeletal disorders, improve workers' physical abilities and posture, and reduce tension. At the same time, cobots automate monotonous tasks, adapt tools and workstations, account for sensory limitations, monitor health data, and improve human-machine interaction. In cognitive tasks they support work by visualizing decisions, storing information, suggesting breaks, and observing processes to reduce errors and continuous learning in knowledge-intensive production (Bragança et al., 2019).
- Cloud manufacturing: a virtual network that connects various parties in the supply chain, enabling the storage and exchange of large amounts of data, and the sharing of resources on demand through Internet-connected digital platforms. Cloud manufacturing offers assembly line players a cost-effective, highly scalable, and powerful solution (Margherita and Braccini, 2021). The term was coined by Li et al. (2010) and defined it as "a new networked manufacturing paradigm that organizes manufacturing resources over networks (manufacturing clouds) according to consumers' needs and requirements to provide a variety of on-demand manufacturing services via networks (e.g., the Internet) and cloud manufacturing service platforms" (Siderska et al., 2018). The focus of cloud manufacturing lies in the creation of the cloud manufacturing platform, which is based on many technologies, such as IoT, virtualization, servitization technologies, cloud

computing, service-related technologies and semantic web technology (Liu et al., 2017). Big data are also necessary for the complete implementation.

2.2.2. Human and digital resources: the relationship

While the definition given at the beginning of the chapter suggests a relationship between digitalization and organization (represented in this research by digital and human resources), it should be explored further through the literature. The relationship between technology and organization has traditionally been considered the basis of investigation for the socio-technical systems theory, which depict the technological and social (i.e. organizations, workforce) elements as strongly interrelated and interdependent (Trist and Murray, 1993). Indeed, while in organizational studies technology has always been a part of the problem, it is only with the socio-technical perspective that the strong and mutual link between organization and technology has become clear. With this perspective, technology thus moves from being a contingent factor to a dimension of organizational design. The theory is mainly based on the assumption that the interaction between social and technical factors creates the conditions for successful system performance. These interactions include cause-and-effect relationships as well as unforeseen effects. One of the key principles of this perspective is that the social side does not behave in the same way as the technical side. The social dimension is characterized by human resources, which do not function as machines. Moreover, even the technical dimension itself, under complex conditions, can deviate from its linear behaviour (Walker et al., 2008). I4.0 is characterized by enabling technologies and at the same time its magnitude is such that implications are also expected for the human resources employed in the organization. For this reason, it is defined as a sociotechnical phenomenon, so that during the implementation of various I4.0 technological applications, socio-technical systems theory should be included in every stage of integration (Sony et al., 2020).

This assumption is also justified by looking at previous digital revolutions. Indeed, even the introduction of information technologies has highlighted the close interaction between the organizational and technological dimensions. Early research on the topic that studied the relationship between information technologies and organization considered the organizational structure of the company for the social dimension. Two different reasonings emerged. The first is that organizational structure and technology are both caused and influenced by the organizational environment (Pfeffer et al., 1977). From this perspective, a complex and uncertain environment is associated with an organic, that is, less formalized and more decentralized structure (Burns and Stalker, 1961; Hall, 1972). Similarly, when an organization faces a complex and rapidly changing environment it is more likely to adopt information technology. In contrast, the second perspective predicts that information

technology alters the mechanisms and nature of organizational coordination, thus having a direct effect on organizational structure. This view is shown to be valid by Pfeffer and Leblebici (1977), defining that information technology is positively associated with vertical and horizontal differentiation in organizations, thus affecting breadth and hierarchy of control. This is made possible by the enhanced ability of managers to manage information, having more effective and efficient control and more timely and comprehensive feedback. This effect is also found in Huber (1990), who shows how the information created, modified, transmitted, and stored using IT leads to organizational changes in design, intelligence, and decision making.

These studies, although dated, are extremely relevant to this discussion because they show that technology implementation has effects on the organization not only in terms of organizational structure, but also in terms of job design and microstructure. Technology enables new potentials at the micro level, that is, for the human resources employed (from managers down to operators), and in this new context the organization can evolve and empower. This reasoning is the key assumption guiding this research. In addition, these studies maintain the role of context as an additional variable of influence. In particular, they explain how dynamic, uncertain, and complex contexts can foster technology implementation. This dissertation also maintains a focus on this type of context, looking at the COVID-19 pandemic, not only understanding the effect of context on social and technical variables, but also how technology and organization can help limit the uncertainty of context itself.

Thus, the studies shown so far, i.e., early research on the topic of technologies and organization, demonstrate their relationship and interconnection. The interconnection between technology and organization is so strong that two antagonist visions have often been suggested: “The Technological Imperative” and “The Organizational Imperative” (Markus and Robey, 1988). “The Technological Imperative” sees technology as the cause of organizational change, considering it an exogenous force that determines or limits the behaviour of individuals. In this perspective organization changes to better integrate technologies and the structure does not emerge from a conscious and forward-looking choice, but as a result of constraints and forces on which little control can be had. “The Organizational Imperative” assumes that the organizational structure changes according to the different organizational needs and it considers the technological innovation as a tool for solving organizational problems. The technological variable is seen as the mean to satisfy the organizational requirements and at the same time to make it possible to modify the organizational structure. This perspective includes the possibility to manage the impacts of technological innovation by attending to both technical and social concerns. (Bjørn-Andersen et al. 1986). In summary, the study of the relationship between information technologies and organization provides different points of view about the actual

role of technologies, sometimes seen as the cause of change and sometimes as a means of enabling it. Such a dilemma also arises in the case of I4.0 technologies and their relationship with organization (Cagliano et al., 2019).

Considering the implications on human resources within the organization, the digital transformation can lead to possible evolutions in the definition and execution of work, as well as a change in skills required by operators. According to the World Economic Forum, it is expected that I4.0 technologies will be used both to support and enhance operators' activity and to automate certain activities (World Economic Forum, 2018). The current literature suggests a broad spectrum of work development paths, but at the same time identifies two main trends, i.e., upgrading of qualifications and the polarization of qualifications (Hirsch-Kreinsen, 2016). This assumption is not new and had already been considered in relation to any previous technological innovation. Previous contributions have already hypothesized the existence of two possible perspectives: deskilling and upskilling (Attewell, 1992). The first perspective - deskilling – foresees the downgrading of the operators through the simplification of jobs and the reduction in skills of more highly skilled craft workers (Braverman,1974). This approach to skills' polarization focuses on automation technologies with the aim of gaining greater control over operators, simplifying and routing work processes, reducing the need for individual skills and knowledge of the process, materials or quality problems involved. The resulting effect is the devaluation of low and medium-level jobs. The second perspective - upskilling - foresees an increment of the qualification of the operators. Technological change in this case implies an increase in the skills required by operators (Waschull et al., 2017) because rather than automating complex and qualified tasks, the simplest and most routine tasks are automated. The remaining tasks focus on the more complex and value-added aspects, requiring more cognitive needs. "Empowered operators" are thus able and free to perform new tasks and activities previously unknown, such as monitoring and control of equipment, becoming problem solvers for automated processes. Workers will be employed less as "machine operators" and more "in the role of experts, decision makers and coordinators and the work of the individual becomes more varied" (Kagermann 2014). The resulting effect is a constantly increasing level of qualification rather than the disappearance of low-skilled industrial work. Both perspectives have been criticized for the tendency to simplify and generalize issues and assume a one-way effect. In the literature a change in the competences and in the level of qualification of workers has already been suggested (Gehrke et al., 2015). In this scenario new tasks could arise requiring new personal and digital skills. It is possible to include the new required skills in four main categories: technical, methodological, social and personal (Hecklau et al., 2016). Technical competences include the professional skills and abilities to work and interact with the new machines or technologies. Methodological competences refer to how an individual plans, undertakes,

manages, and executes his or her work. Social competences refer to the ability to interact, cooperate and work in teams with other individuals. Personal competences include individual behaviour, attitudes, values and motivation.

2.2.3. Human and digital resources: the role in building organizational effectiveness

The research on the role of digital technologies in enhancing organizational effectiveness has raised significant academic attention. Studies have shown how information technologies impact operational, structural, and strategic flexibility, as discussed by Batra (2006), leading to improvements in organizational performance. Additionally, the development of technological capabilities has been linked to advancements in organizational effectiveness, as proposed by Bustinaza et al. (2019). Expanding on this discussion, Wang (2005) introduces an additional dimension to the concept of organizational effectiveness, suggesting that it can be achieved not only through technological innovation but also through strategic human resource management (HRM) strategies. This insight is particularly noteworthy as it opens the door to hypothesizing a relationship between human and digital resources in enhancing organizational effectiveness. However, it is important to note that the definition of organizational effectiveness itself is multifaceted and subject to variation. In examining various models, Steers (1975) has identified a recurring set of criteria commonly associated with organizational effectiveness. Notably, adaptability and flexibility emerge as primary considerations from this analysis. Bustinaza et al. (2019) provide further clarity on the interplay between technologies, resilience, and organizational effectiveness. Their findings show the positive impact of technologies on organizational efficiency and highlight the mediating role of resilience in this relationship. In this scenario, the role of human resources remains essential for quickly adapting to changes and new circumstances, as underscored by Shin et al. (2012). Despite the time that has passed since these studies, recent events demonstrate that the importance of these factors for organizational effectiveness has not diminished. On the contrary, it has gained even greater relevance, becoming an integral part of what we now refer to as organizational resilience, as elucidated by Ma et al. (2018). Indeed, in recent years organizations are often coping with external disruptions, such as natural disasters or political turmoil (McKinsey and Company, 2020), and the recent 2019 coronavirus pandemic (COVID-19) or the Russia-Ukraine conflict are two prime examples. For this reason, the term "organizational resilience" is back in popularity among practitioners and researchers. The literature addresses and defines the concept of organizational resilience from two different perspectives. The first defines organizational resilience as the ability to recover from unexpected, disruptive, and adverse situations and restore conditions to their initial state (Gittel et al., 2006; Sutcliffe and Vogus, 2007). According to this perspective, organizational efforts focus on adapting

the company to the new context (Lengnick-Hall et al., 2011). The second perspective goes beyond the concept of adaptation, concentrating instead on developing new capabilities to pace the changing environment and draw new opportunities from the changes (Lengnick-Hall et al., 2011).

Beyond definitions, it is worth considering how resilience can be realized. In the I4.0 context, digitalization can play a significant role in establishing and sustaining organizational resilience, and it has already demonstrated its potential in overcoming obstacles and challenges that emerged during the pandemic (Cybersecurity and Infrastructure Security Agency, 2020; Spieske and Birkel, 2021). Existing literature has shown that the management of risks and disruption SC can be facilitated by supporting operational decision making with the use of digital technologies in SC; however, current knowledge can still be considered insufficient due to the paucity of research conducted (Fischer-Preßler et al., 2020).

Among the applications capable of providing a valuable contribution to resilience are decentralized and interorganizational IT systems among the SC (which can reduce information asymmetries and facilitate disruption identification), the utilization of collaborative technology and information sharing (to enhance visibility within the supply chain), and the utilization of big data and analytics (to increase proactivity and reactivity). Harju et al. (2023) demonstrate how the potential of digitalization for resilience can be extended and amplified through practices aimed at more effectively sharing information among supply chain partners. This finding is highly relevant to this dissertation, as it allows for the hypothesis that the interaction of digital resources with other types of resources can lead to a significantly greater contribution to organizational resilience.

Thus, it is clear from these considerations how resources, including digital ones, are critical to resilience. Annarelli and Nonino (2016) describe resilience as a resource management challenge where firms need to move preventive actions to more proactive strategies. Parker & Ameen (2018) build on Ambulkar et al. (2015) to suggest that resource reconfiguration is a crucial adaptative capability that allows firms to respond to environmental changes and achieve resilience. Resource reconfiguration includes rearranging resources in response to environmental disruptions, and firms can experience resource rigidity that prevents them from rapidly reconfiguring their resources when external shocks occur (Parker & Ameen, 2018). To achieve resilience, while Ambulkar et al. (2015) mentions the need to recombine and reorganise existing resources, they insist on updating and acquiring new valuable resources without describing how the recombination and acquisition of complementary resources unfold over time. Blessley & Mudambi (2022) recently highlighted that resource reconfiguration, in the context of a pandemic or a US-China trade war, plays a crucial role in achieving resilience not only to anticipate change but also in adapting and recovering from

exogenous shocks. This insight echoes Dohmen et al. (2022), who described pre-emptive measures as insufficient in extreme and widespread disruption. Hence, while this literature recognises the importance of understanding how firms dynamically reconfigure their resources to respond to exogenous shocks by tapping in both existing and new resources, it does not provide theoretical foundations on how this happens.

This section of the theoretical background, therefore, clarifies and confirms the positive role of digitalization for resilience, while also explaining how this can occur through a process of recombination and reconfiguration of digital resources. As for human resources, although a similarly positive role can be hypothesized through the study of the literature, further research on this implication is needed.

2.3 Research objectives

The literature review and background reveal that research on the role of human and digital resources in organizational empowerment is already ongoing and has produced significant results. Firstly, it allows us to hypothesize a relationship between the social and technological dimensions of organizations and how they can contribute to organizational effectiveness and empowerment. However, the same analysis highlights some gaps that this dissertation aims to address. The common thread among these gaps is definitely linked to a lack of specificity. Firstly, the majority of research pertaining to I4.0 digitalization focuses on the direct relationship between technologies and organizational effectiveness, without considering the role or implications on the social and human dimension. Research that also considers the social dimension lacks further specificity; at times, it discusses the implications of I4.0 on human resources and work environment without considering specific technologies or technological approaches. In other instances, it discusses the implications of a single technology on human resources but without delving into the specifics related to the dimensions and characteristics of work. Lastly, there is a lack of a specific study context. Below, starting from the introduction of the purpose of this research, we will introduce the research objects and related questions, the answers to which aim to address the gaps.

This research aims to simultaneously study the technological and social dimensions that characterize the 4.0 revolution by analysing the potential relationship between the two domains. *The aim is to understand how organizations evolve in the I4.0 context and how they can achieve the empowerment leveraging on their human and digital resources*. This purpose is the common thread running through the three essays presented in this dissertation. The collection of essays aims to give an omni-comprehensive picture of the empowerment path considering technological and human resources in the organizational contexts most affected by digitalization, namely manufacturing and purchasing.

Specifically, the above-mentioned purpose can be divided into two main research objects: i) assess the interaction between digitalization and organization by investigating whether and how digital resources contribute to professional empowerment of human resources; and ii) assess the interaction between digitalization and organization by investigating the role of digital and human resources for the empowerment of organizational effectiveness, with a particular focus on resilience. Figure 2.1 depicts the research structure in terms of objectives, connected research questions and the chapters in which each of them is discussed.

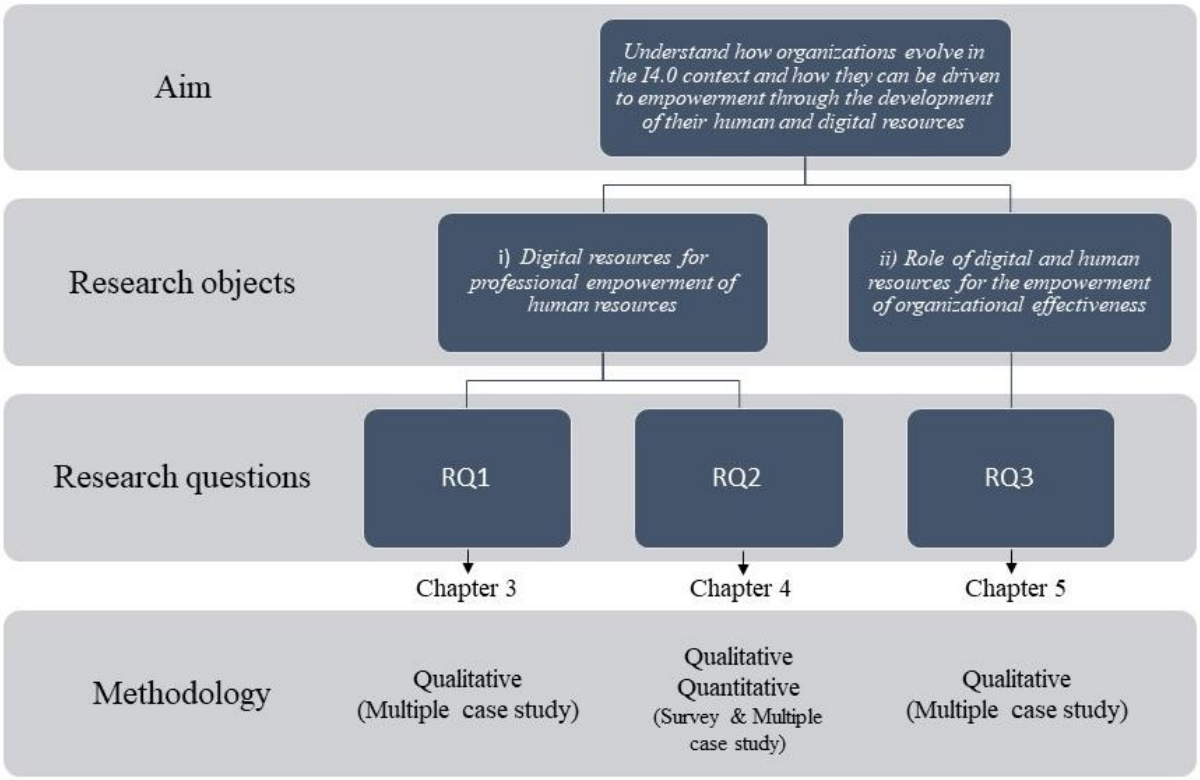

Figure 2.1 – Research structure

As already mentioned, one of the most evident limitations that has emerged in the literature related to I4.0 is the generalist approach with which it is treated. Especially in reference to the interaction with human resources, a variety of research merely refers to “digitalization”, without distinguishing different types or applications.

The theoretical section concerning technologies demonstrates how I4.0 is characterized by different technologies, particularly those with varying approaches and purposes. Specifically, mention has been made of augmenting technologies, designed to support human resources in their work and enhance their abilities, and automating technologies, intended to automate tasks previously managed by human resources. The distinct nature of these technologies implies equally diverse implications

for human resources, not only in terms of employment but also, and above all, in terms of job design. This uncertainty is complemented by that of technological implementation. Currently, the existing knowledge does not provide clarity regarding the optimal mix of augmentation and automation resources needed to bring effectiveness and efficiency to the company, while simultaneously improving the work of individuals and empowering the organization and its human resources.

Hance, driven by the willingness to immediately overcome this limitation, the first essay distinguishes two different technological approaches, thus attempting to answer the following question:

RQ1 - How do social systems and human resources evolve in relation to automation and augmentation technologies?

This essay, as discussed in Chapter 3, aims to examine the impact of augmentation and automation technologies on the socio-technical dimension within organizations, considering processes, organizational structures, and personnel. This chapter goes beyond the current generalist approach found in the literature and introduces a novel theoretical framework that delineates how automation and augmentation affect the social dimension of purchasing department and overall efficiency and effectiveness. Furthermore, it provides valuable insights for managers looking to implement digitalization, with a particular emphasis on creating a balance between automation and augmentation. It underscores the importance of adequately preparing personnel to navigate this transformative process. To gain a deeper understanding of how to professionally train human resources, it is fundamental to understand the implications of digitalization on job design dimensions.

Consistent with Chapter 3, the Chapter 4 is also aligned with the mission of providing greater specificity on the subject. While Chapter 3 achieves this aim in the technological dimension, Chapter 4 does so in the social one. Existing literature addressing the implications of digitalization for human resources tends to focus on describing the directions of professional development paths, such as upskilling and deskilling. In contrast, this dissertation seeks to analyse and investigate dimensions, characteristics, and work-related outcomes influenced by digitalization, while also maintaining a technological focus by choosing a specific technology, namely Manufacturing Execution System (MES). This application currently leverages Industry 4.0 technologies and is chosen as the technology reference for this research because of its widespread and pervasive use, often serving as a starting point for Industry 4.0 digitalization. This technology effectively links the manufacturing environment with the management environment, enabling real-time data exchange

between these two organizational domains. Indeed, cross-functional data exchange is a key principle of Industry 4.0; digitalization heavily relies on the data availability, and without a technological application capable of collecting and exchanging data from manufacturing, digitalization could not be realized. Thus, with the willingness to overcome current limitations and present the implications of technological implementation on specific dimensions of the job, in this essay, the following research question is answered:

RQ2 – How the technological implementation affects the job characteristics and outcomes?

Chapter 3 and 4 contribute to the generation of knowledge concerning the interaction between digitalization and organizations by illustrating how digital resources contribute to the professional empowerment of human resources. However, the interaction between human and digital resources does not end there, nor do the possibilities for development. Therefore, while Chapters 3 and 4 offer valuable insights into the development of the social dimension related to individuals, Chapter 5 aims to extend this development to the entire organization.

This development can be studied in relation to numerous topics, including the development of new organizational structures, the establishment of new processes and procedures, and the creation or elimination of professional roles. However, in this dissertation the focus is aligned with a concept that has been a trending topic during the historical period in which the research was conducted, namely, resilience. Indeed, the cases analysed in this work have undergone significant disruptive events in recent years, most notably the COVID-19 pandemic and the Russia-Ukraine conflict. These events have reinforced the interest and the urgency of organizations in creating and strengthening their effectiveness through resilience. Having already observed how human and digital resources, and their interaction, can lead to significant developments, the research in Chapter 5 is based on the assumption that this interaction can also be beneficial in improving the effectiveness considering the resilience criteria and the ability to respond to disruptions. For this reason, Chapter 5 will address the following research question:

RQ3 - How human and digital resources contribute to the organizational effectiveness in responding unexpected and sudden exogenous shock?

2.4 Research design

The first logical step in this research was to dive into the existing literature review with the aim of identifying relevant research topics, gaps, and limitations. Concurrently, the literature analysis was enriched by consulting non-academic sources to augment the understanding of the research topic,

thereby avoiding the oversight of potential subjects and relationships due solely to a lack of competence or experience.

The literature analysis, presented earlier, not only facilitated the selection of the research topic but also underscored the need for a deep and nuanced exploration. As previously explained, this directed the formulation of research questions primarily oriented toward examining the "how". Consequently, qualitative methodologies are needed to provide clarification of the mechanisms and dynamics of the relationships and phenomena under investigation, rather than to test the influence of variables or models.

In the first essay (Chapter 3) the case selection process consisted in three key steps. Initially, input was sought from ADACI, the Italian association of purchasing and supply management, and EIPM, the European Institute of Purchasing Management, to identify potential cases relevant to purchasing department digitalization. Subsequently, a pilot phase was initiated, where an activity model was developed through a literature review and refined through discussions with 20 recommended purchasing managers. These interviews, conducted in English, assessed the digitalization level, application types, process integration, and usage extent within the 20 companies. Finally, the outcomes of the pilot phase were employed to select eight companies with varying digital intensity levels, a minimum level digital technology adoption history, and centralized purchasing operations. Interviewees included managerial personnel and category buyers to gain insights into digital technology impact on various purchasing facets.

In the second essay the research employed a framework based on reviewed theory, centering on the Job Characteristics Model adapted for MES implementation. It embraced a mixed-method approach; combining a quantitative survey involving 40 Italian manufacturing firms (examining MES relationship to I4.0) and qualitative case studies conducted with six companies, selected from the survey's first part based on their advanced digital maturity and MES implementation status. This multifaceted methodology aimed to comprehensively explore the subject while maintaining a balance between quantitative and qualitative insights.

To gain an in-depth understanding of a phenomenon, the scientific method inherently includes an observational phase. While the previously discussed case studies certainly provided a form of observation, they remained partial and limited to what could be discerned during interviews. To overcome this limitation, beyond the specifics of individual essays, as a general approach the researcher decided to complement research activities with direct professional activity, personally working with Italian companies as they embarked on their digitalization journeys. Working closely

with practice, observing daily processes and individuals, facilitated a rapid accumulation of experience and expertise, which significantly aided in the research and article writing phases.

The accrued experience never influenced the research outcomes but profoundly impacted the research design, allowing for a better definition of variables and dimensions to analyse. This integration of personal knowledge with the one derived from the scientific literature ultimately enhanced the research depth and breadth.

Following the initial two introductory chapters, the dissertation is structured around three research papers, organized as follows. Chapter 3 presents the first essay titled "Navigating the socio-technical impacts of purchasing digitalization: a multiple case study". Chapter 4 introduces the second essay titled "Manufacturing execution system in Industry 4.0 era: from implementation to impacts on job design". Lastly, Chapter 5 concludes the results section of the research with the third essay titled " Balancing exaptation and absorption of human and digital resources to achieve organizational effectiveness through resilience". Finally, Chapter 6 summarizes the main conclusions of the dissertation, highlighting its theoretical and practical contribution.

3. NAVIGATING THE SOCIO-TECHNICAL IMPACTS OF PURCHASING DIGITALIZATION: A MULTIPLE-CASE STUDY

Acknowledgement: *This chapter is derived from the article "Colombo, J., Boffelli, A., Kalchschmidt, M., & Legenvre, H. (2023). Navigating the socio-technical impacts of purchasing digitalization: A multiple-case study". The paper was presented at the Euroma 2021 and IPSERA Conference 2022 and published in the Journal of Purchasing and Supply Management (JPSM). I thank my co-authors for working together on this research project. I was very happy to work with the EIPM network thanks to the collaboration with Prof. Hervé Legenvre. I also particularly thank the JPSM reviewers and editor for making a great contribution to the improvement of this work, both in terms of content and methodology.*

3.1. Introduction

As part of the studies on the impact of digitalization on organisations, the evolution of the purchasing department has received increased attention (Bals et al., 2019; Hallikas et al., 2021; Srai and Lorentz, 2019; Wehrle et al., 2022). Scholars are highlighting the changing role of purchasing from a cost centre to a business leader in response to the digitalization opportunities (Seyedghorban et al., 2020), and how to approach the digitalization process of purchasing and supply management functions from an intervention point of view (Srai and Lorentz, 2019). With a promise of reaching a 40 percent increase in annual savings and 30 to 50 percent less time spent on transactional sourcing (De la Boulaye et al., 2017), making purchasing digitalization work efficiently and effectively is challenging. In particular, further studies are necessary to expand our understanding of the effects of digitalization on the purchasing department, particularly to comprehend whether this phenomenon will empower the function and its employees or whether they will be weakened and replaced (Van Hoek et al., 2020; Wehrle et al., 2022). Specifically, digitalization's impact on the purchasing department's social dimension is still to be unveiled (Gottge et al., 2020). In this regard, Bals et al. (2019) provide evidence the increasing digitalization is challenging previous assumptions on the necessary competencies for modern purchasing and supply management. Moreover, digital innovation may create the fear of loosing the job caused by the evolution of the required competences. The latter has also been identified by Seyedghorban et al. (2020) among the main challenges in the path towards business leadership of the purchasing department.

Research on digitalization has highlighted two complementary approaches to the implementation of digital technologies into organizations, i.e., automation and augmentation (Weyer et al., 2015; Raisch and Krakowski, 2021). While automation aims at taking humans out of the loop and replacing them

with technology (Bailey and Barley, 2020), with augmentation, humans collaborate with machines to perform tasks, creating a complementary relationship with technology (Markoff, 2016). In this paper, we use the automation-augmentation paradox to understand the impact of digitalization on purchasing department and the possible coevolution of technical and social systems coherently with the socio-technical systems theory. In particular, the following research question is addressed:

RQ - How do social systems and human resources evolve in relation to automation and augmentation technologies?

We adopted a multiple-case study approach, selecting eight companies with a high level of digitalization of the purchasing process. Our results show how digitalization could support the evolution of the social dimension of purchasing in terms of organisation and human resources. We see an effect of professional empowerment consisting of job enlargement and increasing decision-making autonomy. Then, this research shows how digitalization supports internal collaboration, i.e., between the purchasing department and other business areas, and external collaboration, i.e., with suppliers. The research contributes to the operations management literature that studies the relationship between the technical and social dimensions, using a socio-technical perspective and contextualising it within the purchasing department. The novelty of the theoretical contribution lies in having identified a specific relationship between digitalization and social impacts, showing the potential implications on organization and human resources for each adopted technological approach (automation and augmentation) and for each level of the purchasing process (strategic, tactical, operational). The implementation in purchasing of technologies with different purposes, such as automation and augmentation, is an already known topic; however, the novelty of the practical contribution of our study is that it does not limit itself to defining cuts in approaches. Specifically, it brings specificity with respect to the different tools that characterize the two approaches, and, more importantly, it identifies and links approaches and tools to the different levels of the purchasing process. Finally, while maintaining the same specificity by level, the study makes it possible to identify the relationship between the different technological approaches and the impacts on the social system. All this evidence provides practical support for purchasing managers facing a path of digital innovation.

The paper is organized as follows. First, the theoretical background is presented, including an overview of the existing literature on purchasing digitalization and the main theoretical perspectives used in the article. Second, the research method is detailed and described. Next, the main and most relevant findings are reported, followed by a discussion of the same. Finally, the conclusions close the article.

3.2. Related literature

3.2.1 Purchasing process and its digitalization as automation or augmentation

Purchasing is a formal entity within the organisational chart, and a process characterised by many activities that ensure that maximum value is delivered to the organisation. This value can be summarised with the "five rights": getting the right quality, in the right quantity, at the right time, for the right price, from the right source (Monczka et al., 2015). The purchasing process is characterised by different sub-processes (Bals et al., 2019) organized within a general model, where activities are divided along three levels, namely strategical, tactical and operational (Van Raaij, 2016). In all these stages, data are generated and exchanged. Consequently, the purchasing department is a business function that has already been benefited from technological innovation in the past, such as the application of corporate ERPs and the advent of e-procurement (Dong et al., 2009). However, the new wave of digitalization known as Industry 4.0 has the potential to affect purchasing in a deeper way, transforming this function from tactical and administrative to a strategic unit inside the organisation (Seyedghorban et al., 2020). From a technological point of view, the digitalization of the purchasing department is characterised by enabling technologies that fit different technological groups (Klünder et al., 2019) such as connectivity and communication, data analytics, Human-Machine & Machine-Machine interaction and advanced procurement systems. Among these technologies, artificial intelligence is described as a mean to support supply market analysis and cooperation with suppliers (Hofmann et al., 2017). In addition, the use of big data can help select suppliers, formulate sourcing strategies and predict supply chain disruption (Moretto et al. 2017). Then, multi-agent technology can support the identification and selection of suppliers (Ghadimi et al., 2019) or cyber-physical systems can be used to automate demand generation (Zunk et al., 2014). With these applications digitalization can have a dual purpose: it can automate procurement activities by replacing purchasing agents by machines or it can support humans who make decision. This is consistent with research on the digitalization of management activities where two fundamental concepts have been identified: automation and augmentation (Weyer et al, 2015; Raisch and Krakowski, 2021). While automation means that machines take control of a human task, augmentation implies that humans collaborate closely with machines/digital applications to take decisions.

3.2.2 Socio-technical systems theory and purchasing digitalization

Current organisations are intricate and require a comprehensive examination. The socio-technical systems theory (STS) starts from this assumption by emphasizing the need to understand the systems through the connections and interactions between its components, such as the interactions between

people, process, and technologies (Trist and Murray, 1993). STS and digitalization are related, as digitalization is a process that affects both social and technical elements within an organisation (Beier et al., 2020). The application of the STS theory to digitalization, has resulted in distinguishing the human, technology, and organisation (HTO) dimensions (Dregger et al., 2018) where the social system encompasses both the human and organisation dimensions. Building on the HTO concept, this study examines the relationship between technology, organisation and human resources, specifically considering the different digital applications introduced in purchasing and the purchasing department itself. Relative to previous digital introductions, STS theory has identified coevolution of these dimensions, highlighting impacts at the human level (Leonard-Barton, 1988) and the organisational level (Mintzberg, 1989). The literature shows different possible evolutions and how different technologies and applications influence the human dimension. Makarius et al. (2020), examining artificial intelligence (AI) showed how various technological approaches can have different effects on human resources. The first effect is substitution due to the most straightforward applications related to task automation. In this perspective, we observe a reduction in the employees' autonomy of decision and breadth of tasks (Cagliano et al., 2019). The operative work becomes constrained to procedures and reduced to limited and repetitive tasks. The second effect is complementarity in which advanced technologies and humans complement each other. This perspective sees technologies as enablers of a professional evolution characterised by greater autonomy and less standardisation of activities for employees (Venkatesh et al., 2010). In this perspective, technologies provide knowledge and support to the worker, facilitating decision making that remains at the human level. The evolution also involves job enlargement with more interdisciplinary, interactive and team-based activities, mainly thanks to the information exchange enabled by technology (Basaglia et al., 2010). In summary, in the literature we have evidence of different technological orientation and professional evolutions: complementarity of digitalization with human resources maintaining an active role at the operational and decision-making level or digital substitution replacing the human role in favour of technology (Leyer and Schneider, 2021). The literature discusses these developments on a general level, thus it is possible to expect these concepts to also apply to procurement personnel (Klünder et al., 2019) even if purchasing personnel will need to be prepared remains an open question (Schiele and Torn, 2020).

According to STS, we can expect impacts even on organisational dimension. The literature provides some insights into how digitalization can improve collaboration, but often from a supply-chain perspective, with a lack of specificity on purchasing (Srai and Lorentz, 2019). Digitalization can influence the horizontal and vertical integration of the company, opening the possibility for new collaborative dynamics both internally and externally, especially in the interaction with suppliers

(Oesterreich and Teuteberg, 2016; Oztemel and Gursev, 2018). The most common collaboration mechanisms concern information sharing, joint planning and decision making, thanks to the application of technologies such as Internet of Things, Blockchain and Cloud Systems (Glas and Kleemann, 2016). Digitalization can also potentially reduce the complexity and uncertainty of coordination, ensuring better visibility and reducing the risks of demand and information interruption (Ivanov et al. 2019).

3.3. Research framework

Literature designs possible paths of evolution for organization that approach digitalization, still procurement lacks a clear theoretical model that foresees the possible organizational impacts and the conditions affecting these effects.

This study examines the digitalization of purchasing, from drivers of implementation to impacts on organisation and human resources (in both cases we are always referring to the organization and resources of the purchasing department). The conceptual framework that guided the research is based on the socio-technical theory and the automation-augmentation paradox, thus considering the relationship between the technical and social dimensions and studying their coevolution (Trist and Emery, 2005). At top level we consider the drivers that can led to digitalization in purchasing. The technical component is represented by digitalization in terms of automation and augmentation applications. The organization and human resources represent the social component. Cimini et al (2020), starting from the five organisational dimensions (strategy, people, rewards, process, and structure) proposed by Galbraith (2002), introduced a new classification composed of three constructs: competences, job and structure. This study, starting from this classification, at first evaluates within the purchasing personnel the impact at human level in terms of tasks breadth and autonomy (for the job dimension), and in terms of competences. Then, at the organizational level the study considers the evolution of the purchasing department in terms of relations with other functions (internal collaboration) and with other stakeholders in the supply chain (external collaboration). Given the coevolution of the two dimensions, this research hypothesizes a reciprocal relationship between the social and technological dimensions. This reciprocity means that we simultaneously consider the social structure influencing technological choices and being impacted by digitalization. Table 3.1 summarizes the elements that characterize the framework of the study.

Table 3.1 – Framework of the study

Dimension	Component	Item investigated
Social	Human resources	Autonomy, Tasks breadth, competences
	Organisation	Internal collaboration, external collaboration
Technology	Digitalization	Automation
		Augmentation

3.4.Research method

We adopted a multiple-case study approach to answer our research questions. The case study approach is aligned with the study's exploratory nature (Voss, 2016). According to Yin (2009), case study is "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident", as such it adopts an interpretivist view on the phenomenon under study. Given the novelty of the topic covered and the limited knowledge available on the new technical-social dimensions relationship in the context of purchasing, rather than conducting statistical analysis on a large sample, we opted for this method, which allows us better exploration and in-depth detail.

3.4.1 Cases selection

The case selection was developed in three phases. First, representatives from ADACI, the Italian association of purchasing and supply management, and EIPM, the European Institute of Purchasing Management, recommended a starting sample of potential interesting cases with respect to the digitalization of the purchasing department. Second, in a pilot phase an activity model was established based on a literature review and refined through discussions with the 20 purchasing managers suggested. At the end of the preliminary interviews, conducted in English, all the 20 companies were questioned about their digitalization level, examining the types of applications adopted, their diffusion in the process and degree of use. Third, we used the results of the pilot phase to assess the digitalization level of the purchasing department and we applied our selection criteria. We selected companies from industries characterized by different digital intensity levels (Calvino et al., 2018), but at a relatively advanced stage of digitalization of the purchasing department. Also, we selected organisations that had at least five years of experience with the use of digital technologies in purchasing. This allowed us to access cases that had implemented multiple projects at strategic, tactical and operational levels. Finally, we selected organisation that centralized their purchasing activities to ensure that we could gain insight on company-wide and not local implementation of digital technologies in purchasing. This process led to the selection of eight companies. Since the purchasing process can differ significantly between sectors, we decided to consider companies from

different industries, at different digital intensity levels, so the eliminate industry bias and to understand whether there were similarities and differences. The selection of informants for each case was performed as follow. First, we interviewed one individual with a managerial role who has a complete visibility on the use of digital technologies for the organisation. This was typically a member the purchasing management team or someone in charge of purchasing process improvements or purchasing transformation. Then, we targeted individuals who are category buyers or equivalent so we could understand from them how digital technologies impact on strategic, tactical and operational tasks. Table 3.2 shows the case studies considered for this research. For each case, two interviews were conducted with purchasing department managers. All the interviews were conducted in English.

Table 3.2 - Summary of analysed cases

ID	Industry	Digital intensity of sector	Business	Employees	Interviews	Interview duration (minutes)
A	Aerospace	High	Manufacturing	80.000	2	131
B	Automotive	Medium-low	Manufacturing	127.000	2	139
C	Electrical/electronic	Medium-high	Manufacturing	136.000	2	103
D	Telecommunication	High	Service	17.000	2	131
E	Information technologies	High	Service	350.000	2	105
F	Telecommunication	High	Service	100.000	2	157
G	Agri-food	Low	Manufacturing	8.500	2	109
H	Plastic and rubber products	Medium-low	Manufacturing	400	2	145

3.4.2 Data collection and analysis

A specific interview protocol was developed, and the data was collected through semi-structured online interviews conducted between the second half of 2020 and early 2021. Then, we evaluated the technological implementation at different process levels and finally analysed the impacts on the organisation. The interview protocol was developed to give the interviewees a logical path to follow, avoid going off-topic, and make the reasoning easier and more immediate, allowing the gathering of useful information in the shortest possible time. In this regard, the protocol also includes the general model of the purchasing process drawn from the literature. Thanks to this inclusion, besides giving a logical path in the responses, we were also able to verify that the model of the purchasing process

was aligned with the one implemented by the organisation analysed. This allowed us to ensure homogeneity in the case studies and results related to technology implementation. Finally, at least two researchers always participated in each interview. In addition, all the interviews were recorded and transcribed verbatim.

A within-case and cross-case analysis were performed (Eisenhardt, 1989). In the within- case analysis for each company, we have developed multiple tables to structure data. In the cross-case analysis, we have combined the data into summary tables, coding the data according to our conceptual framework, to spot any differences and commonalities among the studied cases. Three researchers independently coded all the cases following the research framework presented, but also inductively identifying new codes. To ensure consistency, the research team discussed potential discrepancies till consensus was reached.

3.4.3 Methodological rigour

Data collection and analysis were designed to guarantee construct validity, internal and external validity and reliability. To ensure construct validity, we triangulated different sources, that are data from cases with internal documents provided by the company and information found from the website. To ensure internal validity, we defined a specific protocol, conducting more than one interview for each case and having the interviewees verify the correctness of the information to reach saturation. Concerning external validity, being the analysis exploratory and based on case studies, it does not aim to completely generalise results. However, the sample was purposely designed to include companies at an advanced level of digital maturity, so the impacts identified may be valid for companies with these characteristics and provide best practices to be followed by companies at lower levels. We also reasoned about commonalities and emerging differences in the cases analysed. Finally, multiple researchers were involved in coding and analysing the data to ensure reliability.

3.5. Results

This section describes the findings of the study on the main dimensions presented in the research framework. In particular, the drivers that drove the digitalization of the purchasing department are initially described. Then for each level of the purchasing process we detail the main technologies implemented and their applications, differentiating in terms of automation and augmentation, and their effects on human resources (in terms of autonomy and tasks breadth) and on the organisation (in terms of internal and external collaboration). Each section provides the table containing the main quotes for each of the covered items. The number of quotes for each item is proportional to its presence.

3.5.1 Digitalization implementation: drivers

To understand the digitalization process of purchasing departments, first we investigated why they invested in technologies by identifying the main drivers. The results delineate three main drivers, namely data aggregation, efficiency and effectiveness. Table 3.3 reports the main quotes collected from our informants for each of the three drivers.

Table 3.3 - Drivers to digitalization and evidence from cases

Drivers	**Main evidence from the cases**
Data aggregation	*Q1: "In terms of data, the focus was to completely restructure, orchestrate and harmonize them"* *Q2: "We need digitalization to improve in the field of compliance, to avoid what is happening right now, involving exchanges of certifications and information between multiple stakeholders"* *Q3: "The company is overwhelmed by data, the information extracted is not at a satisfactory level, especially when compared with the amount of data collected"* *Q4: "Ultimately data quality is key: after a diagnosis phase now investments in poka-yoke techniques to move away from Garbage-in-Garbage-out phenomena;"* *Q5: "There is the need to start asking the question about what is the data that is needed and wanted, instead of what is the data that can be collected"* *Q6: "Through automation a lot of information can be obtained, but it can generate an overflow, and this is where intelligence becomes fundamental, either through augmentation or human intervention to separate what matters from what doesn't and to devise a strategic intent out of it"*
Efficiency	*Q7: "Transactions are being automated and made quicker; issues are automatically corrected this led to an improvement in operational efficiency"* *Q8: "We realized that procurement activities took too long or cost too much, due to the complexity and size of the company, with many handoffs and multiple approvals"* *Q9: "We realized that our purchasing was not fast enough, and we needed to really do something and transform"* *Q10: "Digitalization allows to collect data faster and more efficiently from different fields"* *Q11: "Digitalization leads to more proactiveness, quicker results, fewer escalations and crisis to manage, due to better anticipation"*
Effectiveness	*Q12: "We have a significant push for automation but still some areas exist in which human decision is kept and technology is there to augment and support decision making"*

	Q13: "Anything that is not highly collaborative, or complex should be prone to automation, leaving for augmentation things that have a collaborative complexity" *Q14: "Digitalization is helping to accelerate decisional processes and providing more information for them"* *Q15: "The effort is in really structuring the procurement to be working in an agile way, not just conventionally, like category managers and supplier managers"* *Q16: "Digitalization allows a broader vision on the market, implying wiser and more accurate decisions, by being able to monitor bigger ranges of data"* *Q17: "Digitalization was mainly driven by the need of ensuring supply chain resilience, commitment to the market in terms of compliance and, ultimately the need of providing means to devote more time to strategy rather than operational level activities"* *Q18: "We invest in digital tools to improve the visibility of the purchasing organisation"*

According to the interviewees, the shift towards digitalization in purchasing was driven by the need for data aggregation. One of the goals highlighted by all our informants is the pursuit of the development of their data aggregation capability to harmonize and orchestrate data (Q1). Data harmonization consists in creating data repository or data warehouse out of the many systems and tools used by the different departments and legal entities across a company (Q2 & 3). The quality of data is a concern in digitalization initiatives as manual entries, manual transfers or mistakes in a spreadsheet can results in poor data quality (Q3 & 4). Because of the abundance of data that can create an information overload, our informants highlighted the importance of carefully selecting and harmonising data that contribute to improve decision-making (Q5 & 6). Digitalization plays a crucial role in helping purchasing departments sift through the noise and focus on the data that is most relevant to decision making.

Efficiency is the second driver of digitalization highlighted by our informants. Through automation, purchasing departments reduce their operational costs, streamline their process, reduce unnecessary information transfers, and eliminate unnecessary approvals to make the process more efficient (Q7 & 8). All our informants highlighted the need to collect data faster and to reduce the time and effort required to complete purchasing tasks (Q9 & 10). This causes quicker results, less escalations and better anticipation as issues can be identified before they become problems (Q11).

Effectiveness is the third key driver of digitalization in purchasing. This driver is supported by augmentation, through which humans and machines work together. With access to a larger range of data, companies can better handle complex and collaborative tasks and come up with faster, more reliable and accurate decisions (Q12, 13 & 14). Digitalization also allows companies to be more agile

and flexible. Thanks to digitalization and the accessibility of a wide range of data, it becomes easier for buyers to perform projects in across different segments of purchase. Three of the organisations in our sample were exploiting to a different extent this increase in flexibility (Q15). Digitalization improves effectiveness by providing more accurate understanding of the market and producing detailed information on suppliers that improve decision-making (Q16). Two of our informants provided examples of significant cost savings ranging from 10% to 15%; they were generated by costs analysis using data collected from multiple sources. Moreover, digitalization improves effectiveness by ensuring supply chain resilience and reducing risks. The ability to monitor and track the performance of suppliers and supply chains helps companies to identify issues before the problems occur. Some of our informants said that risks that were not anticipated before are now becoming predictable and easier to address (Q17). Finally, digitalization allow companies to improve the image of the purchasing organisation (Q18). As digitalization allows rapidly reaching data-driven consensus, purchasing departments are perceived as valuable contributors to effective decision-making.

3.5.2 Automation and augmentation in the purchasing context

Following the description of the main drivers for the digitalization of purchasing departments, in this section we summarize the main types of technological applications, how they impact on the performance of purchasing departments and their scope of application. Pushed by the three identified drivers, the analysed companies have adopted two main technological orientations: automation and augmentation. Automation addresses the need for greater efficiency by reducing lower-value activities, simplifying and speeding up the process and providing faster access to data. Augmentation addresses the need for increased effectiveness by improving the quality of decisions and the ability to sense and respond to risks and opportunities rapidly. Automation applies to simple, repetitive tasks, while augmentation enables more complex and collaborative tasks where human knowledge is necessary to complement available data. Table 3.4 provides a characterisation of automation and augmentation in terms of definition, as well as impact and scope of application deriving from our observations in the case companies.

Table 3.4 - Automation and Augmentation in purchasing

	Automation	Augmentation
Definition	Automation implies that machines take over a human task (Raisch and Krakowski, 2021; Makarius et al., 2020).	Augmentation means that humans collaborate closely with machines to perform a task (Raisch and Krakowski, 2021; Makarius et al., 2020).
Impact	Increased efficiency through a reduction of human resources, faster processes and access to more data (Q6, 7).	Effectiveness through improved quality of decision and the ability to sense risks and opportunities earlier (Q12, 13 & 14).
Scope of application	Simple tasks that can be performed autonomously through automation (Q6 & 13).	Complex and collaborative tasks where complementary knowledge is required to take specific decisions (Q6 & 13).

3.5.3 Automation, augmentation and the impacts on the social dimension of purchasing

For each level of the purchasing process (strategic, tactical and operational) we provide some examples of the collected data. This includes the implemented technologies and applications covering both automation and augmentation. To understand the relationship between the technical and social dimensions of purchasing, we include the effect of technological application at the human level, in terms of autonomy, task breadth and competence, and at organisational level, in terms of internal and external collaboration.

3.5.3.1 Applications and impacts at the strategic level

Digitalization of purchasing at the strategic level is mainly characterized by the implementation of technologies with augmentation orientation. Table 3.5 shows the technological applications and the impacts on the social dimension of purchasing at the strategic level.

Table 3.5 - Digitalization and impacts on social dimension at strategic level of purchasing

Strategic applications and impacts	**Main evidence from the cases**
Technologies	E-procurement system Business Intelligence Artificial Intelligence Spend management tool Market intelligence

	Predictive pricing and costing tools
Applications Automation	*Q19: "For specifications and clarifications, there is an automated tool to define in detail specifications"*
Applications Augmentation	*Q20: "The business intelligence solutions employed takes data from the e-procurement tool and generates analysis on financial performances for different segments, geographies or business units"* *Q21: "Time was wasted in market assessment done inefficiently. Last year, to solve this, we implemented a project with a market intelligence provider"* *Q22: "We have lots of specific applications, like those enabled by artificial intelligence, used for example for contract intelligence or supplier intelligence or pricing intelligence"* *Q23: "For commodities it may be possible to automate, but for technical categories, augmentation is more likely, since humans cannot be replaced"* *Q24: "For forecasts, plans and requirements, there's a dedicated portal for Supply Chain Management, which is linked to a platform for Supplier Relationship Management"*
Autonomy of decision in existing tasks	*None*
Tasks breadth	*Q25: "Our personnel are now able to concentrate on more important tasks of their job, consisting in category strategy, high level negotiation and contracting"* *Q26: "Digitalization allows to spend more time in high added value activities, moving the focus to strategical discussions rather than tactical or operational"*
Competences	*Q27: "People will need to switch from the role of doers to the role of thinkers to support this"* *Q28: "The process of making decision requires certain skills in terms of identifying whether the data are making sense or not"* *Q29: "It's important to make sure people in purchasing have the competences needed and, if that is not the case, to accompany them and to develop the competences that they are missing in order to do their new job well"* *Q30: "A lot of focus is on procurement skills transformation, moving from being a generalist to having special skills, whether they are on technology, data or any aspect of that"* *Q31: "The management realized that tough decisions were needed, and they replaced those employees with new ones, less experienced but more energetic"*

Internal collaboration	*Q32: "Digitalization brings improvements in cross-functional collaboration, mainly with shared KPIs, which are made easily available in dashboards"* *Q33: "Better ability to react quickly and take better decisions internally, due to those being shared by all the relevant people of various department, in a limited amount of time"* *Q34: "Ultimately, more internal interconnection is present, with procurement having more of a pro-active role, instead of a reactive one"*
External collaboration	*Q35: "We are creating more relevant interfaces with suppliers, through dedicated portals to bring more strategical interactions with the suppliers"* *Q36: "There are capabilities to capture strategic innovation through proposals, for example value engineering proposals from suppliers are captured in a new centralized database"*

The managers we interviewed described several augmentation applications. For instance, business intelligence solutions take data from the e-procurement tool and other sources to generate analysis for different segments, geographies, business units or groups of suppliers (Q20). One of the interviewed managers explained that before implementing augmentation technologies the market analysis was performed inefficiently and wasted time but with the implementation of a market intelligence tool this problem was solved (Q21). Then, our results show that artificial intelligence is used for specific applications such as contract management, costing and supplier management (Q22). Augmentation also supports the development of forecasts and the management of supplier production capacity thanks to dedicated portal for supply chain management, linked to a platform used for managing suppliers (Q24). Our informants also suggested that specifications and related clarifications can be supported by tools that ensure that all suppliers have access to the same level of information. The automation orientation is very limited at strategic level, which is reduced to tools to simplify specification and clarification activities (Q19), since the activities at this level tend to require complementary knowledge and human interventions that cannot be replaced by machines (Q23). However, augmentation is facilitated by the continuous automation that has occurred before and facilitated the aggregation of multiple data sources.

Concerning the impact on the social dimension, at the individual level our results show an enlargement of tasks due to augmentation. Automation and augmentation allow personnel to concentrate on important tasks in their job, including developing category strategies, high-level negotiation, and contracting activities (Q25). They spend more time in high added-value activities, moving the focus towards more strategic discussions and collaborative decision-making activities

with other functions rather than tactical or operational tasks (Q26). In contrast, no effects of technologies on decision-making and operational autonomy at the strategic level were identified.

Digitalization at the strategic level enables a shift in the role of purchasing professionals from "doers" to "thinkers" (Q27). This shift requires a different set of skills and competences to support the new activities brought about by digitalization effectively. The decision-making process becomes more complex as it requires data analysis and interpretation skills to ensure that the data being used is accurate and meaningful (Q 28). To mitigate these challenges, organisations need to focus on the development of the necessary competences and skills within their purchasing teams. This includes providing training and support to help professionals acquire the necessary skills in technology, data analysis, and other key areas (Q29). The need to move from being a generalist to having specialized skills is also essential to stay competitive in the digital age (Q30) and management gave more weight to the energy of new resources than to experience, thus introducing in new staff.

Considering the impact on the organisational dimension, we identified an increase in terms of internal collaboration thanks to augmentation. Automation and augmentation facilitate internal communication and the sharing of strategic information, including KPIs and supplier information (Q32). By providing purchasing professionals with advanced tools and technologies, such as artificial intelligence (AI), predictive pricing and advanced costing tools, augmentation leads to improved decision-making and increased effectiveness. In turn, an improved internal collaboration is experienced as purchasing professionals can share their insights and collaborate more effectively to make strategic decisions (Q33). Augmentation technologies can also be used to support and enhance category management, which is a key element of the purchasing department's internal collaboration. With the support of these technologies, the purchasing department can improve the performance of the internal team. Augmentation technologies can also be used to improve the internal collaboration by facilitating the use of collaborative platforms, where stakeholders can capture both initiatives and data and document decisions at the strategic level. This allows for better alignment of the purchasing department with the rest of the organisation and leads procurement to work closely with other organisational units in a proactive manner (Q34).

In terms of external collaboration at the strategic level, especially with suppliers, we identified potential improvement due to augmentation applications. First, augmentation technologies allow purchasing professionals to access and analyse vast data and share their insights to collaborate with suppliers to negotiate better prices, terms, and conditions. The dedicated interfaces and portals support this strategical interaction (Q35). Then, augmentation can help to establish and strengthen the relationship between the purchasing department and the suppliers by providing a more transparent

and efficient communication and negotiation process. This allows for a better alignment of the objectives, leading to a mutual understanding and cooperation between the parties. Finally, augmentation facilitates the analysis of supplier performance, the identification of risks and opportunities and the strategic decisions. This leads to improved external collaboration as purchasing professionals can collaborate with suppliers to ensure continuity of supply, mitigate risks, and identify new opportunities in the market thanks to the new digital capabilities to capture strategic innovation through proposals (Q36).

3.5.3.2 Applications and impacts at the tactical level

At the tactical level, various technologies have been implemented to increase efficiency and improve decision-making. These technologies are used combining both augmentation and automation, to optimize and support the processes and tasks of the purchasing department. Table 3.6 shows the technological applications and the impacts on the social dimension at the tactical level.

Table 3.6 - Digitalization and impacts on social dimension at tactical level of purchasing

Tactical applications and impacts	**Main evidence from the cases**
Technologies	E-procurement tool Digital application for supplier management Contract life cycle management tool External database E-signature RPA (robot process automation) for RFQ (request for quotation) and RFI (request for information) Enhanced compliance systems
Applications Automation	*Q37: "In terms of negotiation and contracts, the managing of contracts now implements e-signatures, which are much more efficient than the previous method, which were wasting time"* *Q38: "For contract management there is an AI-based application to automatically read all contracts and create a contract hierarchy, identifying which contracts needed to be updated and where, leading to savings of hundreds of manhours"* *Q39: "Cost breakdown and analysis are part of the e-procurement tool"* *Q40: "The process of capturing suppliers' risk is automated and digitalized, through the integration in the system of dataflows from external providers, especially in terms of financial risk and ratings"*

	Q41: "Thanks to digitalization you can now know much more about suppliers in terms of compliance or other information useful for screening"
Applications Augmentation	*Q42: "Work is being done on product costing by quickly providing buyers with a price target for negotiation and by making sure that the supplier is offering the right cost"* *Q43: "In source to contract subprocess, many phases are supported by technologies: man and machine can then work together to create a greater impact"* *Q44: "The purchasing department is equipped with a tool is tool for supplier evaluation, with matrixes and grids, which are shared with internal partners during business reviews, with the additional objective to improve their performance"* *Q45: "Process of supplier identification, selection, qualification evaluation is digitalized with an application for supplier management, so that everyone involved can access data and comments that are then shared, with visual aspects included, with the suppliers"*
Autonomy of decision in existing tasks	*Q46: "There are programs to automate several aspects of tactical activities, such as providing category managers automatic alerts for risks, not to waste time to receive data from others"* *Q47: "Digitalization is improving decision making autonomy by giving more confidence to employees, who can take better decisions thanks to the better availability of data"* *Q48: "Thanks to digitalization the increase in delegation was made possible, without putting the company in danger"* *Q49: "People in purchasing have experienced an increased autonomy in negotiation, due to a higher delegation threshold, made possible by digitalization"* *Q50: "The degree of digitalization has a positive impact on decision making, but you can hurt yourself by taking the level of implementation to extremes"*
Tasks breadth	*Q51: "Digitalization helped to redistribute tasks, releasing buyer from the most tactical moving to the most strategical"* *Q52: "We observed a higher number of tasks related to analysis, while other operational activities were eliminated"* *Q53: "The support offered by digitalization leads to a wider breadth of tasks horizontally speaking, in terms of having to coordinate their work with other departments (finance, legal, business, tax)"* *Q54: "Digitalization allows for enlargement of tasks, but that can ultimately be overwhelming"*
Competencies	*Q55: "Need to perform training to improve digital skills in certain employees who are lacking in that department, as people must reach the competences needed to use tools autonomously"*

	Q56: "Sometimes data literacy is severely lacking among employees" *Q57: "Employees must have skills to access the data and generate the necessary reports independently"*
Internal collaboration	*Q58: "Digitalization leads to an easier and better communication by having factual information at disposal"* *Q59: "The dashboards had a big impact on internal collaboration, allowing real time monitoring of performance and, moreover, the better tracking of the process"* *Q60: "Internal collaboration was definitely improved, even considering that now the collaboration is more formalized, and this makes it possible to immediately notify problems"* *Q61: "The legal teams, purchasing and other departments are supported through this improved service, which now takes roughly 16 days to work on one contract, instead of 25-30 days"*
External collaboration	*Q62: "Digitalization plays a role in most of the interfaces between procurement and other external stakeholders"* *Q63: "Digitalization is viewed as a mean to filter out noises that don't add value in the collaboration with suppliers, thus allowing more efficient processes"*

Automation at the tactical level is mainly aimed at reducing wasted time in performing certain operations, especially in negotiation and contract management activities (Q37 & 38), but also at speeding up the collection of internal information (Q39) and especially supplier information (Q40 & 41). Augmentation at the tactical level ensures rapid access to information needed in negotiation and contracting activities (Q42 & 43), but more importantly it supports employees in managing suppliers in the identification, selection, qualification and evaluation phases (Q44 & 45).

Both automation and augmentation at tactical level can have significant impacts on autonomy of the purchasing department personnel in conducting existing activities. Automation technologies, such as RPA and e-signatures, can streamline processes and reduce the need for manual collecting data and input from other departments, increasing employees' autonomy (Q46). This can lead to increased efficiency and free time for employees. Augmentation technologies, such as digital applications for supplier management, contract life cycle management tools, and enhanced compliance systems, can also increase autonomy by providing employees with access to more information and resources. Thanks to this, digitalization gave employees more confidence, leading to improved decision-making (Q47). Because of the control (over the process, not the people) offered by digitalization, even managers were able to increase the confidence in their personnel, making it possible to delegate more without endangering the organisation (Q48). One of the managers interviewed stated that

procurement people have experienced greater autonomy in negotiation due to a higher threshold for delegation, made possible by digitalization (Q49). In addition, another interviewed manager, confirming the growing possibilities of greater autonomy for employees, reminds that too extreme level of decentralization of decision-making could be harmful and could congest the organisation (Q50).

Digitalization of the purchasing department at the tactical level can have a significant impact on tasks breadth. Adopting both automation and augmentation technologies can lead to job enlargement of purchasing department employees with new tasks. On the one hand, automation technologies can automate repetitive and time-consuming tasks, such as contract management, supplier evaluation, and cost analysis. This can free up time for purchasing employees to focus on more strategic and value-added activities (Q51), such as supplier relationship management and cost negotiations. On the other hand, augmentation technologies, such as e-procurement tools, digital applications for supplier management, and contract life cycle management tools, can provide purchasing employees with access to real-time data, analytics, and other information, increasing the number of tasks related to analysis (Q52). These tools can also increase the collaboration with other departments and external partners, such as suppliers and legal teams, which can lead to an expansion of the tasks related to the coordination of their work with other stakeholders (Q53). To ensure the feasibility of the job enlargement effect, it is necessary that automation also accompanies augmentation. Without freeing resources from low-value activities, the new tasks would over allocate employees, making their work overwhelming (Q54).

Furthermore, it is important to note that while digitalization can lead to job enlargement, it is not always the case, as it can also lead to job displacement or job loss, especially in the case of automation technologies. Therefore, it is important for organisations to consider the potential impacts of digitalization on employment and implement measures to mitigate any negative effects, such as upskilling and reskilling programs for employees (Q55). Data literacy is a key skill that is often lacking among employees (Q56). The integration of man and machine is also a key consideration in the tactical level of purchasing, with the need for employees to have technical skills to use tools autonomously, to access data and generate reports independently (Q57). These skills are also essential for employees to be able to handle new activities related to internal and external collaboration. Without them, employees may struggle to perform their duties and the implementation of digitalization may not be as successful as intended.

Digitalization can have a significant impact on internal and external collaboration at the tactical level. Augmentation technologies can improve internal collaboration by providing a centralized platform

for communication and data sharing among different departments and teams within the organisation. This provides everyone with shared and update information. (Q58) and automation ensures that data are collected automatically and quickly. For instance, digitalization allowed the real time monitoring and tracking of the process and of performances (Q59) and made possible immediate notification of problems (Q60). Increased internal collaboration between different departments also supports activities involving suppliers, with improvement in supplier management and more effective supplier selection processes. Similarly, contract life cycle management tools can allow legal teams and procurement teams to collaborate more effectively, resulting in improved contract management processes (Q61). Considering the external collaboration, digitalization (Q62) is a key interface to collaborate with external entities, with the use of e-procurement tools and external databases. For instance, an e-procurement tool can facilitate the communication with suppliers and make the process of purchasing more streamlined, while an external database can provide access to external market and compliance data, which can be used to make better purchasing decisions. Automation helps to filter out noises that don't add value in the collaboration with suppliers, thus allowing more efficient processes (Q63). For instance, without the help of digital tools, reviewing contracts with suppliers could be extremely problematic, with huge time losses in useless tasks such as verifying that everyone was on the same version of a contract.

3.5.3.3 Applications and impacts at the operational level

At the operational level, digitalization is characterised by the implementation of automation technologies to gain efficiency (Q64 & 65). These technologies are primarily focused on streamlining and automating routine tasks such as purchasing order preparation and approval (Q66), as well as automating invoices settlement and payments to make the transaction with supplier more efficient (Q67). Additionally, the implementation of automation tools for data collection and automated tracking of purchase orders (Q68) also contribute to the digitalization of the operational level. Table 3.7 shows the technological applications and the impacts on the social dimension at the operational level.

Table 3.7 - Digitalization and impacts on social dimension at operational level of purchasing

Operational applications and impacts	**Main evidence from the cases**
Technologies	ERP RPA E-procurement

	Automation of purchasing order preparation, approval and contract Automation of invoices settlement and payments PI and metrics automated Automatic data consolidation
Application Automation	*Q64: "There is a lot of process efficiency due to automating and simplifying processes: the gain is easily 40-60 or even 70% for invoice processing or order processing"* *Q65: "We use RPA at operational level, which makes any process faster, cheaper and reproduceable"* *Q66: "Our focus was on the implementation of tools related to purchasing orders treatment, in particular aimed at automating preparation and approval of the orders"* *Q67: "Efficiency has improved especially at this level, due to smoother processes, in terms of transactions with suppliers becoming more efficient"* *Q68: "We developed a new tool to send purchase orders capable of sending orders and receiving confirmation receipts, but also tracking the performances and delivery dates"*
Applications Augmentation	*None*
Autonomy of decision in existing tasks	*Q69: "Digitalization is providing tools that give relevant data and contribute to reach a higher level of autonomy"* *Q70: "Buyers now need to seek less approval from managers"* *Q71: "Buyers are benefitting from the digital information provided by the implementation of automatic catalogues, where pricing and latest prices from vendors are presented"*
Tasks breadth	*None*
Competencies	*Q72: "We faced problems with the qualification of the procurement personnel, which wasn't prepared nor trained, in terms of competences, to use digitalized tools"* *Q73: "After the implementation, the main issue is how people will react to the new tools"* *Q74: "Digitalization didn't happen in a top-down way, with centralized decisions, but rather happened with interactions with final users, to understand their needs, collect their inputs about the general direction and understand which of their issues could be solved with digitalized tools"*
Internal collaboration	*None*
External collaboration	*None*

One of the main impacts of digitalization at the operational level is an increased level of autonomy for buyers, as digital tools provide relevant data and enable them to make decisions with less approval from managers (Q69 & 70). For instance, the implementation of automatic catalogues provides buyers with updated pricing and vendor information which allows them to make more informed decisions (Q71). In other terms, employees at operational level can access data and make decisions with less supervision. However, in terms of tasks enlargement, we did not find any significant impacts due to digitalization at the operational level. The automation of routine tasks may lead to job simplification, but it does not appear to lead to a significant change in the breadth or depth of tasks performed by the buyers.

Digitalization at the operational level of purchasing can lead to issues with the qualification and training of procurement personnel in terms of their competences to use digitalized tools (Q72). After implementation, there may be challenges in how employees adapt to the new tools and their ability to use them effectively (Q73). Some tools may be user-friendly, but others may not be as intuitive. To address these issues, it is important to understand the needs of the final users, collect their inputs about the general direction, and understand which of their issues can be solved with digitalized tools (Q74). This can be achieved through a hand-in-hand integration between man and machine, where the focus is on training and qualification of procurement personnel to use digitalized tools effectively.

Considering the organisational dimension, in terms of internal and external collaboration, the use of digital tools and automation technologies did not appear to have a significant impact at the operational level. While digital tools may facilitate communication and data sharing, they do not appear to fundamentally change the nature of internal or external collaboration within the purchasing department.

3.5.3.4 Variations across cases

Our results show general trends where automation results into smaller, more effective purchasing departments with more autonomy in decision-making for operational and tactical tasks and where augmentation results in increased effectiveness with an enlargement of tactical and strategic tasks for better qualified purchasing professionals. However, the careful analysis of the cases also highlights that different paths can exist. Compared to other cases, the interviews performed for cases D and F tend to exhibit the characteristics of purchasing departments that are mainly focused on performing operational and tactical tasks in a very efficient way. Our informants for case D highlighted that strategic decisions are taken by directors outside of the purchasing department. They are given access to all data provided by purchasing and they use voting systems provided by the purchasing digital

system. Also, our informant for case F was mainly providing examples where the purchasing department was sourcing commodities and standard goods or services. One hypothesis we can formulate at this stage is that purchasing department that only need to source commodities and standard goods mainly benefit from automation. While purchasing departments that purchase more complex goods and services benefit from augmentation. This was suggested by one of our informants who told us that for commodities, it is possible to automate, but for complex technical categories, augmentation is more likely as humans cannot be replaced (Q23). However, the process of requalification should also be considered to understand this dynamic. Indeed, our case D informant mentioned that senior employees were not able to adapt to their new technical environment and were replaced with less seasoned ones but more capable of doing the expected work (Q31). Instead, for cases A and F we were told that the move towards more strategic tasks was facilitated by the level of qualification that existed in the purchasing department. For case F it was suggested that no problems in term of competence or change management were experienced as the company employs many people with advanced technical education.

3.6. Discussion

Based on our findings, we propose a framework on how digitalization, by enabling both automation and augmentation, impacts the purchasing social dimension (see Figure 3.1).

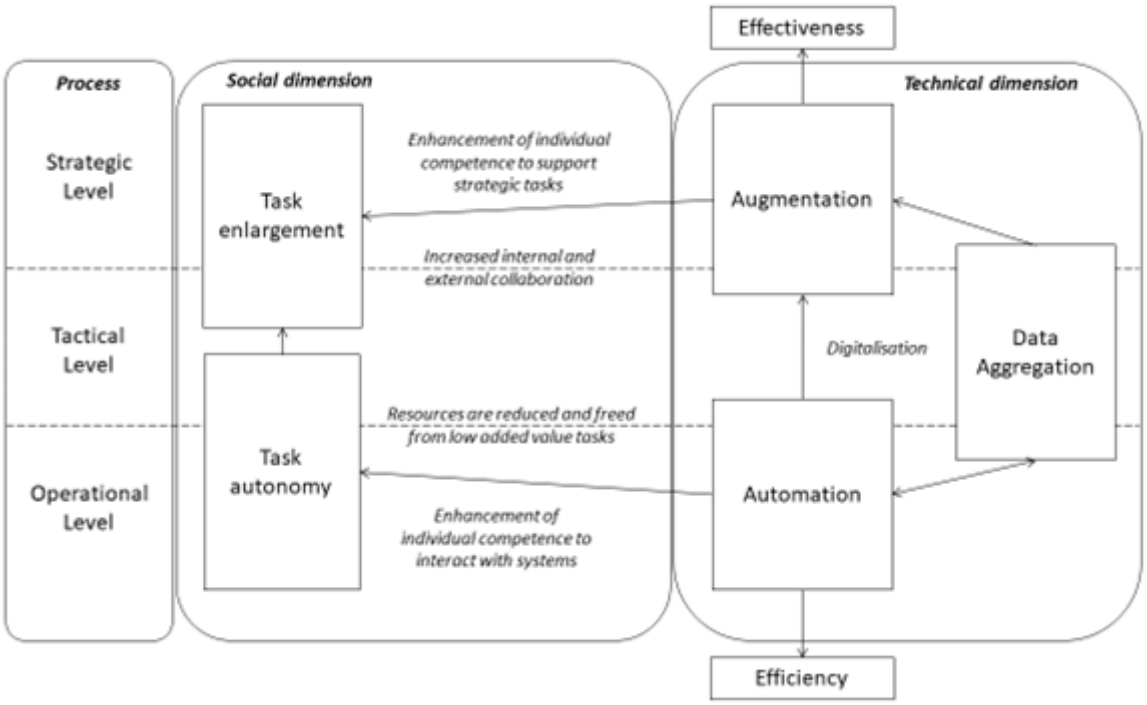

Figure 3.1 – The socio-technical impacts of digitalization: the case of purchasing

The framework describes how automation creates efficiency gains and increases autonomy in decision making while preparing the ground for augmentation that enlarges strategic activities performed by purchasing professionals and increases the effectiveness of the purchasing organisation. This framework suggests a dynamic and evolutive system where cumulative changes can result in better performance and significant organisational and human modifications. However, our results also show that digitalization can lead to different outcomes. The purchasing department can rely extensively on automation and ends up as a highly efficient department that performs operational and tactical tasks. However, the purchasing department can evolve into a more strategic function increasingly capable of performing strategic tasks and contributing to collaborative decision-making.

Purchasing investment in digital technologies is motivated by three drivers that support investment in new technologies: data aggregation, efficiency, and effectiveness. First, data aggregation consists in collecting and bringing into a single repository data from different internal and external sources. Second, efficiency is linked to investments in automation technologies to replace humans by with machines to perform operational and tactical tasks. Automation also allows to access and collect new sources of information. Third, effectiveness is linked to augmentation technologies, so humans and machines work together to perform tactical and strategic tasks. Augmentation helps take more informed decisions and earlier decisions. Data aggregation and automation are mutually supportive. In fact, data is aggregated from multiples sources through automation. This is a complex and cumulative process as data needs to be reliable, timely and relevant. Augmentation is made possible as the automation of tasks and data aggregation progresses. Indeed, digital technologies augment the ability of humans to take decisions by turning data into valuable and well-presented information. This is achieved through extensive combination and treatment of data from very diverse sources. Through augmentation, data is transformed into information that improves decision making. Summarizing, to answer the part of the first RQ related to the "why" purchasing organisations implement digitalization, we can state that:

RP1a: Digitalization of purchasing is driven by the search for the push of data aggregation, efficiency and effectiveness.

RP1b: Efficiency is mainly achieved through automation applications, while effectiveness is achieved through augmentation applications.

RP1c: Data aggregation and automation are mutually supportive, together they facilitate augmentation.

3.6.1 Technical dimension

Coherently with the literature previously presented, our findings show that digitalization can be introduced to automate purchasing process activities and support the process by increasing its capabilities. Automation and augmentation, i.e., the two types of digitalization discussed, constitute the technical dimension of the framework. The introduction of automation technologies is driven by the strategic choice for savings and efficiency, leading to shortened cycle times, efficient use of resources and error reduction (Lorentz et al., 2021). On the other hand, other augmentation-oriented technologies may improve coordination and control mechanisms and support process activities (Lorentz et al., 2021). Both the literature and this research make clear that digitalization in purchasing department can serve two purposes: automating tasks and augmenting capabilities. The results of this study contribute to current knowledge by identifying how purchasing organisations have implemented digitalization at each level of the process, thus defining for each level the specific technologies and applications. Summarizing, we can state that:

RP2a: Augmentation prevails at the strategic level of the purchasing process, particularly in complex and collaborative tasks with higher value-added activities.

RP2b: A mixed approach combining automation to augmentation prevails at the tactical level.

RP2c: Automation prevails at the operational level of the purchasing process, especially for simple and lower value-added activities.

3.6.2 Social dimension

Impacts on the social dimension affect the entire purchasing, with different implications in the three levels, i.e., strategic, tactical, and operational. From a social perspective, automation results in productivity gains and the reduction of the number of people employed for purchasing operational and tactical tasks as machines increasingly perform these tasks. Employees who are involved in operational and tactical tasks experience an increase in their decision-making autonomy. Indeed, through the sharing of data they depend less on other departments, and they can take decisions at a tactical and operational level in more complete autonomy. From a performance standpoint, automation results in an increased efficiency for purchasing operational and tactical tasks. Augmentation results in task enlargement for purchasing professionals, especially at tactical and strategic levels. Indeed, as some purchasing professionals are freed from some tactical and operational tasks, they can become more engaged in internal and external collaboration. The purchasing professionals who enhance their competence and have access to complementary knowledge on suppliers and supply market can support strategic tasks as part of cross-functional teams, hence the

enlargement of tasks that we observed in our findings. From a performance standpoint, augmentation results in an increase of effectiveness.

Hence, our results show that the professional evolution depends on automation and augmentation technologies. If a beneficial effect could be expected for augmentation technologies, it was not so for automation. The automation introduced by digitalization has been investigated in relation to employment risks and job elimination (Gregory et al., 2016). Instead, this study reveals that automation is necessary for professional development and may not affect the entire role but the lower value-added activities. This study does not seek to assert that automation of entire jobs does not exist. Still, it does seek to show how opportunities related to its implementation can benefit both the firm and the people employed. Summarizing, to partially answer the second RQ on how the purchasing department social system evolves in relation to purchasing automation and augmentation, we can state that:

RP3a: The combination of automation and augmentation technologies in purchasing enables operators to evolve professionally through increased decision-making autonomy and job enlargement.

RP3b: Automation substitute humans with machines and increases the autonomy of decisions of professionals who continue to perform operational and tactical tasks.

RP3c: As automation expands, purchasing professionals who become more involved in external and internal collaboration need to enhance their capabilities and knowledge to support strategic activities.

RP3d The combined use of automation and augmentation enlarges the strategic tasks performed by purchasing professionals.

This evolution is not systematic as some of our informants suggested that they recruited new people who were better fitted for the more strategic tasks. Moreover, the technological effect is not deterministic, and even if the technological choices are similar, the professional evolution can have a different magnitude. To make a digital innovation project successful, purchasing managers need to be aware that implementation must be managed; often, digitalization is carried out without careful consideration of the employees who will have to use it (Makarius et al. 2020). The manager must facilitate and support professional development to have adequately trained personnel. In addition, our results show that the operator's evolution will require new skills and capabilities. Hence, managers will be required to maximise the social potential of digitalization for human resources. These results are consistent with Leyer and Schneider (2021), who show that managers are not only involved in choosing technologies and their applications, but also in making the technology available and usable for the department. The technological choices made in implementation can influence professional

development possibilities. Unbalanced investments in favour of automation could hurt the job content, but in the same way, investing only in augmentation technologies could not guarantee sufficient free time for employees to take advantage of the new support possibilities. Second, human barriers such as a lack of skills, resistance to change, or a lack of a development plan can slow or even block opportunities for evolution. These considerations extend the findings of Flechsig et al. (2022), who, by considering the implementation of RPA, identify barriers of different nature, namely technical, organizational and environmental. While Flechsig et al. (2022) defines barriers with respect only to technology implementation, our article also shows potential difficulties in using and enabling professional development. The barriers addressed in this study, therefore, are not limited to the technical dimension, but also affect the social one.

Finally, in terms of social dimension the research has explored possible changes in the organisational collaborative dynamics in which the department is involved. The results show how digitalization can have a positive effect on internal collaboration. Simplification and standardisation, and improved visibility into processes, make it easier for departments to relate to each other. Besides, to manage the complexity of digitalization projects, companies will experience an increased need for cross-functional teams in which personnel from the purchasing department is also involved. This tendency may be accentuated in companies where purchasing department is directly involved in implementing digitalization for the entire company. It is possible to define distinct roles of the purchasing department concerning digitalization: a simple "user" of the technology or involved in scouting and buying technologies of interest for the entire company (Legenvre et al., 2020). In the second case, our results are in line with Sjödin et al. (2021), in which the purchasing department is indicated as an orchestrator who guides internal processes that clarify the roles and activities of each function during the procurement of digital solutions. This means that the purchasing department does not have an administrative role but has an active role in coordinating activities with other organizational units. Thus, internal collaboration becomes not only an effect of digitalization, but also a requirement for the procurement and implementation of digitalization to be successful. Furthermore, the results show that digitalization can support the external collaboration with suppliers and stimulate the integration of the supply chain. Integration involves the flow of information and data not only at an operational level such as transactions and material movements but also at a more strategic level, such as the sharing of sales plans. The integration can also cover purchasing activities, even coordinating decision-making processes. This duality finds confirmation in the literature in the field of Supply Chain Management that suggests two interrelated forms of integration, i.e., information exchange and operational integration (Kulp et al., 2004; Leuschner et al., 2013). The increasing possibilities for internal and external collaboration is mainly due to augmentation technologies, especially for their

ability to provide visibility, traceability and exchange information in real-time. However, automation plays its role here as well. By freeing the process from non-value-added activities, it allows the firm to focus on reasoning of a more strategic nature internally, while it makes collaboration more agile and efficient externally. These considerations lead to the formulation of the following research proposition.

RP3e: Digitalization enhances internal collaboration with other departments and external collaboration with suppliers; augmentation contributes primarily, but even automation has a positive effect.

3.7. Conclusion

Our research findings describe an evolutive socio-technical system characterised by cumulative changes where automation and augmentation impact on the purchasing department social system and on purchasing efficiency and effectiveness. We show how automation, by replacing humans with machines, supports data aggregation and generates efficiency gains. Automation increases the autonomy in decision making for purchasing professionals working at tactical and operational level. Then, automation and data aggregation enable augmentation that enlarge the tasks performed by purchasing professionals once they were requalified to perform this expanding set of strategic tasks. Augmentation then results in an increased effectiveness of the purchasing organisation.

This research shows that the adoption of a technical system, here digitalization, can result in different impacts on the social system. Purchasing department by steering changes towards either more automation or more augmentation as they progress on their digitalization path can end up either as a highly efficient operational and tactical team or as more strategic function. In the first case, automation creates a smaller purchasing department where individuals experience an increase in decision-making autonomy. In the second case, automation and augmentation result in a more effective purchasing department where the autonomy of decision is complemented by an enlargement of the tasks at strategic level. This finding is important for the STS theory as the adoption of a technical system such as digitalization can lead to different social impacts. The findings demonstrate the benefit of combining the automation-augmentation lenses with the STS theory. In line with Raisch and Krakowski (2021) we show that automation and augmentation are not either/or options but complementary approaches as automation enables data aggregation and then augmentation turns data aggregation into insights that support collaborative decision making. Our findings enrich the automation-augmentation lenses by suggesting that the boundary between automation and augmentation is not solely related to the ability to aggregate data but also to the need for complementary knowledge for taking effective decisions. Consequently, automation loses its relevance as tasks become complex and collaborative, as more advanced problem-solving heuristics

are needed to make sense of information and take relevant decisions. In the case of the selection of suppliers, complex purchase requires, on top of data provided by digital systems, a combination of market and technical knowledge that enables effective decision making.

The main managerial contribution of our research is to offer managers support in implementing digitalization in purchasing, providing visibility into the main technological choices, and showing which new paths of evolution they should plan and facilitate. The research can provide managers with knowledge on the main drivers of implementation and increase their awareness of possible technological choices and their effects on organisation, human resources and performance. Consistent with the socio-technical perspective, managers should consider the entire social dimension when designing the technological innovation of the procurement department. Hence, purchasing managers must balance effort over time to benefit from both automation and augmentation and have to prepare personnel for the path of professional development.

3.7.1 Limitations and future research

The study is primarily exploratory, and its findings deserve further investigation. Further research could expand our understanding of how human and machines complement each other. While our findings emphasize the need to access multiple sets of quality data, it also suggests that bringing all operational and tactical information into a single platform is not sufficient to take informed decision at strategic level. More data is needed and should be collected from difference sources. Also, some of our informants have highlighted that beyond data aggregation effective decision making depends on the quality of visual representation. We therefore suggest that to progress our understanding of the digitalization of purchasing department we need to further investigate how data is turned into insights in this context. Future research could focus on the organisational interfaces between the purchasing department and other functions, identifying the data and information exchanged through digital tools. Instead, looking at external collaboration, future research can explore the types of partnerships that have been established and understand if digitalization can help remove additional barriers to collaboration. Finally, future research should investigate why and when a purchasing department is likely to remain a highly efficient operational and tactical task performer or become a more strategic function. Our findings suggest that the complexity of the purchased goods and services and the antecedents in terms of profile of purchasing professionals play an important role here. We also believe that the leadership aspiration of chief purchasing officers might impact on this evolution. A last possible development relates to the adopted perspective in the analysis of the socio-technical system. Our work was aimed to analyse how technology influences the social system, and, consequently, of the evolution of the latter influences the former. Moreover, our work provide evidence that the decision to proceed in a certain direction in the development of the socio-technical

system is influenced by certain factors (i.e., drivers). As Bailey and Barley (2020) suggest, technology designers often operate from a cultural perspective that privileges the technical over the social. Thus, a gap might exist between their idea of reality and the user's experience of reality. This suggests a move towards user-centred and value-sensitive design approaches, where technology designers have more information about the social context in which the technology is going to be adopted, including the needs of the organization and the social dynamics that it is willing to enhance. Our framework suggests a possible evolutionary path, that companies could take into consideration since the early stages of their digital innovation processes.

4. MANUFACTURING EXECUTION SYSTEM IN INDUSTRY 4.0 ERA: FROM IMPLEMENTATION TO IMPACTS ON JOB DESIGN

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4.1. Introduction

The Fourth Industrial Revolution is transforming manufacturing through a process of digitalization. Thanks to new enabling technologies, methods and tools, a flexible and cost-efficient production becomes possible in the context of Industry 4.0 (I4.0), thus improving the quality of products. However, the digitalization of manufacturing began before the advent of I4.0. One of the most important technology applications historically used in the manufacturing environment is the Manufacturing Execution System (MES). The Manufacturing Enterprise Solutions Association (MESA) International defines this technology as "a dynamic information system application that drives execution of manufacturing operations, and by using current and accurate data, MES guides, triggers and reports plant activities as events. The MES set of functions manages production operations from point of order release into manufacturing to point of product delivery into finished goods. MES provides critical information about production activities to other production-related systems across the organisation and supply chain via bi-directional communication". Furthermore, it is essential to highlight the need to completely integrate the MES with the upper ERP and other systems to fulfil different features of information collection and transmission (Arica et al., 2017). Indeed, MES allows connecting the planning system, usually ERP, with the controlling systems (PLCs) through utilising multiple manufacturing information – resources, equipment, and orders – to support and improve the production cycle (Mantravadi and Møller, 2019). Kletti et al. (2007) grouped the principal MES functions within three specific function groups: production, quality, and human resources. Production functionalities include data collection on production progress and machinery status. Quality features cover statistical process control, collection and analysis of non-conformities and compliance with standards. Finally, human resources capabilities refer to managing personnel involved in production in terms of incentive and authorisation management. MES can bring significant benefits to manufacturing and organization, especially through the availability of real-time

data; key benefits include reduced time-to-market, reduced production costs, improved process and quality (Deuel; 1994). However, more clarity is needed on what the implications of this technology may be at the organisational level, especially in terms of job design. I4.0 has renewed interest in the technology-organisation relationship, and MES may have new development within the fourth industrial revolution, with additional possibilities for impacting company personnel and work content.

This study aims to analyse the relationship between MES and Industry 4.0 with the ambition to identify possible impacts at the level of job design for operators employed in production. For this purpose, we adopted a mixed method, where the survey results on the link between MES and I4.0 were combined with the results of multiple case study analyses to assess the impacts on job design. We based the framework of our research on the Job Characteristics Model (JCM) defined by Hackman and Oldham (1976). This model identifies the key dimensions of the job and the job outcomes. Our study assesses the implications of MES on these dimensions of the model.

4.2. Related literature

4.2.1 MES and Industry 4.0

I4.0 has highlighted the need for a state-of-the-art assessment of MES research and implementations, from both a practical and academic perspective (Shojaeinasab et al., 2022). In particular, the fourth digital revolution puts an end to centralised applications for production control, and MES systems will need to be built to support the new paradigm (Almada-Lobo, 2015). MES has been developed to narrow the gap between the production environment and the office-planning systems (Koch, 2001) and this tool was developed before Industry 4.0, as a system for collecting production data. However, prior to the current wave of digitalization, the collection of information from the production environment (which the MES feeds on) was not so simple and immediate. Originally, existing technologies could also ensure the availability of information, but could not guarantee its accuracy, meaningfulness and immediacy. The MESA standard already included the concept of "real time" but referred to the time at which the MES processed the data, not the time at which the data were collected. In addition, this immediacy in processing the data was only theoretical and the instrument could take minutes or even hours to respond (de Ugarte, 2009). A further limitation was related to integration. The management systems with which the MES must interact initially were not designed to work with the production level and therefore could hardly be integrated and connected with the shop floor (Howells, 2000). With the 4.0 revolution new implications arise for MES that may overcome all these limitations and/or add new difficulties. Thus, an entirely new generation of MES is required to address the opportunities and challenges created by Industry 4.0. The following are the four pillars that new

systems must consider: i) decentralisation, ii) vertical integration, iii) connectivity and mobile, iv) cloud computing and advanced analysis. Decentralisation is purely logical, as the MES is still an application, but it operates in a decentralised way with the shop-floor items. Vertical integration ensures control or fulfilment of any other related business process. Combined connectivity and mobile will enable more adaptable and usable interfaces. Finally, analytics will help derive insights from the new multitude of data available and from different sources; for example, by identifying inefficiencies based on data from different sources and enabling corrective or preventive actions. In addition to these pillars, next-generation MESs have to provide real-time information to operational departments, provide insight into the resources involved especially at the production level, and facilitate compliance with customer requirements and offer visibility and traceability. Flexibility and traceability are key goals of I4.0, and it is expected that the use of MES can facilitate the achievement of these goals (Mantravadi and Møller, 2019). These features imply that the MES guarantees the use of data within all company levels, namely business management, production and control/automation.

4.2.2. Job design and Industry 4.0

The study of the relationship between technologies and organisation, especially identifying the technological impacts on the workforce, has characterised several studies founded on the Socio-Technical Systems (STS) theory (Trist and Murray, 1993). STS theory examines the interdependencies between technical/technological aspects and the social context in which work is performed (Trist & Emery, 2005), showing positive influences for the organization in terms of job outcomes (Campion and McClelland, 1993). Given the technological nature of MES and its pervasiveness within the production context, consistent with STS theory, it is immediate to assume implications related to its application not only at the level of the organisation but also for the workforce employed in the department. The evolution of production roles is a relevant topic for digitalization. Current literature suggests a broad spectrum of work development paths related to I4.0, but at the same time identifies two main trends, namely polarisation of and upgrading qualifications (Hirsch-Kreinsen, 2016). The first perspective - deskilling – foresees the downgrading of the operators through the simplification of jobs and the reduction in skills of more highly skilled craft workers (Braverman,1974). The second perspective - upskilling - foresees an increment of the qualification of the operators. Technological change, in this case, implies an increase in the skills required by operators (Waschull et al., 2017) because rather than automating complex and qualified tasks, the simplest and most routinary tasks are automated. These possible job evolutions emphasize the need to analyse specific dimensions of work that may be impacted by digitisation. However, the theory does not address the specific dimensions of work that may be impacted, merely defining the possibility of evolution.

Hackman and Oldham (1976) overcome this limitation by proposing a model known as the Job Characteristics Model (JCM) in which job characteristics and their links to individual responses are made explicit. The two authors identify five job characteristics: i) skill variety defined as the extent to which a job requires different competences; ii) task identity defined as the degree to which a job results in the completion of a set of identifiable deliverables; iii) task significance defined as the extent to which a job impacts other people in the organisation; iv) autonomy defined as the extent to which a job affords the employee the discretion to decide how to perform the task and to establish the schedule; v) feedback defined as the degree to which the work activity provides the employee with clear performance information. These job characteristics solicit three psychological states – i.e., experienced meaningfulness of the work, experiences responsibility for outcomes of the work, knowledge of the actual results of the work activities – that in turn can lead to positive personal and job outcomes – i.e., motivation, performance, satisfaction, low absenteeism. These links are also hypothesised to be moderated by the employee growth needs.

4.3. Methodology

The research was guided by the model developed based on the theory and literature reviewed. Specifically, the starting point of our framework is the Job Characteristics Model previously described, which was then adapted and contextualized with respect to MES implementation. Figure 4.1 shows the framework that guided the research.

Our research adopts a mixed method, combining quantitative survey-based data collection with an exploratory survey conducted through case studies with the aim of intercepting all the nuances of the phenomenon analysed. This methodology was designed in accordance with Stentoft, Mikkelsen, and Jensen (2016, p. 136), who explain how mixed-method research "involves a research design that uses multiple methods (i.e., quantitative and qualitative research approaches) in a research investigation either simultaneously (i.e., independent of each other) or sequentially (e.g., results from one approach inform the other), to understand a phenomenon of interest". The first part of the study aims to highlight possible links between MES and I4.0 and is based on a data collection conducted through a survey involving 40 Italian manufacturing companies. Data collection was conducted in the second half of 2021. The study involved companies that have already introduced the MES, companies that are still implementing it, and cases where the technology has not been introduced yet. In particular, the sample includes 19 companies with MES implemented and 21 companies without MES implemented. The introductory part of the survey focuses on the general characteristics of the company and the technological maturity, especially considering the 4.0 enabling technologies. The

second part of the survey is specific to MES implementation. It is diversified according to the state of implementation to find common points or differences between companies in different states.

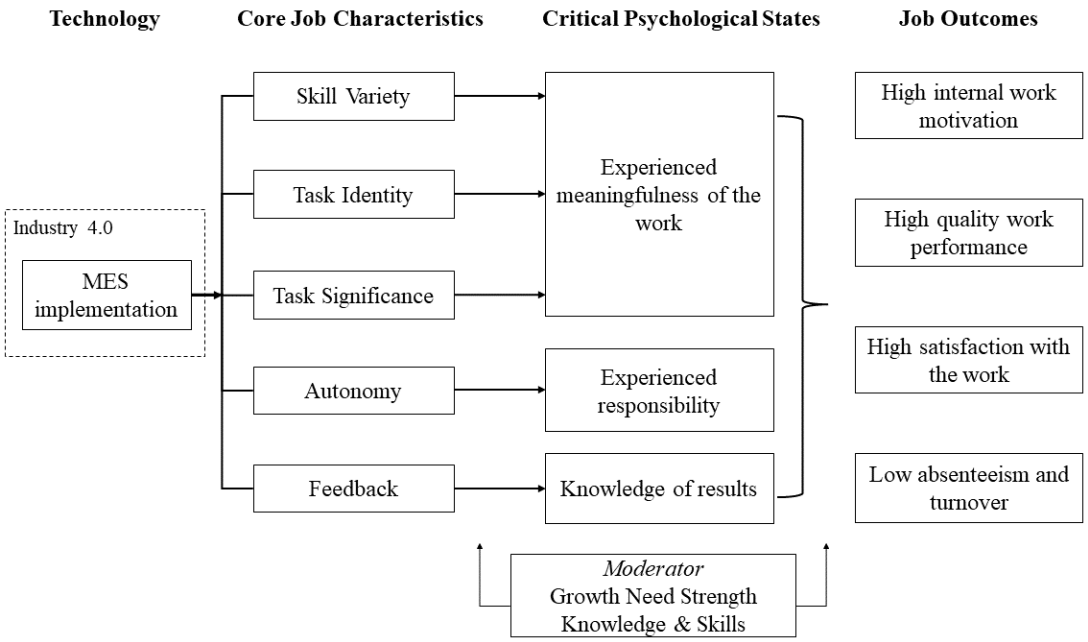

Figure 4.1 – Research framework

Finally, the study aims to gather additional insights related to impacts on job design by delving into a selection of companies. The second part of the study is based on qualitative research conducted through case studies involving six manufacturing companies. This second sample was constructed by interviewing companies that participated in the study's first part. Companies were chosen because they have already implemented MES and at the same time they have an advanced level of digital maturity (measured in the first part of the study). Table 4.1 shows the main characteristics of the company analysed.

Table 4.1 - Summary of the cases for the multiple case studies analysis

Case	Size	Sector
A	> 250	Supply of electrotechnical equipment and materials used for the manufacturing of electric equipment
B	> 250	Manufacture of other taps and valves
C	> 250	Wholesale trade of soap, detergents, and other cleaning products
D	> 250	Manufacturing of equipment for power supply and control

E	51 – 250	Manufacture of machinery for food, beverage and tobacco processing
F	> 250	Manufacture of scales and automatic vending machines (including individual parts and accessories)

Indeed, we felt that these advanced conditions ensured a greater likelihood of capturing any impacts on the organizational and work design dimensions. In addition, we have involved manufacturing companies as our desire is to deepen the impacts relative to the production environment. Data were collected through semi-structured interviews conducted in early 2022 using a dedicated interview protocol. For each company, a 90-minute interview was conducted, involving the production manager and the human resources manager at the same time. We made this choice as we want to include multiple points of view, but also to capture both purely technical aspects of production and personal and/or organizational aspects related to human resources. Thus, the interviews were conducted using the same approach, but also the same protocol. First, each interview started by reviewing the answers provided in the survey, with the purpose of confirming and discussing them. Next, the outline of the protocol was followed, while leaving room for the respondents to range in topics. Since the respondents were Italian speakers, the interviews were conducted in Italian. Interview reports were sent to respondents for confirmation on the reported information; these reports were written and sent in both Italian and English. Additional materials such as interview protocol and data on the analyzed sample are provided in the appendix.

4.4. Results

This section is divided into two main subchapters. In the first subchapter, the link between MES and digitalization related to I4.0 is discussed. In the second, the impacts of MES in terms of job design are discussed.

4.4.1. MES and Industry 4.0

Before analyzing the differences in terms of digital implementation between companies with MES and those without, we present an overview of the sample in terms of investment in digital technologies. Before going into the results, we show how the two groups are balanced to support the statistical evidence: companies with MES are 19, those without are 21. Table 4.2 shows the average scores related to the adoption of I4.0 enabling technologies. The scores refer to the 6-point Likert Scale adopted for survey data collection.

Table 4.2 Adoption of I4.0 technologies

I4.0 technologies	Average score
Big data analytics	2.7
Cyber Security	4.3
Additive manufacturing	2.3
Horizontal and vertical integration	3.0
Internet of things	3.0
Cloud computing	3.4
Augmented reality	1.8
Advanced robotics	3.2
Simulation	3.1

Our results, based on the survey, show that almost all the organisations (90%) carried out some investments in cyber security. Consequently, the level of maturity of this technology is remarkably advanced since more than 70% of the companies employ it at least with a systematic use, also confirmed by its average score, which is the highest (4.3). Given the increasing involvement of the Internet and IT tools, for all companies, but especially for larger ones, the protection of the data, processes and information systems is increasingly becoming an essential feature to ensure the optimal functioning of all activities. Secondly, the Internet of Things (IoT) has reached a good adoption degree, considering that most of the sample (72%) already started the orientation stage. Also, in this case, the reason is not accidental but due to the enormous importance of IoT in interconnecting all devices to exchange data streams and interact with each other, representing practically the essence of I4.0. However, just 16 of the firms have tested the technology. For this reason, the score related to the maturity level of IoT is equal to or lower than Integration, Cloud computing, Robotics, and Simulation, indicating that although it is quite widespread among organizations, so far it is mostly present in the early stages. On the other side, the enabling technologies with the highest rate of not use are additive manufacturing (56%) and augmented reality (62%). For the former, it depends on the difficulties to fully implement it in some specific industries (i.e., metallurgic, food), so that, currently, it is principally spread just for prototyping activities. Regarding augmented reality (AR), although it is quite popular for personnel training, maintenance processes, and warehouse operations, the complexity of adoption is due to the lack of maturity of the technology for the most demanding tasks

and the need to have an AR system compatible and aligned with the company's current practices. In these two cases, the scores are the lowest, perfectly reflecting how the technologies maturity level is still premature.

Then, the organisations have been divided based on the MES implementation as a distinctive factor to highlight the possible relationships between investments in I4.0 technologies and the presence of a Manufacturing Execution System within a company. Group 1 includes companies with MES, Group 2 without it. Comparing the different groups, there is a substantial difference between companies that have already implemented MES and those that have not implemented it yet. Analysis has been conducted through different statistical tests (t-test) to evaluate potential differences or similarities between the single enabling technologies of Industry 4.0. A t-test is a useful tool to examine whether the means of a certain variable in two independent groups are significantly different from each other. Since the t-test compares two different groups, companies with MES represent the first group, while the second one includes organisations without it. Additive manufacturing has not been considered in this analysis due to its scarce adaptability to many industries since its use is very specific and related only to some companies. Table 4.3 show the t-tests results.

Table 4.3 - T-tests on investments in I4.0 technologies comparing companies with and without MES

	Group	Mean	Std. Err.	Std. Dev	[95% Conf. Interval]		Pr (T > t)
Robotics	1	4,16	0,45	1,98	3,2	5,11	**0,0016**
	2	2,33	0,37	1,68	1,57	3,09	
Simulation	1	4,05	0,38	1,65	3,26	4,85	**0,0003**
	2	2,14	0,34	1,56	1,43	2,85	
Cyber Security	1	4,84	0,26	1,11	4,3	5,38	**0,0123**
	2	3,81	0,35	1,6	3,08	4,54	
Internet of things	1	3,68	0,39	1,73	2,85	4,52	**0,0083**
	2	2,43	0,31	1,43	1,77	3,08	
Augmented reality	1	2,16	0,38	1,64	1,37	2,96	**0,0495**
	2	1,48	0,21	0,98	1,03	1,92	
Integration	1	3,58	0,39	1,71	2,75	4,40	**0,0255**
	2	2,52	0,35	1,6	1,8	3,25	
Big data analytics	1	2,68	0,35	1,53	1,95	3,42	0,4491
	2	2,62	0,36	1,66	1,86	3,37	
	1	3,89	0,40	1,73	3,05	4,74	**0,0299**

Cloud computing	2	2,86	0,35	1,62	2,12	3,60

Note: Group 1 includes companies with MES implemented (19 companies); Group 2 includes companies with MES not implemented yet (21 companies)

We can observe how in almost all the cases, except for the big data analytics, the p-value is lower than 0.05. Consequently, the null hypothesis (Ho), that the means of the two groups are equal, is rejected. Therefore, it can be asserted that the means related to investments in I4.0 technologies significantly differ, and, as previously anticipated, the organisations provided with the MES on average present higher values. These results suggest a potential relationship between MES and I4.0. Our analysis did not test the causality between the two variables (MES and I4.0), however it is certainly possible to say that MES technology was born before the advent of I4.0.

Moreover, in all the cases analysed, companies stated that they had introduced MES before investing in I4.0 technologies. This evidence allows us to assert that companies without MES might find it unprofitable to invest heavily in some I4.0 technologies without equipping themselves with MES first. This result is reasonable as MES guarantees the presence of data from production, and this data is the main "food" that feeds I4.0 technologies. Without a solid database in place, I4.0 would not be able to manifest its potential.

4.4.2 MES and impacts on job design

The results from the case studies show how the implementation of MES has generally had an impact on the workforce employed in production, particularly at the operational level. The results have been analysed starting from the characteristics of the job described by the JCM. In particular, results have emerged regarding decision-making autonomy, tasks and skill variety and task significance. Below we report the general effects of MES implementation for each job characteristic. In our cases, a potential moderating effect also emerges that can influence the impact of MES on job dimensions. This effect is due to lack of skills, but also to purely personal and behavioral factors. Finally, the JCM predicts a positive link between these dimensions and the described work outcomes. Our cases show consistent results considering the job outcomes motivation, satisfaction and performance.

Autonomy. Thanks to the control offered by the application, operators after the implementation of the MES can work more autonomously, also being able to take decisions on the process. The main impact was observed in relation to decision-making autonomy of operators involved in production. This phenomenon was observed in all of the cases analyzed, but in case D it was most evident. Indeed, the company has also implemented a feature whereby operators are now able to see additional

information about the production to be made (e.g., technical drawing, reports on previous nonconformities, alerts about new production) directly on the monitor on the machine. Since the introduction of the MES, more skilled operators have also been allowed to intervene in the process by changing the sequence of production orders or even changing the sequencing of work cycle steps. Although the MES has also been supplemented by a production scheduler, exceptions can occur in the production process that operators are able and allowed to handle on their own. This change has been relevant to the roles currently employed in production and has also led to the creation of new roles between the restricted operational roles and the low-level managers employed in production. This result shows that the professional evolution following the implementation of MES is not only limited to job content, but also opens the possibility for empowerment of current roles. Autonomy has been positively impacted not only in terms of decision-making, but also in terms of operational autonomy. We observed how, as a result of the implementation of MES, production and office operators need less interaction with other colleagues for information gathering. The interaction between the ERP system and the MES makes information available to everyone, in a comprehensive and timely manner. This does not imply less internal collaboration; the less interaction is limited to information retrieval activities. Eliminating this low-value activity leaves room for interactions related to to more strategic aspects.

Variety. One of the dimensions included in JCM is skill variety; we have extended this dimension not limiting to skill but also considering the variety of the tasks performed. In fact, in our cases, effects can be observed on the variety of tasks and skills. Even if, in the cases analysed, there has not been a radical change in the activities performed after the introduction of the MES, the usability and guidance offered by the application can simplify operations by enabling new activities for operators, such as process intervention in case of minor problems. While there have been no radical changes from a content perspective, it should be noted that the MES enables existing activities to be carried out in a different, more effective and efficient way, with a positive impact on both the operator's work and the business. The introduction of MES technology foresees a radical change in the way production is managed and monitored and the way data is collected. In the traditional mode, based on paper, the operator must manually record all production progress. This low value-added activity is monotonous for the operator and, above all, prone to human error. From the cases analysed, we learn, for example, how sometimes operators write down information in an unreadable way or even misreport it, leading to dangerous misalignments for the management. An automated and digital collection of production data frees the operator from this activity, leaving more time to devote to value-added activities. Likewise, managers will spend less time correcting and resolving errors in production records while having more reliable data to make better decisions. Finally, in terms of the

variety, we observed an increase in the skills required, particularly in the digital skills needed to operate the application correctly.

Task significance. In cases A, B, E and F, we observed increased task significance at both operational and managerial levels. In particular, at the operational level, the interviewees stressed how, with the MES, operators could become responsible for part of the information that arrives from production to the ERP system. If, on the one hand, it is true that the MES automates data collection; on the other hand, we have shown that operators have greater working autonomy so that they are responsible for opening and closing production sheets, as well as categorising machine stops or breakdowns, rather than opening extra-cycle sheets (e.g., the final balance of non-cycle activities, cleaning, maintenance). If the operators do not correctly input this information, dangerous misalignments will be created in the management system since there is no longer control by the office staff. We can also see an increase in significance at the management level. The implementation of MES offers a multitude of new data made available to management. However, these data need to be analysed and become a valuable basis for decision making. Only one of the cases analysed (Case C) mentioned the possibility of adding new roles dedicated to data analysis (e.g., data analyst), in the other cases this activity has been attributed to production manager. However, in all the cases, it is believed that data analysis has a great added value and significance for the achievement of production goals and, in general, for the achievement of business objectives.

Job outcomes. Our cases show interesting results as they consider all phases of the MES implementation, from the initial introduction to the complete application of the technology. If we dwell on the early stages of implementation, contrary to the assumptions provided by the JCM, the reaction of production personnel was not positive. Our cases showed the existence of personnel resistance, mainly due to the fear that the technology would act as a control mechanism and the fear of not knowing how to use the new tools correctly. This resistance was accompanied by a lack of understanding of the potential benefits (intended in terms of work content) and the value of the technology, making it difficult to achieve positive job outcomes. However, the situation is radically different if we look at the stage when the technology is fully applied and used. Once the operators have been able to use the MES fully, they have appreciated its functionality and, above all, the benefits for their operations, abandoning their initial fears and resistance. In this phase of application maturity, our cases have shown that production operators are more satisfied, motivated, and perform better. Thanks to the increased work autonomy, the growing variety of activities (with greater added value), and the possibility of recognising and valuing their contribution, operators have proved to be more motivated in approaching their work. They are likely more satisfied after completing it the activity.

Operators are also more efficient; this is not only because the characteristics of the technology allow them to work more effectively and efficiently, but also because thanks to the greater sense of responsibility and greater perception of the value of their work, operators are also more proactive in proposing improvements and solutions for the production department. Considering the last job outcomes previewed from the model, that is, low absenteeism and turnover, we do not observe meaningful impacts.

The JCM also defines a moderating effect between job characteristics and outcomes due to individual aptitude and growth predisposition. In our cases, managers could only assess the general effect and not the specific impact on each worker. However, in Case D, a moderation effect was observed similar to that predicted by the model. The manager stated: "motivation and satisfaction increase, especially for people who enjoy digitisation and are more open to innovation and changes". This statement confirms how personal behavioural characteristics can influence job outcomes. Again, competencies (already described as a moderating variable that can affect the impacts of MES on job design) have a potential moderating role. Operators may incur frustration and dissatisfaction when they fail to develop the appropriate skills to use the application or manage the new tasks with greater responsibility.

Moderators. Our results show a moderating effect between the core job characteristics and the critical psychological states illustrated in the research framework. While on a general level we presented positive relationships between MES implementation and job design dimensions, thus identifying potential for professional growth as a result of digitalization, however, we observed that sometimes the positive effect was dampened. In fact, our results show how professional growth can be moderated and dampened by two main factors. The first factor concerns the skills.The lack or absence of required competencies can severely limit the opportunities for professional development. In Case C, although there is a willingness to leave further greater autonomy to the operators, the skills gaps still do not allow this transition. The skills gap is not only to be attributed to the operators, i.e., the users of the technology. This kind of issue was observed in our cases, and the lack of digital skills to use the tool did not allow operators to fully exploit the potential. However, the lack of competencies can also be attributed to the management roles in charge of managing and leading the technological implementation and the necessary reorganization. In other words, we observed both situations where managers did not adequately prepare personnel through preventive training and reorganization actions, and situations where personnel despite having received training were unable to fill the gap. This second situation is related to the second factor that can influence the relationships in the model. This factor is more difficult to study and evaluate, as it is strongly related to the personal and

behavioural sphere, sometimes even flowing into the psychological domain. Through the perspective of human resource managers, we have learned how some individuals (and so we are talking about human characteristics and not necessarily professional ones) are by their own nature not interested in undertaking a path of professional, individual and personal growth.

4.5. Discussion and conclusions

Our results first highlight the relationship between MES and investments in I4.0 technologies. While MES functionality can benefit from investments in the new wave of digitisation, our results show also that MES can be an important enabler for I4.0, especially for manufacturing applications. The technology allows to collect real-time production data and makes them immediately available to the business, enabling possibilities consistent with 4.0 applications. Therefore, companies with MES find it more willing and easier to invest in next-generation technologies. In the I4.0 context, MES can reach the maximum of its potential, bringing the expected benefits to the organisation and with relevant impacts on the workforce and job design. Our study shows how its implementation can influence some of the dimensions defined by the JCM. The implementation can increase the decision-making autonomy of production operators and the variety of activities and skills. New activities with a higher added value increase the significance of the work content. However, this effect is neither immediate nor deterministic. First, some organisations may decide not to assign greater autonomy or variety to operators due to business choices and priorities. One reason may be that workers are not yet ready to manage this change. Secondly, the possible professional development enabled by the MES requires time for operators to become familiar with the application and to be adequately trained and prepared to use it. Where the conditions for professional development are in place, our results show that it positively affects job outcomes such as motivation, satisfaction, and performance. Studies from STS theory already hypothesise a positive link, suggesting that job redesign initiatives can favourably influence job outcomes (Parker and Wall, 1998).

However, other studies (Boudreau and Robey, 2005) also show how this effect can be altered in the presence of significant changes, potentially leading to negative effects on job outcomes. Research conducted by Morris and Venkatesh (2010) evaluating the impact of ERP system implementation on job characteristics found a similar effect. However, the technology variable was placed as a moderator among the different dimensions of the JCM. Our study differs, identifying the technology variable as independent and affecting job characteristics. Beyond the structure of the model, our research is aligned with the findings of that study, confirming the dynamic nature of the JCM and these disruptive effects even in presence of the MES introduction. In addition, consistent with the JCM, the effect appears to be moderated by individual characteristics. Some workers may not be interested in this

development or see it as increasing their workload. More positive effects are seen where there is an interest and attitude toward personal and professional growth. Our results are unable to go beyond this consideration, and we are therefore unable to identify any correlations to better characterize this factor. However, we believe it is relevant to be aware of this moderating effect; managers planning a digital and organizational reorganization must carefully consider which people are able to cope successfully with such a change, and especially how to focus efforts to enable professional evolutions of their staff. Moreover, lack of skills can be a barrier, as it can accentuate the resistance and fear of not being able to adapt to the new work scenario.

First of all, our study has a relevant theoretical contribution as it extends the JCM, a reference model for discussing job design issues. The research traces the model to the effects of a specific technological application, namely the MES. Moreover, the results improve the model by defining precisely which individual characteristics can influence the relationships. This study stands as a basis for research aiming to address the effects of digitisation on the organisation, particularly regarding I4.0 and the workforce. From a practical perspective, this research can support managers required to run a technological implementation project. The study offers insights specific to the implementation of MES, but it is expected that some of the considerations may also apply to other technological innovate.

4.6 Appendix

INTERVIEW PROTOCOL: IMPLICATIONS OF MES ON JOB DESIGN

Interview objective: Analyse the dynamics of manufacturing execution system (MES) implementation and the consequences for the organization and the workforce.

In answering the questions, keep a manufacturing plant as a reference.

A. THE COMPANY

- GENERAL INFORMATION ABOUT THE COMPANY
  - Sector
  - Company size (e.g., number of employees)
  - Turnover
  - Served markets (domestic/international, B2B/B2C)
  - Products/services offered

B. MES: IMPLEMENTATION

- LEVEL OF ADOPTION
  - In what year was the MES implemented? Has the project been completed? If so, has the MES module been updated over the years or has it remained the same?
  - What devices (e.g., tablets, apps...) are used to manage production progress digitally?
  - Does the data exchange between MES and ERP occur fully and systematically?
  - Was the introduction of MES preceded by a change/upgrade of the ERP management system?
  - What % of enterprise machinery is currently interconnected?

- MOTIVATIONS OF MES INTRODUCTION

To what extent was the decision to implement the MES driven by:

  - Provide managers with greater visibility into data and production trends
  - Support the work of "office" (non-production) employees
  - Support the work of production operators
  - Reduce production costs
  - Other

- PERSONNEL INVOLVEMENT
  - Has technological innovation been accompanied by training and involvement of operators?
  - Were managers (management roles) involved in the introduction of the new technology? If yes, how?
  - Was the introduction of the MES, its goals and benefits communicated to employees in advance?

C. IMPACTS ON ORGANIZATIONAL MACROSTRUCTURE

- Has the introduction of the MES led to evolutions in organizational structure or organizational units? E.g. Reduction (or an increase) in hierarchical levels, more significant delegation to lower levels, cross-functional figures, centralization/decentralization of decision-making power, etc.).

- Has the introduction of the MES led to changes in interdepartmental relations?

D. MES: IMPACTS ON WORKFORCE AT OPERATIONAL AND MANAGERIAL LEVELS

- TYPOLOGY AND QUALIFICATION OF ROLES IMPACTED
  - Has the technology introduced resulted in an increase/decrease in staff? Have new roles been added?
  - Which job positions have been impacted by the innovative change?
  - For impacted positions, distinguishing between operational and managerial levels

- Variety
  - How has the variety of tasks performed changed? Do tasks include more interdisciplinary activities (e.g., fewer technical or low-value-added activities and more organizational/analytical activities), or are they very specialized?
  - Have the required skills changed? (see Appendix Skills)

- Autonomy
  - Did the impacted roles receive more or less responsibility and/or decision-making autonomy?

- Task relevance
  - How has the relevance of the tasks performed changed? (A job is defined as important when other people are strongly influenced and dependent on the success of that job).

- Feedback
  - Do technology users receive more or less feedback during their operational activities?

- Task identity
  - Have you observed any changes regarding the identity of the activities?

- PERSONNEL REACTION
  - During and after implementation was there openness to change or did the Company encounter resistance from staff (managers and operators)?
  - What were the main difficulties for employees during and after the adoption of MES?
  - Which figures have benefited most from the shift from paper-based to digital control?
  - Do you think that since the introduction of the MES, motivation has increased in operators?
  - Do you think the performance of operators has increased since the introduction of the MES?
  - Do you think that since the introduction of the MES, operator satisfaction has increased?
  - Do you think absenteeism has decreased since the introduction of the MES?

E. MES: BENEFITS

- To what extent has the ESM benefited:
  - Production process (e.g., greater efficiency, lower costs, traceability)
  - Organization (e.g., flexibility, internal collaboration, coordination)
  - Personnel (e.g., improved working conditions, staff rotation, job enrichment, reduced job stress)

APPENDIX: SKILLS

Technical skills	Technical skills	Technical skills
Examples: Use of management software. Knowledge and use of new types of machinery. Programming and use of new computer languages. Management control.	Examples: Real-time information processing. Use of technological devices. Computerized content creation and data entry. Use of computer tools (e.g.,	Examples: Working in a team. Communication skills. Adaptive skills. Problem solving. Flexibility.

	Excel sheet). Processing and evaluation of content and process data.	Conflict management. Scheduling of work. Aptitude for growth and constant learning.

5. BALANCING EXAPTATION AND ABSORPTION OF HUMAN AND DIGITAL RESOURCES TO ACHIEVE ORGANIZATIONAL EFFECTIVENSS THROUGH RESILIENCE

Acknowledgement: *This chapter is derived from the article "Colombo, J., Boffelli, A., Kalchschmidt, M., Legenvre, H., (2023). Balancing exaptation and absorption to achieve resilience during a crisis". The article was presented at IPSERA Conference 2022 and is currently under review (2 rounds) in the Journal of Business Research (JOBR). I first thank the co-authors involved in this paper. I was very pleased to continue the collaboration with the EIPM network, working with Prof. Hervé Legenvre. I also particularly thank the reviewers and the editor of the JOBR for making a great contribution to the improvement of this work, both in terms of content and methodology.*

5.1 Introduction

5.1.1 Domain and paper's objective

Organisations facing discontinuities and crises respond to external shocks by reconfiguring their resources; they recreate a fit between themselves and their environment. COVID-19 created immediate operational and supply chain discontinuities, characterised by severe time pressure. B2B firms started to reconfigure their resources to respond to this sudden shock. Then, as companies began to learn from their experience, they decided to invest in digital technologies to enhance their capabilities. Such a sequence of resource reconfiguration contributes to creating a resilient organisation. Current literature makes it possible to distinguish a resilient organisation from a non-resilient one (Sutcliffe & Vogus 2003), highlighting the significant role of capabilities such as a flexible supply base, resource reconfiguration, and the creation of loose resources to reduce the impact of disruptions (Iftikhar et al., 2021). However, it remains unclear how the reconfiguration of resources for building resilience occurs in practice (Duchek, 2020). Past literature has described resource reconfiguration as the ability of a firm to reconfigure, realign and reorganise its resources in response to high-impact disruptions in the firm's external environment (Ambulkar et al., 2015). However, when the concept of resource reconfiguration was applied to understand how a firm responds to a sudden exogenous shock, the focus was on how resource reconfiguration helps anticipate and prepare for disruptions (Bode et al., 2011), but the magnitude of recent crises and threats such as the COVID-19 pandemic, the US-China trade war, the Russia-Ukraine conflict call for more research on how resource reconfiguration supports early responses to crisis (Blessley & Mudambinn, 2022; Dohmen et al., 2022). This focus on anticipation leaves a critical gap in the literature as we ignore how, over a short period of time, firms dynamically reconfigure their resources

to respond to very severe exogenous shocks. Moreover, developing the capability to reconfigure resources to cope with disruptions is a need that has been studied and emphasised even before the pandemic, and "practice" in deploying these reconfigurations is critical to defeat organisational inertia and act promptly when necessary (Parker & Ameen 2018). There is, indeed, a need for new theorisation on how B2B organisations can rapidly respond to turbulent scenarios and practical guidance and knowledge on how to build more resilient responses to challenges (Moi & Cabiddu, 2022). On this gap, we built the aim of our study, which is to study how B2B purchasing and supply chain management departments and organisations develop their responses to COVID-19 by reconfiguring internal and external resources.

5.1.2 Empirical approach and contributions of the paper

To achieve the paper's purpose, we opted for a multiple case study approach, studying how seven B2B companies from different sectors responded to lockdowns. The data were collected in multiple stages, thus adding a longitudinal perspective to the analysis of the phenomenon under study. First, we investigated the tensions experienced by procurement and supply chain departments and organisations when they responded to COVID-19. Our results allow us to answer the first research question, "what were the tensions experienced by procurement and supply chain organisations when they respond to sudden and abrupt change?". Second, we investigated how firms repurposed and invested in human and digital resources to overcome tensions and respond to the crisis to answer the second research question, "how do B2B organisations develop responses to unexpected and sudden exogenous shocks?". To answer this second question, we developed a time sequence for each case, thus identifying the tensions encountered and actions implemented over time. Finally, we developed a process model around which we defined our contributions. Our results contribute to organisational resilience and exaptation and absorption literature by redefining resilience as a resource reconfiguration process that combines and balances exaptation and absorption over time, considering the repositioning of human and digital resources during a crisis. Finally, marketing scholars can access and observe from a privileged position the reaction of purchasing departments to exogenous shocks, thus understanding how marketing professionals and organisations in a B2B context can anticipate those moves and plan counter-moves accordingly.

5.2 Related literature

While a crisis displaces an organisation from its original state of balance and forces it to recreate coherence with its external environment, resource reconfiguration is the ability of a firm to reconfigure, realign and reorganise its resources in response to high-impact disruptions (Ambulkar et al., 2015). The analysis of resource reconfiguration in a context of response to sudden exogenous

shocks has focused so far on understanding how resource reconfiguration helps anticipate and prepare for future disruptions (Bode et al., 2011). We therefore ignore how, under severe time pressure, firms dynamically reconfigure their resources to respond to exogenous shocks. Thus, we lack both an understanding of how existing resources are reconfigured and how new resources are accessed and integrated. This research gap is critical as recent events, such as the COVID pandemic and the Russia-Ukraine war, reveal how sudden disruptions can leave no time for B2B organisations to prepare themselves to changing conditions. These events require a new exploration of the role of resource reconfiguration for resilience, aimed less at preparation and more at adaptation, organisational response and recovery. A first stream of literature that address resource reconfiguration as a response to an exogenous shock is the one that address supply chain disruptions (Hendricks & Singhal, 2005; Bode et al., 2011). B2B firms continuously face operations and supply chain disruptions that can be detrimental to their short- and long-term performance (Hendricks & Singhal, 2005, Bode et al., 2011), and this has renewed the focus on supply chain risk management. The risk associated with supply chain disruption is defined as "the potential loss for a supply chain in terms of its target values of efficiency and effectiveness evoked by uncertain developments of supply chain characteristics whose changes were caused by the occurrence of triggering-events" (Heckmann et al., 2015). The study of operations and supply chains disruptions has described organisational responses to abrupt changes as a resource reconfiguration process (Bode et al., 2011). In their model of corporate response to supply chain disruptions, Bode et al. (2011) establish a distinction between intra- and inter-firm factors. Firms develop reactions where resources along a supply chain are reconfigured to address and anticipate supply disruptions. Reconfigured supply chain resources include both resources controlled by the firm (inventory, production sites, warehouses) and external resources (suppliers, logistics partners). In the model established by Bode et al. (2011), external resource reconfiguration is described as a series of boundary-spanning and boundary-shifting actions with external partners. By reconfiguring their supply chain resources, B2B firms cope with turbulent changes; they recreate a fit between the organisation and its external environment. The continuous reconfiguration of supply chains where diverse firms adapt to external changes has sometimes been described as a complex adaptative system (Pathak et al. 2007). It means that within a supply chain, multiple agents adapt their behaviour to match external threats and changes; altogether, they create this latent reconfiguration capability and develop responses to disruptive events. While this research stream describes the reactions to external shocks as a resource reconfiguration process, it does not illuminate how these responses are developed. Firms scan and learn from their environment to predict disruptions, improving their responsiveness and ability to reconfigure resources. This focus on anticipation is a

classic orientation within the supply chain academic community. However, research has focused on how anticipation is formed, not how responses are developed.

The organisational resilience literature is another stream of literature that can help understand how resource reconfiguration occurs in a context of sudden exogenous shock. In this literature, the development of responses to external shocks has been described as a collective sensemaking process and the development of responses out of action that already exist in the organisation (Duchek, 2020). However, how such organisational responses are developed in practice remains unclear (Duchek, 2020). Annarelli and Nonino (2016) describe resilience as a resource management challenge where firms need to move preventive actions to more proactive strategies. Parker & Ameen (2018) build on Ambulkar et al. (2015) to suggest that resource reconfiguration is a crucial adaptative capability that allows firms to respond to environmental changes and achieve resilience. Resource reconfiguration includes rearranging resources in response to environmental disruptions, and firms can experience resource rigidity that prevents them from rapidly reconfiguring their resources when external shocks occur (Parker & Ameen, 2018). To achieve resilience, while Ambulkar et al. (2015) mentions the need to recombine and reorganise existing resources, they insist on updating and acquiring new valuable resources without describing how the recombination and acquisition of complementary resources unfold over time. Blessley & Mudambi (2022) recently highlighted that resource reconfiguration, in the context of a pandemic or a US-China trade war, plays a crucial role in achieving resilience not only to anticipate change but also in adapting and recovering from exogenous shocks. This insight echoes Dohmen et al. (2022), who described pre-emptive measures as insufficient in extreme and widespread disruption. Hence, while this literature recognises the importance of understanding how firms dynamically reconfigure their resources to respond to exogenous shocks by tapping in both existing and new resources, it does not provide theoretical foundations on how this happens.

To study how internal resources are reconfigured to develop responses to external shock, we considered the literature on how B2B organisations responded to COVID-19. The Coronavirus crisis introduced new challenges for B2B companies (Cortez & Johnston, 2020), unprecedented and different from previous ones (e.g., financial). The difference between this crisis and others lies in multiple factors: the uniqueness of its formation (related to sociobiological aspects), the effects on the personal and individual sphere (e.g., concern for the health of self and other people), the uncertainty about short-term developments, the absence of protocols or procedures to rely on, and above all, the magnitude of the impacts that also affected the everyday life of people and organisations. The ambiguity associated with the spread of the pandemic and the lockdowns has

created a wealth of tensions and contradictory forces; it forced people to develop creative responses to the occurring disruptions. Giustiniano et al. (2020) have described resilient leadership in the context of COVID-19 as "vigorous combinations of contrary elements such as preparedness and improvisation, clear direction-setting and flexibility in the face of specific circumstances". COVID-19 has forced organisations to search for new routines as contradictory, yet interdependent forces were at play. Within a short time, absorption through the investment in and integration of radically new resources and capabilities was unlikely. Therefore, responses needed to emerge from a rapid incremental exaptation process by which pre-existing resources were repurposed to solve different problems. Innovation scholars have adopted the concept of exaptation to understand how existing resources find new uses in new contexts (Garud et al., 2016). Exaptation consists in repurposing specific resources to achieve a goal different from their original function. Dew & Sarasvathy (2016) suggest that artefacts, technologies, processes, skills, and organisations can be repurposed through exaptation. The COVID-19 pandemic showed the implications and challenges of change and the urgency of efficient and effective responses. It has already been characterised in the academic literature by numerous cases of resource repurposing. One example is the repurposing of drugs to tackle COVID-19, as researchers have discovered the potential of anti-HCV medicines against the newly emerged disease (Elfiky, 2020). Ardito et al. (2021) portray exaptation within the drug discovery process as a phenomenon where a resource used to solve a given problem is used in a more or less distant problem space to solve other issues. As a result, companies from different industries have repurposed their design and manufacturing to create new products within days. While exaptation is relevant for drugs and specialised equipment, it might also explain how B2B organisations have developed effective responses to the pandemic and lockdown. By repurposing existing resources, firms can unleash an exaptation process; existing resources can be repurposed to address new problems as they emerge. A crisis like the pandemic forced organisations to resolve critical issues and brought opportunities. Kusa et al. (2022), referring to the COVID-19 crisis, defined factors accompanying opportunity-seeking to achieve company growth during crisis phases. Hence, within a discontinuity, the ability to develop resolution responses is accompanied by the ability to seize opportunities and build capabilities and growth (Kusa et al., 2022). One of the outcomes of COVID-19 has been a more diffused adoption of digital technologies (Döhring et al., 2021). Xiong et al. (2021) described how firms leapfrogged their digital transformation. This acceleration took place across many activities and sectors, including within supply chains (Pujawan & Bah, 2022; Zhou et al., 2023). This means that COVID-19 drove B2B firms to invest in digital technologies embracing technological discontinuities to cope with the ripple effects of the pandemic. The technological discontinuity literature also describes change as a process where external and internal resources are

reconfigured through an absorption process (Zahra & Georges, 2002). According to Zahra & Georges (2002), absorption occurs through acquiring, assimilating, transforming, and exploiting new knowledge. Regarding acquisition, embracing discontinuities pushes the organisation to span organisational boundaries and pull heterogeneous resources together (Lavie & Rosenkopf, 2006). New partnerships and alliances are established to access new valuable resources (Lavie & Singh, 2012). Anderson & Tushman (2018) and Asgari et al. (2017) described resource reconfiguration in the context of technological discontinuities as a range of mechanisms that include adding, reinforcing, challenging, leaving unaffected, and terminating relationships. The process of assimilation and transformation occurs by combining internal and external resources till a coherent network of relationships is established (Zahra & Georges, 2002). Recent literature has further explored the significance of absorption for digitalization. Lanzolla et al. (2021) explained that digitalization occurs through a process of search and recombination in which different resources are reconfigured. They also show how digitalization generates idiosyncratic tensions that can lead to different positive and negative outcomes.

This review of the existing literature shows that while the supply chain disruption and resilience literatures recognise the importance of understanding how firms dynamically reconfigure their resources to respond to exogenous shocks, they lack theoretical foundations to explain how this happens. Also, the review of the literature, by looking at recent studies on COVID 19 suggests that, to understand the dynamic reconfiguration of resources, we need to study how firms address tensions (Smith & Lewis, 2011). This literature also highlights the importance of considering both resource repurposing and the pursuit of technological discontinuity, a phenomenon that can also be understood as a resource reconfiguration process.

5.3. Research design

5.3.1 Research method

To perform our research, we opted for an exploratory, qualitative methodology suited for emerging phenomena with limited pre-determined hypotheses (Barratt et al., 2011). This choice allows us to build and extend theories (Strauss & Corbin, 1997), so we follow established case study research methods in line with theory-building approaches (Miles & Huberman, 1994). Theory development is performed employing a process model, a representation of the evolution of the phenomenon under study over time, thus incorporating the temporal progression of activities as elements of explanation into theorizing (Langley et al., 2013). A multiple case study, with companies as unit of analysis, was developed, but we collected cases in various phases, as explained in the following section, progressively narrowing the sample of companies and deepening the richness of data collected for

the seven in-depth case studies developed. Moreover, the construction of a process model that takes into account time requires the collection of longitudinal data, fundamental to observe how processes unfold over time (Langley et al., 2013).

5.3.2 Data Collection

Data collection occurred over two distinct periods in 2020, as described in Table 5.1. Collecting data over two separate stages allowed us to address our research questions with an appropriate time dynamic. During the first data collection campaign, we could access events and challenges as they occurred, which provided us with a clear understanding of the time dynamic. Then, the second data collection campaign provided access to detailed information on how the organisations' responses to the exogenous shock unfolded over time. Five Procurement and Supply Chain Executives were interviewed for over 30 minutes in March 2020. These interviews aimed to develop a good understanding of what had happened over the past weeks in each organisation. The people interviewed were Chief Procurement Officers in companies operating in different industries, which were all impacted by the pandemic. In April 2020, for the first data collection stage, we organised four online workshops, lasting two hours each, bringing thirty-nine Procurement and Supply Chain Executives altogether (additional information is provided in Appendix A). At that time, these Executives had not yet exchanged with peers since the lockdown that started in March 2020. Companies involved in this data collection process operated on a multi-country basis, most on a global scale.

Table 5.1 Data collection protocol

Data collection method	**Interviews and online workshops**	**In depth case studies**
Timing	Spring 2020	Fall 2020
Data source	5 interviews with CPOs 4x2 hours of online workshops with 39 CPOs overall	Data collection with 17 companies. Questionnaires leading to 15 to 20 pages of answers for each company – 4 hours of interviews with executives and managers for each company
Research questions addressed	What were the tensions experienced by procurement and supply chain organisations when they respond to sudden and abrupt change?	How organisations develop responses to unexpected and sudden exogenous shocks?

The online workshops were coded in real-time using an online whiteboard. Participants were able to see the coding as it was developed. Preliminary findings were described in a series of documents and then shared with informants, who were asked to comment on them. This first data collection campaign allowed us to map what happened during the abrupt and unexpected changes. We could identify, out of the data, competing forces and nested tensions unfolding over time. We concluded that we had achieved data saturation (Patton, 2002) on that side. However, we lacked an in-depth understanding of what allowed these companies to navigate the turbulent period. Therefore, during the fall of 2020, we performed a second data collection round with seventeen B2B organisations to gather more information on the mechanisms that helped these organisations navigate the tensions they experienced. The second data collection was performed as part of an award process to identify best practices in procurement and supply chain departments within organisations. Seventeen organisations have described within a questionnaire how they had been able to: (i) restore the continuity of business activities, (ii) recover a high level of performance rapidly, and (iii) regain the business advantage. They were also asked to describe the practices implemented. For each practice, they were asked to explain to what extent the practices described had been systematically deployed, and the impact noticed from their implementation. They were also asked to describe the results they had achieved. Overall, they responded to more than 30 questions in documents 15 to 20 pages long. CPOs also provided additional materials, such as internal presentations and memos that described their practices and achievements. For each company, findings were compiled into five-page documents and submitted to the people interviewed for review. Finally, seven companies operating with a B2B focus, which was relevant for us to understand their reaction to the abrupt change from a purchasing perspective, were selected and further developed as case studies.

5.3.3 Data analysis

The first part of the data analysis allowed us to create a data structure describing how competing forces and nested tensions unfolded over time. The coding process was data-driven, and we followed Gioia et al.'s (2013) systematic, inductive, three-step approach to grounded theory building, namely building theory grounded on the collected data and observations. This approach began by grouping and titling our first-order codes provided by our informants. The coding unit was the concept expressed by the informants. Therefore, multiple concepts could have been expressed in the same answer. Then, the second-order themes were organised by pairs exhibiting competing forces and tensions. Finally, this second-order themes were distilled into aggregate dimensions.

In the end, we have identified four overarching tensions. These tensions emerged out of the identification of consistent patterns within the data. We focused on data from the workshops during

this stage of the analysis. Then, we selected seven organisations from different sectors to increase generalisability, but with predominantly B2B businesses that had achieved outstanding results in reacting to the COVID-19 pandemic among the seventeen organisations we had interviewed. As such, we adopted a purposeful sampling approach (Patton, 2002) by selecting the cases that well repurposed their resources while reacting to the abrupt change. As a result, we considered first the operational financial performance of the organisations during this period. We assessed their ability to cope with specific environmental changes, such as the rapid growth of some of their business activities. In line with the tension perspective and ambidexterity literature, we considered their ability to jointly progress on their longer-term ambitions in innovation and digitalization, to anticipate future threats and developments while coping with immediate challenges. Table 5.2 summarises the main characteristics of the considered firms. As it can be noticed, the companies belong to different sectors but are all united by having experienced substantial impacts from the COVID-19 pandemic. This choice was made to increase the study's generalizability. The detailed case study coding followed a mix of inductive and deductive coding process. We structured the detailed data collected with the previously identified tensions and our second theoretical lens, the role of exaptation and absorption in an organisation's response to exogenous shocks. Therefore, we had a data structure in mind, but we left the specific concepts related to the theoretical lens free to emerge inductively. Due to the processual nature of the study, we classified the information with respect to a time sequence, using the period of discontinuity faced by B2B organisations as a reference. Thus, we identified a time sequence for each case, both in terms of tensions experienced and actions implemented. To show this temporal sequence in our results, we also build a process model that reports the approaches taken by the B2B organisations analysed to move from the initial discontinuity to the new state.

Three researchers independently coded the data to ensure the credibility of the findings, and the various discrepancies were discussed until consensus was reached. This process took five rounds of discussions spread out over eight weeks, two of which face to face with the involvement of all the researchers. The findings were developed following suggested practices for qualitative research; to support the emerging dimensions, we provide a detailed account of our observations (Eisenhardt & Graebner, 2007).

Table 5.2 - Summary of analysed cases

CASE	SECTOR	SIZE (category)	SIZE (# employees)	PROCUREMENT SIZE (# employees)	REVENUES (M€, 2020)
A	Original equipment supplier	Large company	115.000	1.200	17.800
B	Energy	Large company	2.531	55	500
C	Retail	Large company	400.000	200	61.200
D	Healthcare	Large company	8.000	30	1.000
E	Electric utility	Large company	11.600	76	14.333
F	Technology and engineering services	Large company	219.300	280	14.125
G	Hospitality	Large company	10.000	100	50.000

5.4. Findings

This section presents the timeline of events studied and the tensions that emerged from our analysis. In the second part, we describe the four identified tensions and the organisational responses to them. The data structure that represents the tensions is depicted in Figure 5.1. Additional information is provided in Appendix B. The organisational responses to the four tensions took place in a context of crisis and urgency that left no time for companies to look for new resources or solutions to integrate them; therefore, they relied heavily on the resources available. We classified the resource reconfiguration identified into three categories. In the first category, we grouped resource reconfiguration activities that consist in repurposing human resources. In a second category, we grouped resource reconfiguration activities that consist in repurposing digital resources. Finally, in a third group, we grouped absorption of new resources that involve new investments. The data structure that describes the organisational response to the tensions is depicted in Figure 5.2.

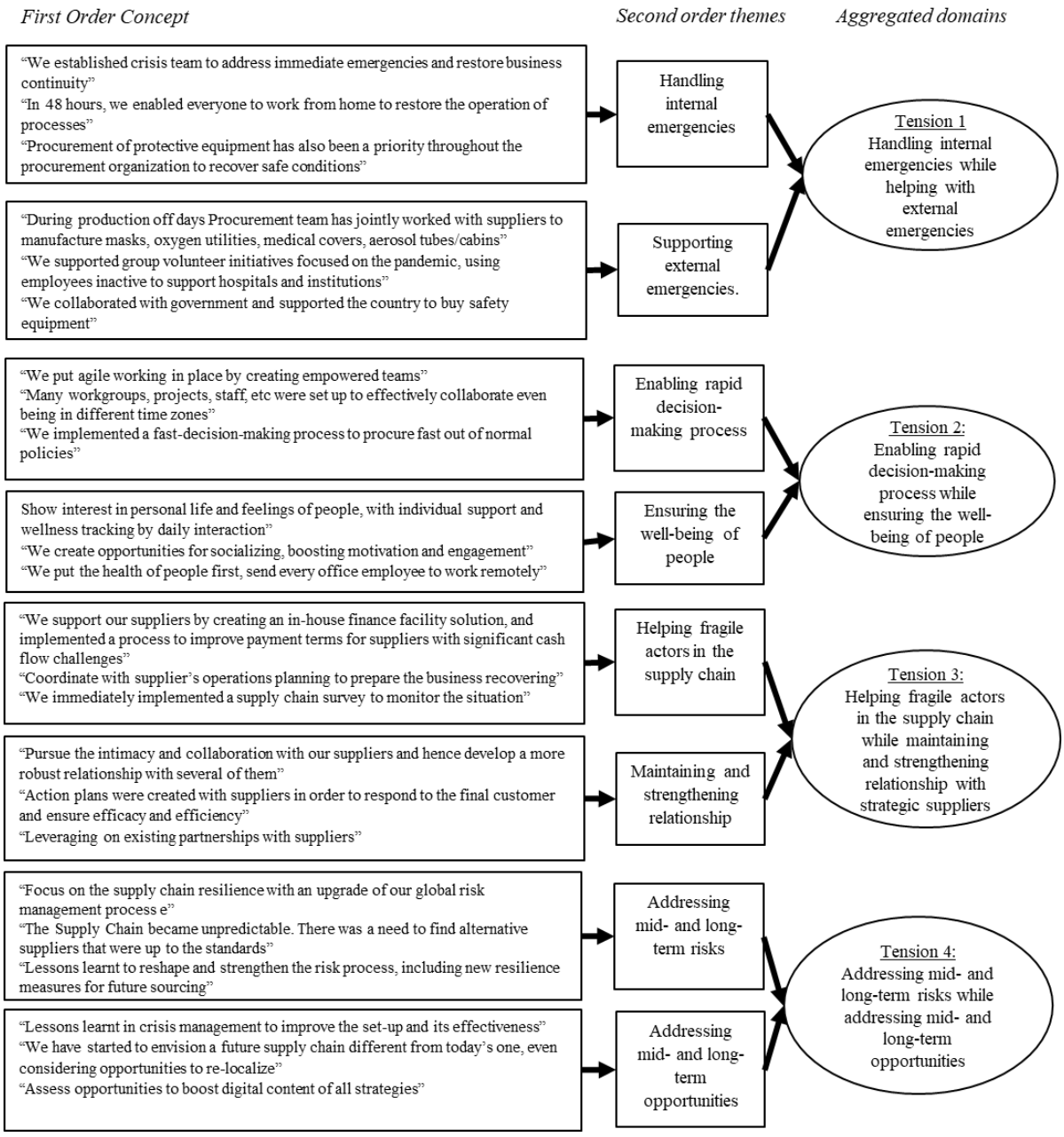

Figure 5.1 - Data Structure: tensions

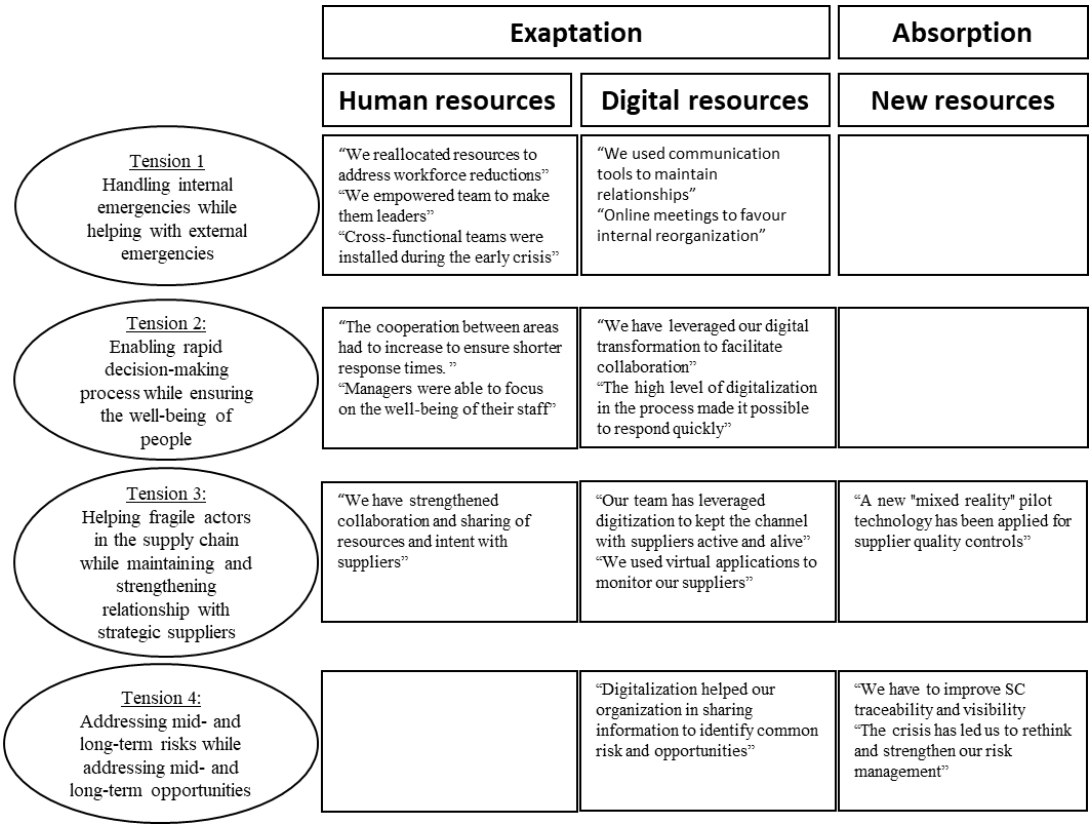

Figure 5.2 - Data Structure: solving the tensions by resource exaptation and absorption

5.4.1. Development of a timeline of events

In addition to identifying the tensions experienced by the B2B organisations, we identified the position of each tension along a timeline (Figure 5.3). Our analysis allowed us to divide time into three distinct periods: coping, adapting, and anticipating. Looking at the statements collected on Tension 1, managers emphasised the development of responses dedicated to coping with the exogenous shock and restoring business continuity. Tension 1 emerged at the pandemic's start and was devoted solely to coping. The period we called adapting saw the emergence of Tensions 2 and 3. The quotes identified for Tension 2 describe attempts to recover an acceptable level of performance throughout the company. And the statements collected for Tension 3 show how companies also attempted to recover satisfying performance levels throughout their supply chain. As organisations re-established a fit with their environment, including their supply chains, they started to examine how they could move into the third period we identified: anticipating.

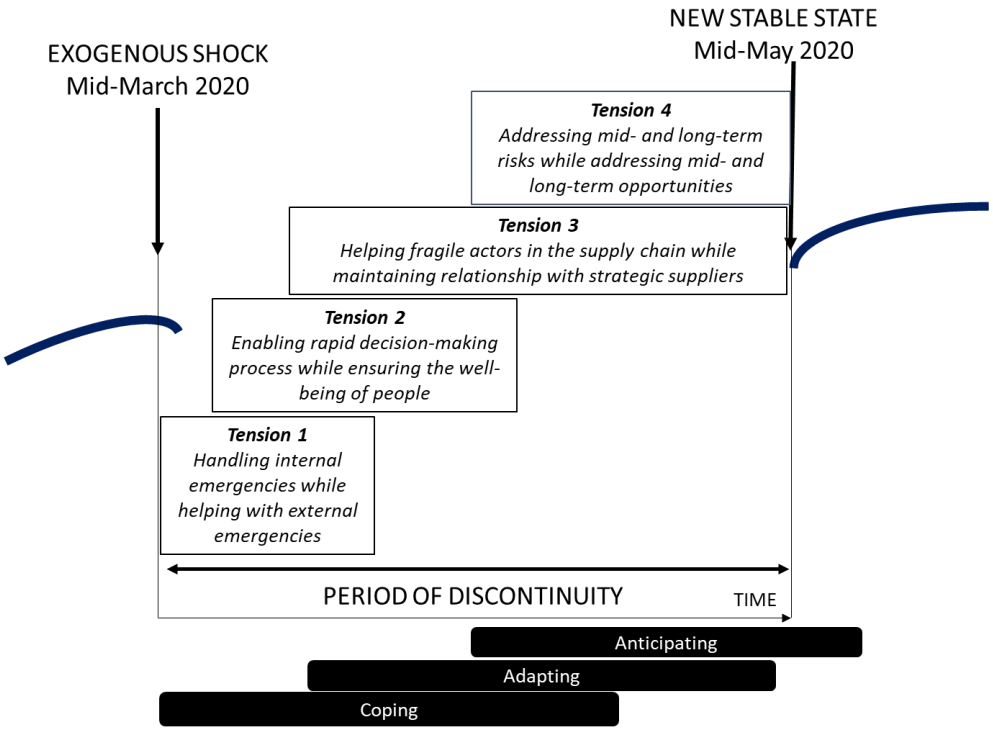

Figure 5.3 - The four tensions over time

The statements associated with Tension 4 fit this period well. They show a long-term orientation, dwelling not only on threats but also on the opportunities to gain new competitive advantage thanks to weakened competition, lessons learned, and new possibilities for improvement. During this period, B2B companies also developed more robust ties with their suppliers, contributing to their ability to anticipate later changes. On our timeline, we identify mid-May as a common return date to a stable state. This evidence does not mean that organisations in our sample no more experienced turbulence; it was our interviewees view, who described this time as a period where they were routinely managing turbulences.

5.4.2 Tensions and resolution through the resources repurposing

Tension 1: handling internal emergencies while helping with external emergencies

The first tension emerging from the data collected (additional information is provided in Table B1 in Appendix B) relates to internal and external competing forces. While in the early days of the lockdown, purchasing teams were handling internal emergencies and helping their companies with business continuity; they also paid attention to external emergencies. They helped the broader society when they were able to do so. In this context, purchasing teams reacted rapidly on the internal operational side while maintaining attention to what was happening outside the company. At the start of the lockdown, our informants described a similar pattern of events. One of the informants reacted by saying, “it was amazing to hear how different industries, geographies, and types of organisations

have been facing very similar challenges and are trying to overcome them by using a quite similar set of actions and redesigns.". Companies have established crisis teams to address immediate emergencies and maintain business continuity. Purchasing leaders were participating in these crisis teams. At first, some companies have had to set up cost containment plans and financial protection measures to protect their business. Then, everyday key actions included enabling employees to work from home, sourcing protective equipment, adopting e-signatures, and implementing specific processes to procure some purchasing items faster than usual. Purchasing has played a crucial role in enabling work from home, as it required buying and equipping computers or other equipment before delivering them to employees and sometimes external contractors. While for some B2B companies this was rather straightforward, for others, it was a complex project that needed to happen quickly. Besides business continuity, the purchasing team's immediate priority has been employees' safety. Focusing on the protection of employees required to purchase several millions of masks and some personal production equipment. The procurement staff worldwide acted as a unified team to make this happen. A company CEO commented on this on 10 April 2020 "I would like to thank you for your efforts and success in securing our mask supply from China. Your support and success have been critical to our global restart program 'Safer Together'". As part of this effort, the procurement team also helped some suppliers who had difficulty sourcing personal protective equipment. Furthermore, the companies shared their sanitary measures with suppliers so they could benefit from immediately available best practices. This tension emerged immediately as lockdowns were imposed and lasted over two to four weeks. Some of the organisations' responses, such as sourcing computers or protective equipment, continued over time but were then addressed as part of later tensions.

As the first tension emerged, the main resources repurposed were human resources. One of the interviewed managers emphasised the lack of staff that could work seamlessly and stated that they "had to adapt to the significant reduction of the workforce". The continuous and dynamic reallocation of people to different tasks and goals helped to address the first tension. Repurposing started with HR, IT and Health and Safety teams, who played a primary role in enabling work from home; then, repurposing rapidly expanded to all internal organisational units. This expansion led the organisations to immediately set up cross-functional teams dedicated to addressing the first tension. These teams were working autonomously, and issues were escalated to a central team only when it was an absolute necessity. One of our informants described autonomy as "teams were empowered to make them leaders in fighting the pandemic". Digital resources were also repurposed during the early stages of the pandemic, as they enabled everyone to work from home, ensuring the continuity of business activities and keeping people safe. Some companies had already adopted this form of work and had all the needed resources already available. Still, it was only during the pandemic that work-from-

home found its widespread and extensive use. Inevitably, the pandemic created physical distances between people, but organisations leveraged communication tools to "shorten the distance", operate and keep relationships alive. One informant stated that "group procurement globally uses Microsoft Teams to foster collaboration and communication". During the lockdown, digital tools were used on a large scale for internal communication and online meetings between employees and managers and to support internal coordination and exchanges with suppliers. Also, while procurement systems were already accessible remotely by employees, remote access was primarily contingency-based. With the pandemic, remote access became a new normal. Procurement systems helped organisations during the first phase of the pandemic by facilitating rapid decision-making and the reorganisation of activities. As factories were stopping activities, systems were used remotely to access supplier files and understand how to reduce the volume of purchases.

Tension 2: enabling rapid decision-making process while ensuring the well-being of people

After the early responses to the lockdown impact, we identified in our data (additional information is provided in Table B2 in Appendix B) that purchasing leaders were confronted with a new tension between accelerating the decision-making process and the need to ensure the well-being of people. On the one hand, it meant accelerating and taking action rapidly, while, on the other hand, it meant slowing down and caring for people. Teams across companies were addressing the following issues they discovered; speed was essential to ensure business continuity. Concurrently, procurement leaders also took the time to ensure the well-being of everyone within their team. The lockdown and its multiple implications also impacted the same individuals addressing emerging issues. In this context, while the flow of daily decisions was accelerating, it was essential to slow down and take the time to ensure team members were safe and fine. Moreover, in addition to making sure of the physical and emotional condition of personnel, procurement leaders ensured that employees were in a condition to work in the new remote mode; this required checking and addressing people's skills, balancing workloads, and ensuring work best practices. This tension emerged immediately after the initial business continuity plans were implemented. It took organisations about a month to respond to this tension. The response introduced during this period were maintained beyond the first months when the implementation of responses took place. It then evolved through a more continuous adjustment process over time.

The dynamic repurposing of human resources continued and helped to address many challenges and situations rapidly. People started to address new needs as they were able to. They organised themselves in teams capable of speeding up decision-making. A manager declared that "the cooperation between areas had to increase to ensure shorter response time and this also led to the

creation of cross-functional teams". Many informants described the change as adopting an agile approach and flexible working practices that increased the speed of decision-making. They also described a dynamic resource rotation and exaptation process where people with some availability and appropriate skills offered to help with emerging challenges. To help people operate in this dynamic environment, training was provided to help implement new behaviours. Managers we interviewed described to us how they were able to let others focus on operational concerns while they were focusing on the well-being of their staff. We heard many accounts of how managers could talk to many employees to understand their personal situation and help them in a disorienting context. Digital tools were also repurposed to accelerate decision-making. Digitalization helped foster collective decision-making dynamics regardless of the locations of people. One informant, for instance, stated, "our procurement system drives the simplification, standardisation and automation of the process, so that employees reach their goals". Digitalization accelerated decision-making processes, consistent with the greater speed of response required by the crisis, even if the activities were performed remotely. Focusing on well-being, the communication tools kept people's engagement high, facilitating activities and socialisation prioritisation. As part of this exaptation process, organisations used digital tools to monitor the engagement and workload of their people to ensure they could benefit from the best possible working conditions. One of our informants declared that "managers have to be extra careful not to overload their employees through constant monitoring; this can be done using our platform where all the processes assigned to people are described". Communication tools were also repurposed to create socialisation where participants could chill, express themselves, and exchange views beyond their work. One of the managers told us that "procurement leaders put in place individual support and wellness tracking by daily interaction through online meetings while employees were working from home". Digitalization ensured that the direct line between managers and operators was never broken, but managers' empathy and expertise made the difference, ensuring that personnel were not overworked and stressed.

Tension 3: helping fragile actors in the supply chain while maintaining and strengthening the relationship with strategic suppliers

The third tension that emerges from the data collected (additional information is provided in Table B3 in Appendix B) deals with the diversity of focus on the supplier side. While some supplier relationships are given more importance in a normal, steady-state context, in the lockdown context, strategic and non-strategic relationships were considered important and deserved attention. Following the lockdown, the purchasing teams conducted regular exchanges with their strategic suppliers to anticipate and address emerging challenges; they were also scrutinising and engaging with small, potentially fragile suppliers or some of their tier 2 or tier 3 suppliers moving into lockdown. In a

context of high uncertainty, issues to be addressed could come from any source, including large or small suppliers and close and distant suppliers. Besides supporting the most fragile suppliers, companies have also sought to keep current relationships alive, especially the most critical and strategic ones, while forging new connections. Initially, it was critical to leverage existing partnerships to plan a common response. The climate of uncertainty has called for greater collaboration between supply chain players based on a continuous and transparent exchange of information, exploiting the potential of digitalization. This coordinated reaction, however, was not only established through consolidated relationships, reinforcing existing ones, but also involved new players or occasional partners, opening possibilities for new partnerships. This tension emerged immediately after the initial business continuity plans were implemented. It became a continuous adjustment process, especially for global companies that faced a series of lockdowns across different parts of the world over time.

Even in resolving the third tension, we kept observing a phenomenon of exaptation through repurposing human and digital resources. People were helping suppliers who were facing difficulties in maintaining continuity in their operations while searching for new suppliers who could help respond to new needs. Later, they could be engaged in a weekly exchange with key partners to ensure rapid alignment between organisations. One supply chain manager described to us how people in her organisation were working in “commando style” as new needs or challenges emerged; people were “moving to the front” while others were “recharging batteries before their next move”. Digitalization also contributed to solving this tension by using the tools with new purposes and creating new tools out of the existing digital assets. One Supply chain manager described how his team developed a tool that identified suppliers they needed to contact based on public Covid-19 data, weather data, and supplier information. By doing so, they could contact suppliers ahead of competitors and better adapt to the situation. Another informant described how the organisation developed a digital financial stress test for the small suppliers so they could ask for help early enough. Companies started to use artificial intelligence and mixed reality technology during this period. For instance, procurement managers implemented new tools to handle supplier evaluations, assessments, and qualification processes. For one of the companies in our sample, the manager explained that “for supplier quality checks, new halo-lens mixed reality technology pilot applied with selected suppliers.” This evidence shows how different resources were suddenly recombined and extended to create new solutions that helped companies adapt to the situation. Some of the features of the digital applications that were used occasionally with some large suppliers were extended to smaller players during the pandemic. Repurposing digital resources did not simply replace previous interaction; it augmented the collaboration with suppliers. One informant stated that “moving to fully remote conditions has

allowed for more frequent digital contacts with the suppliers," which has opened possibilities for new discussions.

Tension 4: addressing mid- and long-term risks while addressing mid- and long-term opportunities

After the first emergency response to the lockdown, we could see in our data (additional information is provided in Table B4 in Appendix B) that purchasing leaders were confronted with competing forces in terms of their attention to threats and opportunities. For instance, while they realised they could reduce their demand volumes over the coming months to spend less, they also recognised the need to ramp up rapidly when demand would peak again. In other words, tackling mid-term risks could jeopardise the ability to seize the next opportunity. In the COVID context, the challenge was jointly addressing short- and long-term opportunities. Our data collection also reveals that purchasing leaders saw some opportunities at an early stage in terms of performance improvement, change of purchasing strategies, technology adoption, and competitive advantages. First, we have witnessed that our informants did not take for granted that we would end up with lower performance. Some informants described that before Covid, one of their goals was to strengthen their relationships with suppliers, and they saw the Covid period as an opportunity to do so. They even measured their progression through a supplier survey. Second, our data has also shown that while being conscious of the short-term challenges faced, purchasing leaders saw the benefits of revisiting their strategies. One of our informants commented, "we now see our strategies as hypotheses that need to be revisited on a regular basis". Another suggested, "It is important to revisit our strategies as market dynamics change fast. Yesterday we had a supplier who paid little attention to us. Now as their prime market is on-stop, they are more willing to work closely with us". Third, the lockdown has accelerated the adoption of new technologies. One of our informants told us that remote monitoring solutions for contractors operating on-site had not been prioritised for many years. These solutions had been identified in the past as an opportunity to reduce some internal costs, but some stakeholders had resisted adopting them. However, with Covid, the adoption of some new technologies was accelerated. Fourth, many of our informants have highlighted that periods of rapid changes provide opportunities to gain an advantage over competitors. They suggested they could create a lasting differential in performance. One of our informants working for a healthcare company told us that they had to serve all their clients. Being regarded as a reliable supplier throughout the pandemic was described by this informant as an opportunity to stay or become their clients' preferred supplier. We often heard the quote, "never waste a good crisis", or similar expressions throughout the focus groups and interviews. This tension emerged a couple of months after the lockdown as companies started to capture lessons from the exogenous shock and their response.

During this tension, companies started to face risks and opportunities in the medium to long term. From a human resources perspective, managers began to ask how they could continue to benefit from the new ways of working beyond the disruption they were experiencing. People were asked to keep a proactive exaptation dynamic. One of the procurement managers interviewed stated, “we developed a specific program that requires buyers to be disruptive and creative to explore new fields of savings and opportunities for the future”. Others were focusing more on maintaining close relationships with internal stakeholders and suppliers. This attention to anticipating future development shifted the focus from the current problematic situation to a more optimistic and forward-looking scenario. Digitalization played a vital role in the cases analysed, but unlike previous phases, in this stage, we observe the prevalence of developing new resources rather than repurposing existing ones.

Regarding risks, companies planned to invest in digital procurement solutions such as spend visibility tools, modules for indirect purchases, digital online sourcing, or risks-related modules or data. Smart tools used to monitor the supply chain were developed to identify potential risks. One of the managers interviewed stated: “As we looked at the lessons learnt from the crisis, the digitalization of the sourcing process improved traceability and resilience”. Procurement organisations leveraged new digital tools and resources, such as market intelligence, to anticipate future risks and opportunities. One of the managers interviewed declared, "we now use market intelligence solutions that support our sourcing team with market data”. Before the pandemic, these resources and tools were only poorly employed or inexistent. Still, during the pandemic, their adoption and usage have been extended and focused on precise outcomes dues to the abrupt changes experienced. One of the informants said that “the acceleration of the digitalization roadmap of purchasing processes is a must for more resilience and agility, better data management, leaner and faster-automated processes, but also to increase the productivity of the purchasing operating mode”. These improvements are not only valid and valuable in crisis time but also become relevant for the company's survival in the usual operating environment and for achieving competitive advantage.

5.5. Process model

In the previous section, we presented the tensions emerging during the crisis due to the pandemic and the solutions implemented by B2B firms. In this section, we report a grounded model (Figure 5.4) built on the analyses performed to theorise how firms’ reaction occurs during a crisis and how organisational resilience emerges out of a resource reconfiguration process. The decision to represent our results through a process model emerged mainly from the need to shape the temporal perspective and visualise first, the sequentiality of the elements that characterised the crisis and second, the sequential process of response to it. Tensions and the use of different resources followed a precise

temporal order along the crisis consistent with the different stages already predicted by organisational resilience models. Consistent with the approach already described by Duchek (2020), we identified a process model characterised by several consecutive steps.

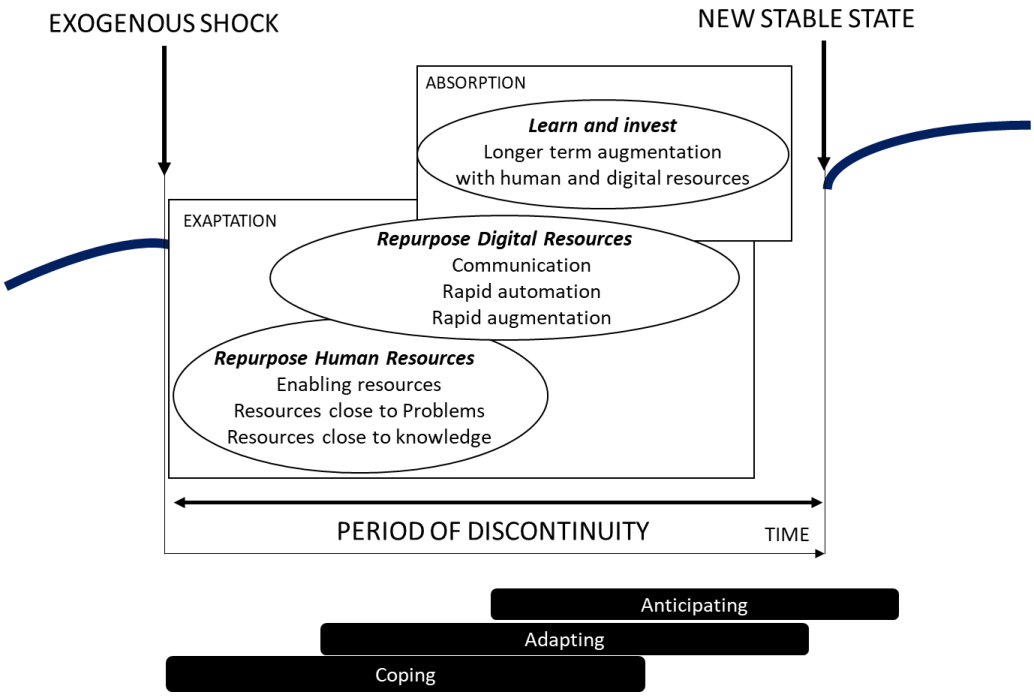

Figure 5.4 Process model of the study

Duchek described the "resilience-as-a-process" perspective as a processual approach with different stages to highlight the dynamic nature of resilience. Similarly, our model reinforces the sequentiality and dynamism of organisational response; specific tensions characterise different phases and require a different resource reconfiguration approach as exaptation and absorption. We have differentiated human and digital resources for each approach because, as shown in the following paragraphs, they serve different purposes; however, they are complementary, and their coexistence characterises the goodness of the two approaches.

5.5.1 Repurpose Human Resources

The repurposing of human resources is the first stage of our process model. As an exogenous shock occurs, the organisation starts navigating through a series of competing forces. It experiences tensions that lead to a dynamic and continuous repurposing of human resources. People close to emerging problems or with access to relevant information and resources are repurposed dynamically to cope with issues that arise. In parallel, other people who hold specific knowledge or have access to complementary resources are repurposed to help the organisation adapt to the crisis beyond the

immediate coping stage. At this stage, the organisation copes with the abrupt change and starts to adjust to an unraveling discontinuity. First, human resources are immediately repurposed to ensure the continuity of operations. These resources comprise people from HR, IT, Health and Safety, or other operational teams. They operate as a crisis team to warrant that everyone is safe and capable of supporting the organisation. As members of the organisation become available, they can now contribute to coping with the crisis by identifying emerging issues and responding to them. Human resources close to specific problems are dynamically repurposed as new issues emerge. When a given concern appears, some people who are best positioned to access information, interact with other persons on the matter and implement responses take on new tasks and roles. These are the resources that are repurposed to cope with the continuous challenges that are emerging. In parallel, human resources, who hold specific knowledge, are repurposed to develop mid- to long-term responses to the crisis. They have the best access to knowledge, information, and complementary resources to help frame, develop, and implement these mid- to long-term responses. These resources are repurposed to help the organisation adapt to the discontinuous state it is experiencing. As part of our research, we observed that some individuals could effectively balance the development of both types of responses. They were able to work against different time horizons and goals concurrently. They inform their midterm responses from their direct experience and knowledge of the problems they experience. According to our observations, other persons worked in waves; they focused for a given time on responding to an immediate issue before stepping back and taking a broader view of the priorities or the mid- to long-term responses needed. Other people preferred to stick to a type of repurposing on a more continuous basis.

5.5.2 Repurpose Digital Resources

The repurposing of digital resources is the second stage of our process model. Digital resources extend the ability of people to sense, communicate, and respond to changes. The dynamic and continuous repurposing of digital resources helps organisations cope and adapt to a discontinuous state. Digital resources are scale-free resources that can be used concurrently for different purposes and can be easily mixed and matched for new purposes. On the one hand, digital resources help automate coping routines that can be performed systematically and extensively. On the other hand, digital resources augment the ability of people to make effective decisions and adapt to new situations. As a disruption occurs, digital resources that support communications are repurposed to ensure the continuity of operations and enable people within and across B2B organisations to work together. Consequently, the ability to sense what is happening, exchange and communicate on issues and solutions, and develop and monitor the appropriate responses needed to cope and adapt to the situation is restored. More digital resources are rapidly repurposed to automate daily routines and

cope with emerging issues. The rapid automation of tasks extends organisational routines and accelerate their implementation; it simplifies access to information and reduce human interventions as the organisation sense change and copes with them and broadens an organisation's capacity to cope concurrently with diverse issues and constraints. Beyond automating coping routines, digital resources are also repurposed to develop new routines that help the organisation adapt and regain control over the crisis. The dynamic repurposing of digital resources augments[1] humans' ability to make effective decisions and adapt to new situations. As part of our investigations, we observed several rapid developments that accelerated organisational absorption and augmented the decision-making capabilities of people within B2B organisations. As a critical sequence of events unravels, repurposing digital resources can provide companies precious time advantages against competition. Being ahead of competitors in understanding what might go wrong is instrumental to succeeding in such a context. New routines are developed over short periods; they leveraged databases and tools to sense what is happening from a distance and suggest adequate responses. The repurposing of digital resources helps decision-makers anticipate and focus on critical matters.

5.5.3 Learn and invest

In this last stage of our process model, we shift from exaptation to an absorption logic. While exaptation is a process by which pre-existing resources are repurposed to solve problems, absorption is a process by which investment in new resources strengthens the ability of an organisation to solve new problems. During the past stages of our process model, the organisation has accumulated experience and knowledge on the issues it encountered, the different responses it implemented, and how the organisation was able to cope with the crisis. This accumulation of knowledge provides learning, orients future investments, and helps the organisation anticipate and address future threats. Based on their experience of discontinuity, B2B organisations can acquire new combinations of human and digital resources to innovate and anticipate future threats. In this stage, an investment in an adequate combination of human and digital resources can strengthen the performance and resilience of an organisation. An organisation that effectively learns from a crisis further invests in automating some tasks and augmenting its people capabilities to sense, predict and anticipate issues. Investment and absorption of new resources do not solely focus on defining solutions to problems in advance or systematically preventing specific problems; absorption can also consist of accessing valuable resources that can be promptly repurposed to cope and adapt to future changes. Through

[1] Automation consists in machines taking over a human task while augmentation consist in humans collaborating with machines to perform a task. See Raisch, S., & Krakowski, S. (2021). Artificial intelligence and management: The automation–augmentation paradox. *Academy of Management Review*, *46*(1), 192-210.

learning and investment, an organisation can better tackle emerging tensions, develop rapid responses and new routines out of diverse resources.

5.6. Discussion

We studied B2B organisational responses to crises by analysing how resources are dynamically reconfigured when an exogenous shock occurs. Consistent with the study by Grewal et al. (2007), we identified different phases to characterize the crisis; however, the sudden nature of the pandemic has significantly reduced the awareness and sensemaking phases of the crisis management, quickly leading organizations to the response implementation phase. This led us to focus our findings and discussion on organisational resilience, exaptation and the organisational inertia literature.

5.6.1 Contribution to organisational resilience literature

Our main theoretical contribution is to describe organisational resilience in a context of crisis as a resource reconfiguration process that combines and balances exaptation and absorption over time. Resilience is a firm ability to cope effectively with unexpected events, to bounce back from crises, and even to foster future success (Duchek, 2020). Unexpected events and adversity can stem from different internal and external sources and the severity and time pressure exerted by these events can vary. Our findings are relevant for severe and sudden crises, where anticipation is not sufficient and resource reconfiguration plays a key role right from the coping and adapting stages. In the supply chain literature, resilience has been portrayed as a resource reconfiguration process (Bode et al., 2011) with a stringent focus on how to anticipate and prepare for shocks. However, recent crises and threats such as the COVID-19 pandemic, the U.S.-China trade war, and the Russia-Ukraine conflict require further research on how resource reconfiguration occurs, not only to anticipate and prepare for future crises, but also to understand how resource configuration develops during the coping and adaptation phase of organisational responses. For instance, in the case of COVID-19, recent studies (Suder et al., 2022) have focused on strategies to be developed to mitigate the negative effects of the pandemic and adapt to new conditions. Consistent with these previous studies, our model considers pre-existing resources (Gittell et al., 2006) and the development of new ones (Bonanno, 2004; Do et al., 2022) to foster the resilience process. However, our results do not merely underline the role of different types of resources in responding to abrupt changes; we provide a dynamic perspective on how resources are reconfigured along the different stages that characterise resilience. Our research unveiled two resource configuration capabilities: resource expectation and resource absorption. While exaptation consists in repurposing of existing resources, absorption consists in the searching for, integrating and exploiting new resources. Indeed, to overcome tensions, the organisation combines and balances exaptation and absorption over time. As they cope and adapt to the abrupt change, they first repurpose

existing human and digital resources before gradually absorbing and investing in new resources to adjust and anticipate future challenges. Combining and balancing exaptation and absorption enable B2B organisations to return to a stable state where a new fit with the environment is established. Table 5.3 describes how these resource reconfiguration capabilities match with different stages that characterise resilience (Duchek, 2020) and with temporal and spatial perspectives.

Table 5.3 Resource reconfiguration capabilities, resilience, spatial and temporal perspectives

Resource reconfiguration capabilities	**Exaptation**	**Absorption**
Alignment with resilience phase	Repurposing existing human resources to *cope* and *adapt* to changes. Repurposing existing digital resources to *cope* and *adapt* to changes.	Absorbing new resources to *adapt* and *anticipate* future challenges.
Spatial and temporal perspectives associated with resource configuration capabilities	Human resources are repurposed to tackle *immediate* challenges based on their *proximity* to the problems they face and to the complementary resources needed to solve these problems. Digital resources extend the human ability to sense and respond to *distant and longer-term* challenges.	New combinations of human and digital resources might help to anticipate *future* threats and seize *upcoming* opportunities.

For the coping phase, we show that human resources tackle challenges based on their proximity to both problems and complementary resources. In contrast, digital resources extend the human ability to sense and respond to more distant and longer-term challenges. During the coping phase, organisation repurpose digital resources, to rapidly automate, simplify and speed up revised processes; this helps them accelerate their response speed. This dynamic reconfiguration generates new knowledge and allows the organisation to envision how new combinations of human and digital resources might help to anticipate future threats and seize upcoming opportunities. At this stage, unlike the scoping stage, the organisation combines and balances acquisition and absorption. As

digital resources complement and augment the capabilities and skills of human resources, they help scan and diagnose the environment, provide forecasts, and develop scenarios. When organisations reach the latest phases of the resilience process, they have accumulated learnings. By absorbing new resources, they can better respond to turbulence, anticipate future threats, and seize incoming opportunities.

5.6.2 Contribution to exaptation and innovation literature

Organisational evolution occurs not only due to absorption but also exaptation (Schweizer & Vahlne, 2022). The literature on exaptation is exhaustive in showing how resource recombination can support innovative processes in organisations (Andriani & Kaminska, 2021) or the generation of disruptive innovation (Beltagui et al., 2020). The results of our study show that the contributions of resource recombination go beyond innovation by also playing a relevant role in building and maintaining organisational resilience. We showed how the dynamic reconfiguration of human and digital resources can offer generative power. Our research shows that exaptation emerged as a response to nested tensions when the severity of the disruption and the time constraints created. Our research therefore suggest that exaptation is a capability that generate creative responses in a context of nested tensions (Lüscher & Lewis, 2008; Miron-Spektor & Erez, 2017). Severe time pressure can galvanise people and foster creative responses that manifest through a rapid repurposing of human and digital resources.

5.6.3 Contribution to the understanding of inertia and crisis

One interesting theoretical puzzle is that firms that face discontinuities and tensions also tend to experience persistent inertia and rigidities that hinder change (Tushman & O'Reilly, 2008; Eggers & Park, 2018). The explanation of this phenomenon suggests that routines and organisational processes are tightly aligned with a given environment (Miller & Friesen, 1980; Teece et al., 1997; Tushman & Anderson, 2018). Gilbert (2005) suggested that we must distinguish two forms of rigidity: resource rigidity, where organisations fail to change resource investment patterns, and routine rigidity, where organisations fail to change the organisational processes that use resources. Resource exaptation and resource absorption align well with these two forms of rigidity. However, we did not observe significant inertia in our findings. On the contrary, many individuals revealed their leadership capabilities in this period of crisis. These observations align with the literature on individual resilience (Williams et al., 2017). We often spoke with people galvanised by the change and the response of their organisation. We believe that this can be explained by two factors that our research uncovered. First, the change was so immediate and sudden that pre-existing routines were no more applicable; individuals across the organisation could rely on pre-existing resources but not on pre-existing

processes and routines. Second, the multiplicity of tensions and concerns provided individuals with a significant degree of autonomy. They picked problems they could handle without exposing themselves to excessive risks of failure and repurposed resources they were already familiar with. So, while on an aggregated level, B2B organisations were facing significant changes, individuals could not rely on existing routines, but they could reconfigure familiar resources to address problems. As they experienced initial success, individuals realised they could generate a positive impact and continued to develop new responses. Some gained confidence and developed new responses by, as some of our informants highlighted, re-using ideas that had been disregarded in the past or by experimenting with new ideas in a context where organisational defensive routines appeared to be down. Our research therefore shed lights on the inertia puzzle and complements the work of Dutton (1986), who suggested that the immediacy of a threat affects responses, and with Gilbert's (2005) distinction between routines and resources for explaining rigidity and inertia.

5.7 Conclusions

Our research on organisational responses to crisis offers valuable insight, advancing academic knowledge of the processual aspects of dynamic resource reconfiguration under severe time pressure and, more generally, the role of adaptation and absorption in organisational discontinuities. When we embarked on this research, we knew that navigating technological disruption was described in the academic literature with the lenses of tension and paradox. We therefore assumed that the navigation between operational perturbations under strong time pressure could be studied by adopting the same prism. Our process model not only described nested tensions resolved, but it also highlighted how firms combine and balance exaptation and absorption over time. Further, our process model draws attention to human and digital resource repurposing in B2B organisational dynamics. We would like our work to inspire further research on the micro foundations of dynamic resource reconfiguration and how pre-existing resources are repurposed to respond to change.

5.7.1 Limitation and future research

Our research illustrated how reconfiguring human and digital resources supports the response to disruptive events and contributes to building organisational resilience. The results are drawn from the observation of large companies operating on a global scale who successfully coped with the tensions engendered by COVID-19. In terms of limitation, the resource reconfiguration we described occurred with organisations who were able to repurpose relevant resources to cope with the disruption. This assumption may not always be valid especially outside of human and digital resources: future research may address the same issue by considering organisations operating with an extreme resource scarcity or whose resources are challenging to repurpose in contexts different from their intended use.

The role of resource exaptation and resource absorption were initially studied in innovation processes independently of each other; our research describes the combined role these approaches play for organisational resilience processes. We believe that our results should encourage scholars to further understand the role of exaptation-absorption beyond innovation, especially in turbulent contexts. By combining the exaptation and absorption lens to study of how firms respond to technological discontinuities, further research could enrich the understanding of how resources are dynamically reconfigured during such technological changes. Adopting an exaptation-absorption perspective would complement and enrich the perspectives developed by Asgari et al. (2017), who suggested that, as part of technological discontinuities, alliances that provide access to external resources can be added, reinforced, modified, left unaffected, or abandoned.

5.8 Appendix A

List of participants in the four workshops described in the chapter *5.3.2 Data Collection.*

Table A.1 - List of participants to the workshops

Industry	**Companies Headquarters Location**	**# of companies**
Consumer goods companies	3 from France 1 from the UK 2 from Germany 1 from Slovenia 1 from Mauritius	8
Chemical, pharmaceutical, and medical companies	1 from France 1 from Israel 3 from the United States	6
Transportation and engineering	2 from Germany 4 from France 1 from Portugal	7
Automotive	1 from France 1 from Belgium	2
Other Manufacturing, steel and raw materials	2 from Russia 1 from Mexico 1 from Switzerland 2 from France 1 from the UK	7
Utilities and telecom	1 from Belgium	4

	1 from Saudi Arabia 1 from France 1 from the United States	
Services and banking	3 from France 1 from Denmark 2 from the United States	6

5.9 Appendix B

Illustrative quotes from the analysed cases to code Tension 1 described in Chapter *5.4.2.Tension 1: handling internal emergencies while helping with external emergencies.*

Table B1 - Illustrative quotes for Tension 1

Tension	**Component**	**Illustrative quotes**
Handling internal emergencies while helping with external emergencies	Handling internal emergencies	*"We established crisis team to address immediate emergencies and restore business continuity"*
		"It was necessary to reduce costs and to collaborate with other department to assess criticality of purchase"
		"Procurement leaders had to adapt to the significant reduction of the workforce to recover operations"
		"In 48 hours, we enabled everyone to work from home to restore the operation of processes"
		"The procurement team has seen a surge in demand for services and products to react to the changing landscape"
		"Procurement of protective equipment has also been a priority throughout the procurement organisation to recover safe conditions"
	Supporting external emergencies	*"Our procurement has worked tirelessly with our internal stakeholders to identify potential suppliers who could produce suitable face coverings"*
		"During production off days Procurement team has jointly worked with suppliers to manufacture masks, oxygen utilities, medical covers, aerosol tubes/cabins"
		"We supported group volunteer initiatives focused on the pandemic, using employees inactive to support hospitals and institutions"

		"We helped our suppliers with the procurement of sanitiser and personal protective equipment"
		"We collaborated with government and supported the country to buy safety equipment"

Illustrative quotes from the analysed cases to code Tension 2 described in Chapter 5.*4.2 Tension 2: enabling rapid decision-making process while ensuring the well-being of people.*

Table B2 - Illustrative quotes for Tension 2

Tension	**Component**	**Illustrative quotes**
Enabling rapid decision-making process while ensuring the well-being of people	Enabling rapid decision-making process	*"We put agile working in place by creating empowered teams"*
		"With the introduction of remote work, each employee was able to perform his or her function in an agile and autonomous way"
		"With strong policies and processes, guided by world-class leadership, the teams were able to deliver what was required without compromising the overall strategy and value KPIs"
		"The team was empowered to work flexibly in the way that best suited them. Support and coaching were offered to all colleagues and managers"
		"Many workgroups, projects, staff, etc. were set up to effectively collaborate even being in different time zones"
		"We implemented a fast-decision-making process to procure fast out of normal policies"
	Ensuring the well-being of people	*"Show interest in personal life and feelings of people, with individual support and wellness tracking by daily interaction"*
		"Implement guidelines that help to reduce stress and recover well-being, we need to allow some people to take a break"
		"We create opportunities for socialising, boosting motivation and engagement"

		"Managers had to be careful to not overload their employees that kept working and practice a balanced workload, through its constant monitoring"
		"We put the health of people first, send every office employee to work remotely"

Illustrative quotes from the analysed cases to code Tension 3 described in Chapter 5.*4.2. Tension 3: helping fragile actors in the supply chain while maintaining the relationship with strategic suppliers*

Table B3 - Illustrative quotes for Tension 3

Tension	**Component**	**Illustrative quotes**
Helping fragile actors in the supply chain while maintaining and strengthening relationship with strategic suppliers	Helping fragile actors in the supply chain	*"We support our suppliers by creating an in-house finance facility solution, and implemented a process to improve payment terms for suppliers with significant cash flow challenges"*
		"We have monitored the full portfolio as issues can come from everywhere"
		"Coordinate with supplier's operations planning to prepare the business recovering"
		"We immediately implemented a supply chain survey to monitor the situation"
		"We offered help to suppliers to regain operations, including some tier 2+"
	Maintaining and strengthening relationship with strategic suppliers	*"Online meeting improved supplier communication and enabled continuous information flow with transparency; as a result, the trust was improved strengthening the supplier relation"*
		"Pursue the intimacy and collaboration with our suppliers and hence develop a more robust relationship with several of them"
		"Videoconferences with suppliers provided the opportunity to share our priorities during the crisis,

		ensure supply chain continuity, and work together towards the eventual restart"
		"Action plans were created with suppliers in order to respond to the final customer and ensure efficacy and efficiency"
		"Leveraging on existing partnerships with suppliers"

Illustrative quotes from the analysed cases to code Tension 4 described in Chapter 5.*4.2. Tension 4: addressing mid- and long-term risks while addressing mid- and long-term opportunities*

Table B4 - Illustrative quotes for Tension 4

Tension	**Component**	**Illustrative quotes**
Addressing mid- and long-term risks while addressing mid- and long-term opportunities	Addressing mid- and long-term risks	*"Updating our global risk management process and governance at the supplier level led to in-depth reviews of mitigation plans."*
		"The qualification and evaluation of suppliers was revised including a preliminary risk evaluation, considering the material and the potential supplier risk."
		"Critical analysis process that permits the categorisation of specific risks for all supplies."
		"We have started to review and improve our risk management to make it holistic and digitally enabled"
		"A robust supplier risk assessment process has been put on place and driven by Procurement leaders, looking at past disruption and current issues"
		"The Supply Chain became unpredictable. There was a need to find alternative suppliers that were up to the standards"
	Addressing mid- and long-term opportunities	*"Pandemic period has an enormous effect on bonding and strengthening the supplier relation, becoming an opportunity to improve the relation"*
		"Identification of new levers to increase the purchasing efficiency along the product lifecycle"

		"Renewed focus on avoiding waste, both in terms of time and cost (e.g., new savings program)"
		"We have started to envision a future supply chain different from today's one, even considering opportunities to re-localise"
		"Assess opportunities to boost digital content of all strategies"

6. CONCLUSIONS

This dissertation addresses the topic of digitalization and organizational empowerment within the production and purchasing environment, with a particular focus on the development of human and digital resources. The examined relationship is situated within the context of the Industry 4.0 revolution, thereby taking into consideration the emerging enabling technologies that have become prominent in the fourth industrial revolution. The main purpose of the dissertation was to understand how organizations evolve in the I4.0 context and how they can achieve the empowerment leveraging on their human and digital resources. This overarching purpose threads through the three essays presented in the dissertation, which collectively provide a comprehensive view of the empowerment journey. The overall goal can be divided into specific research objectives, that are:

- assess the interaction between digitalization and organization by investigating whether and how digital resources contribute to professional empowerment of human resources;
- assess the interaction between digitalization and organization by investigating the role of digital and human resources for the empowerment of organizational effectiveness, with a particular focus on resilience.

The objectives have been achieved in this dissertation by addressing the research questions previously introduced and reported below and in Figure 6.1:

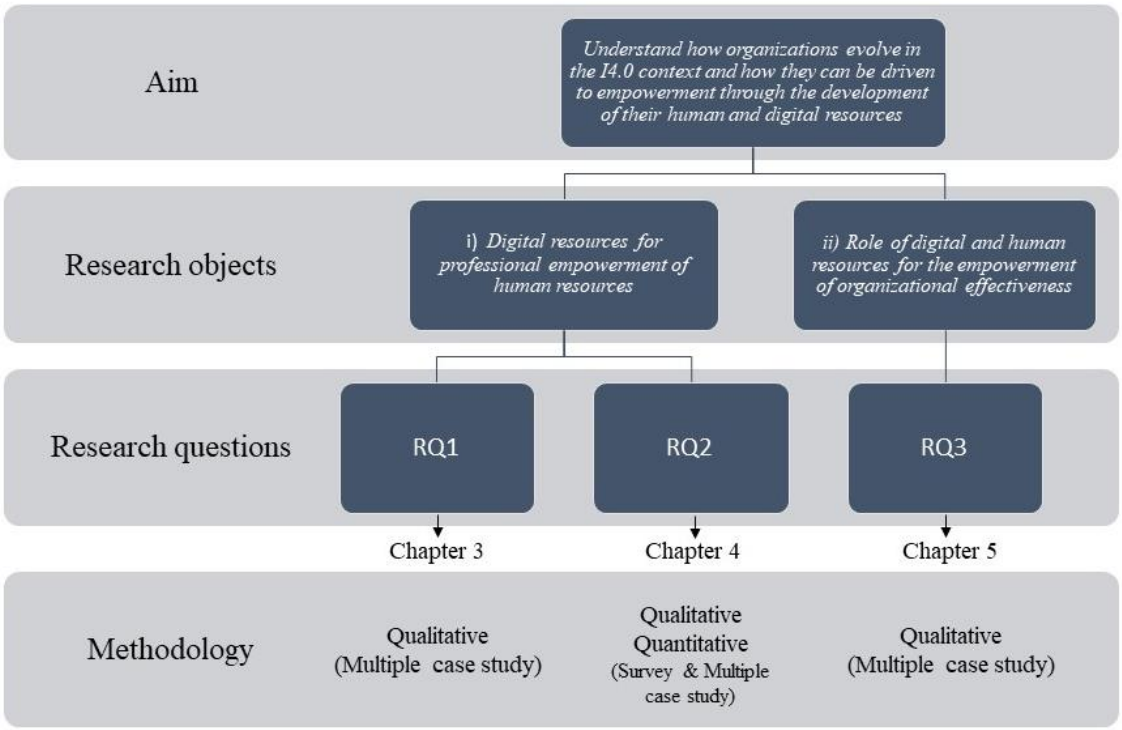

Figure 6.1 – Research framework

- *RQ1 - How do social systems and human resources evolve in relation to automation and augmentation technologies?*

The first research question is answered in the first essay "Navigating the socio-technical impacts of purchasing digitalization: a multiple-case study" by demonstrating how digitalization, based on both automation and augmentation technologies, affects the social dimension of purchasing. Automation improves efficiency and decision autonomy, while paving the way for augmentation, which extends the scope of strategic activities in procurement, improving organizational effectiveness.

Hence, this essay aims to give a comprehensive answer, offering visibility on the relationship between technological and social dimensions, but also deepening and characterizing the individual dimensions. This allows us to go beyond the limitations of the current literature, which sometimes focuses on one of the two dimensions (technological or social) or on the relationship, but without seeing the full picture.

To this purpose, this dissertation provides a comprehensive framework. This framework emphasizes the dynamic and evolutionary nature of the system, in which cumulative changes culminate in improved performance and substantial organizational and human adaptations. The framework allows us to highlight not only how different impacts occur because of different introductions (automation or augmentation) but also how the technological choices themselves are influenced by different drivers, such as data aggregation, efficiency and effectiveness. At the same time, data aggregation and automation mutually reinforce each other, collectively facilitating augmentation.

Automation technologies prevails at the operational level of the process for lower-value tasks, and are adopted to achieve cost savings, efficiency gains, reduced cycle times, resource optimization, and error reduction. Augmentation-oriented technologies predominates at the strategic level of the process for complex, high-value tasks, and enhance coordination, control mechanisms, and process support.

The social dimension of digitalization has a deep influence on purchasing at all levels, strategic, tactical and operational. Automation increases productivity, reducing reliance on human labor for operational and tactical tasks and enhancing decision-making autonomy among employees involved in these tasks. Augmentation, on the other hand, broadens the roles of purchasing professionals, particularly at tactical and strategic levels. Freed from certain tactical and operational duties, professionals can engage in internal and external collaboration, contributing to task enlargement. Digitalization positively impacts internal collaboration by simplifying processes and enhancing visibility, thereby facilitating interdepartmental cooperation. Companies may increasingly rely on cross-functional teams to navigate the complexities of digitalization projects, particularly when the

purchasing department is directly involved in implementing digitalization for the entire organization. Additionally, our research indicates that digitalization fosters external collaboration with suppliers and promotes supply chain integration. Augmentation technologies, in particular, enhance visibility, traceability, and real-time information exchange. Automation also contributes by streamlining processes, enabling more agile and efficient collaboration. This dual effect underscores the importance of both augmentation and automation in facilitating collaboration.

The organizational empowerment is not uniform and determinist. Technological implementation must be managed, considering employee training and development. Our research emphasizes the need for new skills and capabilities as digitalization progresses. Managers must facilitate professional development to maximize the social potential of digitalization for human resources. Our results also reveal potential barriers, such as skill gaps, resistance to change, and the absence of development plans, which can impede or hinder opportunities for evolution.

- *RQ2 – How the technological implementation affects the job characteristics and outcomes?*

The second research question is answered in the second essay "Manufacturing execution system in Industry 4.0 era: from implementation to impact on job design" by demonstrating how the implementation of new digital technology in production can lead to job empowerment through changes in job characteristics and outcomes as defined in the literature by the Job Characteristics Model.

Our research reveals how the digital implementation can empower the decision-making autonomy of production operators and diversify their activities and skill sets. The introduction of new, high-value activities enhances the substantive content of their work. However, this effect is neither immediate nor deterministic. Some organizations may opt not to grant greater autonomy or variety to operators due to strategic priorities or workforce readiness. Furthermore, the potential for professional development facilitated by digital technologies requires time for operators to acclimate to the technology and receive adequate training.

Under conditions conducive to professional development, our findings indicate positive impacts on job outcomes such as motivation, satisfaction, and performance. Nevertheless, as observed in other studies, significant changes can alter this effect, potentially leading to negative job outcomes. Individual characteristics appear to moderate this effect. Some workers may not welcome such development and may view it as an increased workload, while others with an inclination toward personal and professional growth exhibit more positive responses.

Thus, in addition to showing directions and end points of professional development, this research also defines behavioural and individual traits that can influence the empowerment, primarily of human resources, and consequently of the entire organization.

- *RQ3 - How human and digital resources contribute to the organizational effectiveness in responding unexpected and sudden exogenous shock?*

The third research question is answered in the third essay "Balancing exaptation and absorption of human and digital resources to achieve organizational effectiveness through resilience" by how firms respond during a crisis and how organizational resilience emerges through a resource reconfiguration process of human and digital resources. This essay introduces a grounded process model to emphasize the temporal perspective, showcasing the sequential nature of tensions and responses. The model aligns with the stages of organizational resilience, emphasizing the dynamic nature of response.

The initial stage involves the dynamic repurposing of human resources in response to emerging tensions during the crisis. Individuals with proximity to problems or access to essential information/resources adapt to address immediate issues. Meanwhile, others with specific knowledge or complementary resources pivot to assist the organization in adapting beyond immediate concerns. HR, IT, Health and Safety, and other operational teams form crisis teams to ensure continuity and safety. As new challenges emerge, human resources are dynamically reorganized to meet them. Some individuals with expertise in accessing information and implementing solutions take on new roles, while others with domain expertise focus on developing medium- and long-term responses. Some individuals effectively balance both types of response, while others work in waves or maintain continuous reorganization.

The second stage involves the continuous repurposing of digital resources, augmenting human capabilities to sense, communicate, and respond to changes. Digital resources automate systematic tasks and expand the organizational capacity to deal with diverse issues. They support communication, restore operational continuity, and streamline information access. Additionally, digital resources are repurposed to develop new routines that enhance crisis management. This dynamic resource reallocation accelerates organizational absorption and enhances decision-making capabilities. It enables organizations to stay ahead of competition by understanding and addressing emerging challenges.

In the final stage, organizations shift from exaptation to absorption, using their accumulated knowledge to strengthen resilience. Learning from the crisis experience guides future investments in a combination of human and digital resources. These investments strengthen the capability of an

organization to perceive, predict and anticipate problems. Organizations that effectively learn from crises invest in automation and augmentation, enhancing their performance and resilience. Investment and absorption extend beyond problem-solving to accessing valuable resources for future adaptability. Through learning and investment, organizations are better equipped to address emerging tensions, develop rapid responses, and create new routines using diverse resources.

6.1 Practical contributions

The primary practical contribution of this dissertation lies in providing a comprehensive view of the technology-organization relationship, offering valuable insights to managers in charge of overseeing digital and organizational transformation projects. The adopted methodology, which involves case studies with field-collected data, enables the provision of concrete recommendations and practices that managers can readily adopt and implement.

The first essay sheds light on technological choices and how their implementation varies based on the level of process or task content (strategic, tactical, and operational). The research offers specificity regarding implementable technologies in purchasing, guiding managers and practitioners on suitable tools and activities. Importantly, the insights on technological choices can extend beyond the purchasing department. The study defines a balanced mix of automation and augmentation technologies, enabling organizational empowerment while addressing employment-related issues and resistance to change. The first contribution characterizes the technical dimension, outlining technological approaches while laying the foundations for organizational empowerment by demonstrating the implications of technology on both macrostructural and human resource aspects.

This theme is further explored in the second essay, where the primary contribution centers on the social dimension of the organization. This essay provides specificity regarding the implications of technology for organizational work design. Managers can use these insights to design a technological transformation that enables organizational change, improving working conditions for employees while enhancing organizational performance. Effective design must consider the behavioural and individual characteristics of human resources, along with potential skills gaps, to mitigate resistance to change.

In summary, the first two essays offer practical contributions by demonstrating the prerequisites for a sociotechnical coevolution that benefits both human resources and organizational performance. Finding the right balance between automation and augmentation technologies is fundamental for organizational empowerment. However, the introduction of technologies alone is insufficient. To enable empowerment, managers must design a coevolution of the organizational dimension. Aware

of the implications that technologies have on structure and human resources, managers must prepare the organization for change, developing both soft and hard skills (including digital skills) among human resources, fostering a change-oriented organizational culture, and involving all stakeholders in various phases of digital transition. In other words, the social dimension must always be considered in technical and technological decisions, reaffirming the sociotechnical nature of the Industry 4.0 phenomenon.

The study also reveals how the interaction between technology and organization is influenced by the company operational environment. The third essay introduces the sociotechnical dimension into a complex and uncertain context, such as that created by the COVID-19 pandemic. In this context, the interaction between human and digital resources becomes even more relevant, promoting organizational empowerment through increased organizational effectiveness. Responding and adapting to such a sudden disruption required organizations to enhance or build their resilience, with human and digital resources playing a crucial role. Besides their positive role in resilience, this study demonstrates to managers the flexible and adaptive nature of these resources. The need for a rapid response did not allow for the development or introduction of new resources, but organizations repurposed and readapted existing resources, highlighting how human and digital resources can quickly change their application context when the sociotechnical dimension is correctly designed and managed. This contribution is relevant not only for managing a disruption but also for organizations operating with limited and scarce resources. Adequately designing and managing the coevolution of the sociotechnical dimension leads to organizational empowerment, regardless of the operational environment (complex or uncertain) or organization characteristics.

6.2 Theoretical contributions

This dissertation collectively advances the theoretical understanding of various aspects related to technology adoption, job design, and crisis management, thus contributing to extending and contextualizing socio-technical systems theory in the I4.0 era.

The first essay enriches the socio-technical systems theory by demonstrating that automation and augmentation are not mutually exclusive but can complement each other. It introduces the concept that the boundary between automation and augmentation is related to the complexity of the task and the need for complementary knowledge, but also with respect to resource readiness and possibilities for organizational empowerment. This expands our understanding of how technology influences social systems within organizations.

The second essay further extends that knowledge and the sociotechnical relationship, and at the same time it validates and improves the Job Characteristics Model by illustrating how a 4.0 technology can influence job design and workforce dynamics. It identifies individual characteristics that moderate the effects of technological changes on job outcomes, providing a nuanced perspective on job redesign in the context of I4.0.

Finally, the third essay advances the literature on organizational resilience by describing it as a resource reconfiguration process that combines exaptation and absorption of human and digital resources over time. It emphasizes the importance of understanding how resource configuration evolves during crisis response, offering a dynamic view of resilience that is crucial in today unpredictable business landscape.

6.3 Limitations and Future Research:

While these papers offer valuable insights, they also acknowledge certain limitations and suggest avenues for future research. Part of the limitations are related to individual papers and their contributions. The first essay is primarily exploratory and calls for further investigation into the interplay between humans and machines, but also considering organizational interfaces and external collaborations. The second essay suggests the need for deeper exploration of individual characteristics and their correlations in the context of technological changes. In particular, this research would be perfectly completed if future studies could increase knowledge about behavioural and attitudinal characteristics that can influence empowerment. Overcoming this limitation would make it possible to move from a general coevolutionary proposal of the socio-technical dimension to a more customized and individualized solution of professional development. The results of the third essay are based on organizations with ample resources and suggests exploring resource reconfiguration in resource-scarce contexts. Additionally, it encourages further research into the role of exaptation-absorption in various organizational contexts beyond innovation and technological disruptions.

To conclude the dissertation, these collections of papers collectively provide a comprehensive understanding of how organizations can navigate the challenges posed by technological changes and crises. Their practical contributions, theoretical advancements, and identified areas for future research contribute to the growing body of knowledge in these critical domains of organizational management and strategy.

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