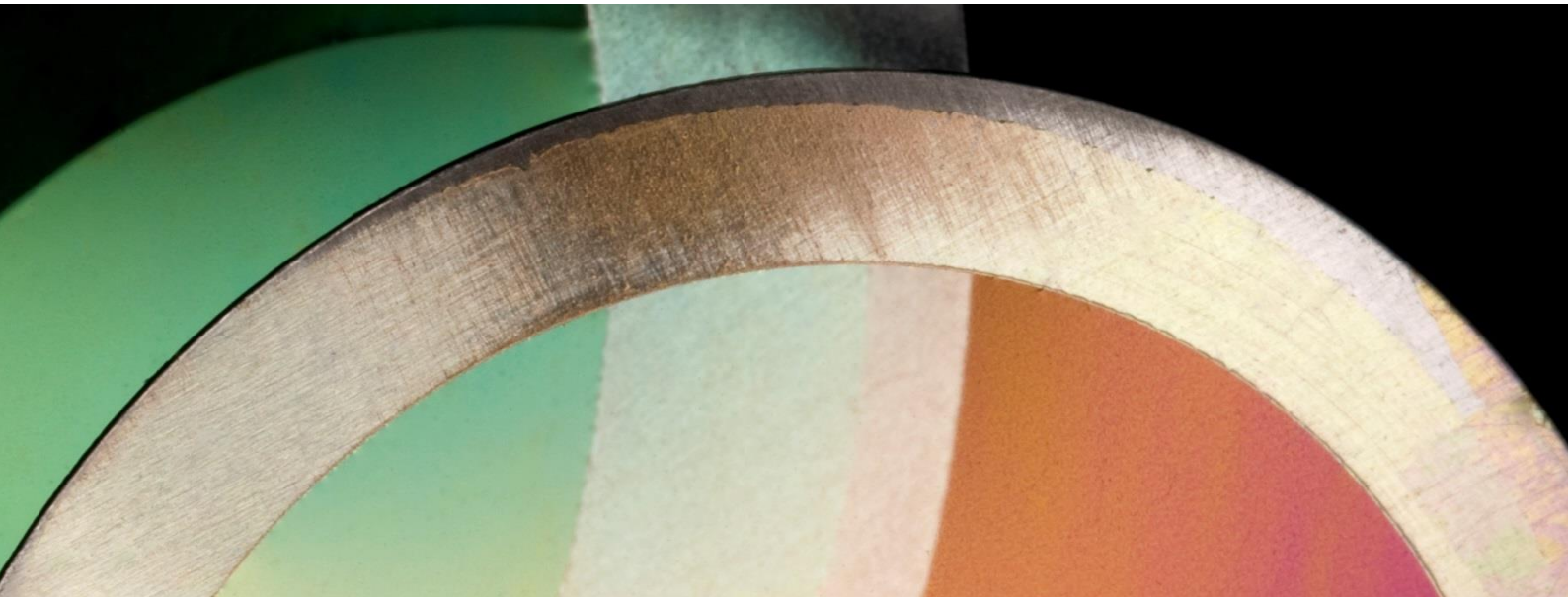
European Commission

Case Studies of Automation in Services

A workplace analysis of logistics, cleaning and health sectors in Italy

Cirillo, V., Rinaldini, M., Virgillito, M.E., Divella, M., Manicardi, C., Massimo, F., Cetrulo, A., Costantini, E., Moro, A., Staccioli, J.



EU Science Hub
https://joint-research-centre.ec.europa.eu

JRC129691

PDF ISBN 978-92-76-58953-2 doi:10.2760/347087 KJ-05-22-402-EN-N

Luxembourg: Publications Office of the European Union, 2022

How to cite this report: Cirillo, V., Rinaldini, M., Virgillito, M.E., Divella, M., Manicardi, C., Massimo, F., Cetrulo, A., Costantini, E., Moro, A., Staccioli, J., *Case Studies of Automation in Services. A workplace analysis on logistics, cleaning and health sectors in Italy*, Publications Office of the European Union, Luxembourg, 2022, doi:10.2760/347087, JRC129691.

Contents

Abstract

A full understanding of the technological complexity underlying robotics and automation is still lacking, most of all when focusing on the impacts on work in services. By means of a qualitative analysis relying on the administration of more than 50 interviews to HR managers, IT technicians, workers and trade union delegates, this work provides evidence on the main changes occurring at shopfloor level in selected Italian companies having adopted technological artefacts potentially affecting labour tasks by automating processes. The analysis of interviews complemented with visits to the companies and desk research on business documents highlights that so far labour displacement due to the adoption of automation technologies is not yet in place, while tasks and organizational reconfiguration appear more widespread. Major heterogeneity applies across plants due to the final product/service produced, the techno-organizational capabilities of the firm and the type of strategic orientation versus technological adoption. These elements also affect drivers and barriers to technological adoption. Overall, the analysis confirms the complexity in automating presumably low-value-added phases: human labour remains crucial in conducting activities that require flexibility, adaptability and reconfiguration of physical tasks. Further, human agency and worker representation, in particular the role of trade unions, are almost disregarded and not considered by the firms when deciding to introduce a new technology.

Acknowledgements

The research project "Case studies of automation in services" has been realised by a consortium of researchers from the University of Bari "Aldo Moro" (Department of Political Sciences), Sant'Anna School of Advanced Studies (Institute of Economics) and University of Modena and Reggio Emilia (Department of Economics and Communication) in cooperation with the JRC Human Capital and Employment Unit (JRC B.4) team. In detail, the researchers of the three Universities that have contributed to the realisation of the research project and to this report are: Valeria Cirillo (University of Bari Aldo Moro) – Chapters 1, 2, 3, 4, 5, 6; Matteo Rinaldini (University of Modena and Reggio Emilia) - Chapters 1, 2, 3, 4, 5, 6; Maria Enrica Virgillito (Sant'Anna School of Advanced Studies) - Chapters 1, 2, 3, 4, 5, 6; Marialuisa Divella (University of Bari Aldo Moro) – Chapters 4 and 5; Caterina Manicardi (Sant'Anna School of Advanced Studies) – Chapters 4 and 5; Francesco Sabato Massimo (University of Bari and Sciences Po Paris) – Chapter 3. The realisation of the project has crucially relied on the participation in fieldwork activities of Jacopo Staccioli (Sant'Anna School of Advanced Studies and Catholic University of the Sacred Heart Milan), Armanda Cetrulo (Sant'Anna School of Advanced Studies), Angelo Moro (Sant'Anna School of Advanced Studies) and Eleonora Costantini (University of Modena and Reggio Emilia).

The authors wish to acknowledge the support in the research activities received by the JRC Human Capital and Employment Unit (JRC B.4) team: Marta Fana, Enrique Fernandez Macías, Annarosa Pesole, Matteo Sostero and Cesira Urzí-Brancati.

The authors would also like to acknowledge the HR, IT technicians, workers and trade unions' delegates of Poste Italiane, Amazon, PMI Manufacturing & Technology Bologna, Santa Maria Nuova Hospital, Azienda Sanitaria Unica Regionale Marche, Humanitas Research Hospital, Coopservice, Nestlé Vera and Dussmann Service Italy that took part in the research project sharing information on their work practices. We especially thank Poste Italiane, Amazon, PMI Manufacturing & Technology Bologna, Santa Maria Nuova Hospital, Azienda Sanitaria Unica Regionale Marche, Coopservice and Dussmann Service Italy allowing for in person visits of the establishments.

The research team would like to thank all companies that have provided their availability to take part in the research, even if not included in the final list of selected cases. These are: Formula Servizi; Lamborghini; Ducati Motor; Bonfiglioli; NCV; Azienda Ospedaliero Universitaria Consorziale Policlinico Bari; Medici Insubria S.C.P.A.; Cooperativa Auxilium S.R.L.; Fondazione ANT Italia ONLUS; CADIAI; Società Dolce; IRCSS – Istituto Pascale Naples; Coop. Gulliver; COLSER Servizi S.c.r.l.; REKEEP S.P.A; Fondazione Monasterio.

Crucial support in the research activities has been also provided by the research and innovation hubs ARS Control, ART-ER, ARTES 4.0; and by AGCI - Associazione Generale Cooperative Italiane, Centro Studi Confcooperative, CGIL - Italian General Confederation of Labour, Dedalus Group, Elettric80, Exprivia, Federturismo-Federalberghi, Fondazione Claudio Sabattini, Fondazione Ergo, Fondosviluppo, Legacoop, ISTAO.

Authors

Valeria Cirillo, Matteo Rinaldini, Maria Enrica Virgillito, Marialuisa Divella, Caterina Manicardi, Francesco Sabato Massimo, Armanda Cetrulo, Eleonora Costantini, Angelo Moro, Jacopo Staccioli.

1 Introduction

In recent decades, investments in digital and automation technologies have significantly increased, shaping production and distribution processes both in manufacturing and service industries. Indeed, new digital and automation technologies promise improvements to production and service delivery processes and imply deep changes in the nature and organisation of employment. Several authors have highlighted possible economic advantages stemming from the application of advanced operational technologies due to increased automation, control and interconnectivity as well as detrimental effects in terms of quality of work, employment conditions and, even, technological unemployment (Brynjolfsson and McAfee, 2014; Ford, 2015).

The fact that technology has never been so widespread throughout humankind – in various and differentiated forms, hugely investing in both the production and reproduction spheres – has seen fresh attention in recent times. The emergence of artefacts embedding some forms of 'intelligent automation', such as 'intelligent robots', has caused some concern both in the academic and institutional debates (for instance, the EC Communication 'Artificial Intelligence for Europe' in 2018 and the EC 2020 Work Programme). In recent years, these artefacts have been equipped with learning algorithms able to process enormous amounts of data in real time and perform functions like classification and interaction with humans. New literature has flourished since 2014 and following the Great Recession, providing figures and forecasts about the future of work. The ground is clearly contested between techno-optimists and techno-pessimists, both largely sharing a strong deterministic perspective on the unfolding of technologies within sectors of activities, companies and their impact upon labour (Calvino and Virgillito, 2018; Mondolo, 2021; Staccioli and Virgillito, 2021b).

Against this background, it should be clarified that new technologies include a diverse set of solutions and capabilities, encompassing robotics, artificial intelligence, the industrial internet of things, big data, cloud computing, augmented reality, additive manufacturing and cybersecurity. Even though it can often be difficult to draw precise lines of demarcation, these are different technologies subject to convergence and recombination adoption among technology users (Cirillo et al., 2022). In fact, it can be hard to assess the exact demarcation between automation, digitalisation and device interconnectivity in quantitative and qualitative types of research.

For the purpose of this research – intended to explore the consequences of automation on work and organizations, as well as drivers and barriers of automation – we consider automation as the adoption of robotic and digitally enabled machines by firms aiming to make production and distribution processes more efficient and, in theory, replacing labour input with machine input (Fernández-Macías, 2018). More often, automation goes hand in hand with the digitisation of processes, which refers to 'the use of sensors and rendering devices to translate parts of the physical production process into digital information (and vice versa), taking advantage of the greatly enhanced possibilities of processing, storage and communication' (Fernández-Macías, 2018, p. 15). As said, digitalisation and robotisation/automation can be interrelated; for instance, the automotive sector provides clear-cut examples of these tendencies (Moro and Virgillito, 2022).

Digitally enabled machines aimed at automating specific phases of production and distribution processes may have profound consequences on work that can be better understood at task more than job level. In fact, the major difference, as compared to the previous technological waves, concerns both the pervasiveness as well as the number of tasks that digital devices and digitally equipped machines are now apt to perform, some of which were previously believed to be an exclusive prerogative of humans (Cirillo et al., 2021). Therefore, tasks more than jobs should take centre stage of the analysis since jobs are more likely a 'bundle of tasks' combined in specific and coherent ways into actual jobs (Fernández-Macías and Bisello, 2022). Workers' tasks are in fact the fundamental entities which can (in theory) be reshaped (or substituted) by digital machines and robots, impacting labour processes and work practices. Is this verified? It is one of the purposes of the research project.

The attention towards tasks more than jobs is not new in the scientific debate. Indeed, the dominant framework for the explanation of human-machine relationships relies on what is known as the 'task-based approach'. Popularised by Autor, Levy, and Murnane (2003), it considers the bundle of tasks executed by each worker as the most important dimension upon which technological change and, particularly in earlier versions, the use of computers at work shapes the dynamics of occupations. Notably, the routine vs non-routine dichotomy has become mainstream in economic literature ('Routine Biased Technical Change', RBTC). The underlying idea is that some human tasks can be more easily substituted by technological change, represented by the use of computers, while others are less so. The degree of substitutability depends on the amount of codified knowledge required to execute a given task.

However, the RBTC approach has also been criticised due to its mere technical view of production, seen as a mechanical process of transforming inputs into outputs, disregarding both human agency and social aspects of production processes (Fernández-Macías and Hurley, 2017). Tasks are understood as discrete units of work activity producing actual output and susceptible to replacement. Indeed, the underlying element relied upon by both RBTC and the task-based approach is the existence of a given degree of substitutability between labour and capital. Other branches of research – such as the evolutionary theory of technical change, capability-based theory for the firm, labour process theory, organisational studies – still evaluating the importance of tasks as embedded in labour processes and work practices have highlighted that the degree of substitutability between human and machines should be evaluated considering the intersection of several other elements, such as existing technological trajectories, the amount of codified and non-codified knowledge, relevance of organisational routines and practices, institutional factors. All of these elements profoundly influence the relation between jobs, tasks and technologies and, of course, automation (Cetrulo et al., 2020; Dosi et al., 2021a).

How do tasks and work processes change in relation to robotisation and automation? To respond to this research question, the project 'Case studies of automation in services' explores the main changes occurring at shopfloor level in selected Italian companies using specific devices – automated guided vehicles in logistics, professional cleaning robots and health monitoring devices – potentially affecting labour tasks by automating processes.

Overall, a full understanding of the technological complexity underlying robotics and automation is still lacking, most of all when focusing on the impacts on work. Indeed, robots are convoluted artefacts whose use may be either labour-augmenting or labour-displacing. From this point of view, focusing on tasks more than jobs could allow a better understanding of ongoing transformations at the level of labour processes and the reconfiguration of work practices. Automation rarely applies to an entire job, but it can often apply to specific tasks.

Both automation and digitisation can displace labour by increasing productivity, although 'compensation mechanisms' should be carefully taken into account (Dosi et al. 2021b). Job losses may occur, but more importantly changes in tasks and skills, which have to be accommodated through work organisation.

Additionally, automation and digitisation affect work organisation in more direct ways. Digital technologies are quite literally technologies of control and monitoring (what is currently referred to as algorithmic management). They tend to standardise work tasks and centralise control (Moro et al., 2019; Wood, 2021).

Much of the current research efforts are focussed on the manufacturing sector, while scarce attention has been devoted to the study of services. What, in fact, seems to differentiate this current wave of automation vis-à-vis the past more, rather than the actual human-machine relationship, is the pervasiveness of automation well beyond standard manufacturing processes. In fact, more recently, artificial intelligence and other computational breakthroughs have also become increasingly relevant to service sectors, which nowadays employ the largest share of the workforce. As a direct consequence, robotisation and artificial intelligence represent a threat not only to blue-collar workers, but to white-collars as well (Montobbio et al., 2022).

Indeed, sectors like medicine and healthcare are still at an early adoption stage for robots and machine-learning algorithms, whose massive usage could be complementary to human activity, rather than replace it. There is potentially ample room to go well beyond the use of robots and artificial intelligence in already standardised and highly productive sectors, like fast-food preparation and delivery, to less standardised sectors, like medicine and healthcare, whose cost curves are disproportionately steep, threatening healthcare access for an increasing fraction of the population both in countries which have universal coverage (e.g. most European countries) and those which do not (e.g. the USA).

All of these elements motivate the need to investigate the consequences of automation in services. To pursue this goal, a qualitative type of approach has been chosen. Qualitative studies allow detailed analyses of ongoing dynamics to be obtained which are usually neglected by purely quantitative approaches. Indeed, at the time of beginning this research, large-scale and representative databases able to integrate firm-level information with labour market dynamics detailed by skills and tasks were still not available. Therefore, the project has been developed adopting a qualitative type of approach based on the administration of semi-structured interviews to specific professional figures operating within the companies (see Chapter 2).

The fieldwork activity has mainly been carried out in Italy, although the diffusion of new enabling technologies – and specifically those related to automation – is scattered and notably based on cybersecurity-type tech (Cirillo et al., 2021). There is a very small cluster of Italian companies – mainly located in Northern

Italy – operating both in manufacturing and services that are introducing technologies aimed at automating tasks within production and distribution processes. Similar figures emerge from Eurostat's Community Survey on ICT usage in enterprises, showing a rate of adoption for service robots of about 4% for Italy.

Against this background of scattered adoption of the technologies of interest by firms –professional cleaning robots, autonomous guided vehicles and remote monitoring devices – an accurate strategy for case selection has been followed by the research group to identify a list of 'adopters' and select cases to be included in the analysis.

This report aims to present the main findings concerning the key dimensions of interest of the research project 'Case studies of automation in services'. These are: (i) the impact of technological adoption on business models, production processes and economic profitability; (ii) the impact of technological adoption on work organisation, the quality of work, health and ergonomics; (iii) the impact of technological adoption on work processes in terms of executed tasks, learning regimes, the degree of upskilling, deskilling; (iv) barriers to adoption and future trends.

After a brief discussion concerning the methodology and the structure of the research provided in Chapter 2, we focus on the main findings emerging from the elaboration of information from case studies. More specifically, Chapter 3 discusses evidence stemming from the case study on automated guided vehicles, Chapter 4 focuses on professional cleaning robots, Chapter 5 on remote monitoring health devices. Chapter 6 closes the report.

2 Methodology

The main objective of this study is to investigate the impact of the automation of processes on work organisation, tasks, working conditions and industrial relations in nine companies located in Italy, by focusing on the adoption of three specific technologies that, to some extent, can be linked to automation. These are automated guided vehicles (AGVs), professional cleaning robots and remote monitoring devices in healthcare. Following previous qualitative works realised by the JRC team (see for instance, Grande et al., 2021 with a similar research design), the research aims at answering the following research questions:

- did the selected technologies bring changes to the business model, tasks and occupations, work organisation, employment and working conditions?
- how did/were the technologies affect/affected by employee participation and industrial relations?
- what were the main drivers/barriers for/to the adoption of the selected technology?

The research has been structured in two phases. The first one aimed to identify a shortlist of 30 potential cases (i.e. companies/organisations where the technology is adopted), that is, 10 for each of the three selected technologies. This meant carrying out several informal interviews (including meetings and video calling) with representatives of the companies and key informants. More than 20 interviews have been conducted with key informants and stakeholders. These interviews have been useful both to collect general information on the sectoral diffusion of the technologies under consideration, and to deepen the knowledge of the macro-impacts of these technologies on economic and industrial processes ([1]). When around 30 potential cases were identified, the research team – in close collaboration with the JRC – selected three establishments per technology to include in the final selection and to be part of the case studies.

The second phase involved both the visit to the selected companies/organisations, and conducting semi-structured interviews with several professional figures, paying attention to include different profiles such as HR management, a trade union representative, technology specialist (the person in charge of implementing or managing the technology) and four workers in key occupations affected by the technology under consideration.

The design of the fieldwork involved conducting semi-structured interviews. In close collaboration with the JRC, the general interview template was structured in order to allow comparability between the different company cases. Such a general template (grid of the questions to follow during the interviews) focused on three macro areas of interest:

- impact of the technology on the economic process;
- impact of the technology on work organisation;
- effects on tasks and job quality.

The research team dealt with two major problems. First, the pandemic limited the possibility of accessing the plants and some previously selected bodies have withdrawn their availability to take part in the research. This meant the need to replace some selected companies/organisations with others previously contacted and, in other cases, to carry out online interviews only without running a visit. Second, the access to the fieldwork through specific professional figures on the company side (for example, HR manager, External Affairs coordinators, Head of R&D Engineering, etc.) has – in some cases – limited the possibility of (i) interviewing workers' representatives because they have been declared not informed on the deployment of the technologies of interest; (ii) interviewing workers/operators affected by technologies under study employed by contracting companies since the specific service has been outsourced to third parties (see, for instance, logistics or cleaning). The research group has tried to fill this gap both by conducting interviews with local union representatives, and through parallel contacts with workers/operators employed by the outsourced

([1]) The identification of adopters has required an accurate strategy for case selection aimed to identify a list of 'adopters' and select cases to be included in the analysis. A mixed strategy – entailing two stages strictly interrelated – has been pursued to identify a list of companies defined as adopters of at least one of the technologies of interest (professional cleaning robots, autonomous guided vehicles and remote monitoring devices). Both phases were carried out from January to March 2021. The first stage – defined as 'desk research' – entailed two main activities: (i) the inspection of survey and patent data; (ii) the analysis of trade magazines. These activities were mainly carried out in January and February. The second stage has foreseen a direct interaction with several stakeholders (firms, trade unions, associations, scientific hubs, etc.) considered pivotal for the development of the research to depict a detailed background of technologies' diffusion and to activate a direct link with firms.

companies. This alternative strategy has not always been successful and would have required a reconsideration of the research design at site instead of company level.

The final selection of the companies/organisations, where the fieldwork has been carried out, included: PMI Manufacturing & Technology (Bologna), Poste Italiane Group (Bologna), Amazon Italia (Passo Corese), Dussmann Service Italy (Milan Malpensa Airport), Nestlé Vera (San Giorgio in Bosco), Coopservice (Reggio Emilia), Santa Maria Nuova Hospital (Reggio Emilia), ASUR Marche (Ancona), Humanitas Research Hospital (Milan).

The fieldwork ended in February 2022. A total of 57 interviews were conducted (about 45 minutes face-to-face interviews, most of them on site, some online) ([2]). All of the interviews were recorded and later transcribed. A content analysis of each individual interview was carried out (according to Annex I); interview transcripts were read and coded in order to move from more abstract content towards more concrete content, and gradually saturate and shed light on the following key dimensions: (i) the impact on work organisation, workflows and processes; (ii) the impact on employment and working conditions; (iii) the impact on occupational composition, job profiles and task content; (iv) other potential effects on the company and workers.

The analysis of tasks has been based on Fernández-Macías and Bisello's (2022) taxonomy. Tasks are classified in two conceptually different axes: one referring to the content of tasks (mainly physical, intellectual and social tasks) and the other which refers to the methods (autonomy, teamwork and routine) and tools (non-digital machinery / digitally-enabled machinery used at work). Indeed, the construction of the grid of interviews relies on this taxonomy and tried to reflect the items covered by the authors as much as possible.

Moreover, the visits to the companies/organisations allowed the research group to collect data through direct observation of both the technology under study and the work processes involving the use of technologies. In parallel, the research team carried out a desk analysis. Informative material and data collected were analysed through an iterative approach, whereby the research group went back and forth from data to theory and vice versa. The use of multiple sources allowed us to triangulate the data, thus providing a stronger substantiation of the emerging constructs (Eisenhardt, 1989; Alvesson and Karreman, 2011). All of the authors read the collected data independently and then shared and discussed interpretations until they were able to converge on a common interpretation.

In the following the report provides a summary and analysis of the findings stemming from the company interviews (supplemented by both desk research and direct observation) concerning AGVs (PMI Manufacturing & Technology Bologna, Poste Italiane Group, Amazon Italia), autonomous cleaning robots (Dussmann Service Italy, Nestlé Vera, Coopservice) and remote monitoring devices in healthcare (Santa Maria Nuova Hospital, ASUR Marche, Humanitas Research Hospital).

([2]) Several other interviews have been conducted with key informants and stakeholders.

3 Automated guided vehicles (AGVs

In this chapter we cover the case of automated guided vehicles (hereafter AGVs) through the analysis of three subcase studies in the logistics sector. More specifically, we focused on three companies: (i) PMI Manufacturing & Technology Bologna (hereafter PMMTB or PMI); (ii) Poste Italiane Group (hereafter POSTE); (iii) Amazon 'Fulfillment Center (FC)' of Passo Corese (hereafter AMAZON)([3]) .

In this sense, the logistics sector has been intended as the sector, per se, 'Warehousing and support activities for transportation' (NACE H52), but also 'Internal Logistics' (both in manufacturing and services). Internal logistics is in fact one of the most important departments within enterprises, especially in large manufacturing companies. It manages, arranges, plans and delivers the finished products.

Before describing the detailed evidence on drivers of and barriers to adoption and the impact of these artefacts on work organisation, job quality and task content, let us outline some industry-level patterns concerning the state of the art of digital and automation technologies in the logistics sector. Indeed, the latter has been within the field most affected by technological change and economic restructuring over the last few decades. As the fragmentation processes of production unfolded and networks of global value chains emerged, logistics stopped fulfilling a secondary function within firms and became an autonomous business field within management (Allen, 1997; Wilson and Bonacich, 2011). The management of inventory, of just-in-time production and of transportation is nowadays crucial to improve and sustain firms' competitiveness. At the same time, the process of manufacturing decentralisation brought about a reversed process of capital concentration and the centralisation of control within the logistics sector. The latter has been made possible, and necessary, by the extension of ICT and increased competition in cost and time delivery. The 'logistics revolution' (Allen, 1997) unfolded not only within the transportation industry but also within manufacturing firms, where, as we said, the management line of logistics increased its role in corporate governance. In order to account for this double dimension of logistics, we decided to include case studies of two kinds:

- internal logistics – internal (to the manufacturing process) transportation activities and warehousing inside manufacturing firms;
- 'third-party logistics' (3PL) – firms who provide specialised logistics services to the client firms, either B2B or B2C.

Despite commonalities and the fact that they proceed from the same transformations in contemporary capitalism, these sectors also demonstrate important differences, especially regarding the adoption of AGV technologies that need to be taken into account. The interviews with key informants operating in logistics highlight the diverse speeds of technological adoption between internal logistics activities inside manufacturing firms or in-house warehouses and 'third-party logistics' (3PL). AGVs are more likely to be adopted in internal logistics operations than in 3PL ones, due to higher market instability (short-lasting contracts), client variation and a greater reliance on labour-intensive operations.

The industry is devoting efforts to reducing labour costs predominantly through lower wages, rather than through costly investments in automation. According to the literature, technological adoption is directed more towards the introduction of monitoring devices and digital technologies – which enable standardising and deskilling some portions of working activity – rather than pure automation. Wearables used by operators and sensors, or RFID tags applied to goods, are the current state of the art. On top of that, algorithmic management software is used to track the production flow and monitor workers' performance (Gutelius and Theodore, 2019).

Indeed, automation and digitisation are relatively different technological choices in terms of the cost of adoption, particularly in warehouses that are still relatively unstructured areas, characterised by environmental and physical variability. While initial fears for what we call the 'future of work' were mostly concerned with workplaces without humans, and therefore robots substituting human activity, digital devices allow humans to become robotic (among others, Bottalico, 2022 for a case study on the port industry). This trend already recognised in the automotive sector represents a more general pattern incorporated within the world of work (Briken et al., 2017; Dosi and Virgillito, 2019).

([3]) As detailed in Chapter 2, these are an initial group of 10 firms targeted for in-depth fieldwork research. Contacts were established and according to firms' availability, and cases' relevance to our study, we selected these three cases in cooperation with the JRC team.

AGV introduction is embedded in a wider process of technological transformation in the logistics sector, which entails the introduction of a wide range of interdependent technologies linked to the process of automation and algorithmic management.

The current technological parks in warehouses include:

- Warehouse Management Systems (software) – among the dominant diffused technologies;
- conveyors and sorting systems – already implemented since the 1990s but requiring high up-front costs;
- radio frequency scanners – used to manage inventories, fairly diffused;
- voice-directed systems – potentially among the newest trendy technologies in warehouses that would overcome reading lists and instructions;
- put walls – already largely used, relatively inexpensive;
- goods-to-person systems (Kiva), autonomous mobile robots, robotic picking, automated guided vehicles – still very costly, less diffused;
- sensors embedded with the IoT – expected to have a huge impact.

In terms of changes in occupational structure and task reconfiguration related to AGV adoption, key informants in the logistics sector report that automation has thus far not been associated with labour replacement because the activity is very labour-intensive; whereas technologies introduced to date, such as sorters and Radio Frequency Identification (RFID), have led to an intensification of work with a more than purely labour-displacing effect.

However, according to literature there are several tasks likely to be affected by the introduction of AGVs. The tasks for which the impact of AGVs has generally been assessed include:

- picking/stowing-type activities tasks
- inventory and quality check tasks
- handling and internal transportation tasks.

In terms of working conditions, AGVs are expected to allow employees to:

- focus on higher added-value activities (such as customisation, reconditioning etc.) and more skilled functions;
- avoid heavy loads, thus improving safety (this is often advertised by technological providers) and reducing physical strength.

Empirical studies have highlighted the manual nature of much warehouse work entailing repetitive movements, awkward lifting and moving positions and a fast-paced work environment, collectively putting workers at risk of injury (Gutelius and Theodore, 2019). Drawing on previous empirical research, mainly based on the US, we could expect that the application of AGVs in the logistics industry may lead to:

- work intensification, linked to reduced autonomy of workers, as part of the control on the labour process that is incorporated in the machine;
- simplification and fragmentation of tasks.

Finally, another important aspect this research accounts for is the market dimension and the change in the business model associated with the introduction of AGV technology. Clear hypotheses regarding this specific technology have not been formulated so far. Key informants and scientific literature stress market constraints affecting firms involved in our study, especially in the field of 3PL, where oligopolistic competition is fierce and profit margins usually low. In this context, the adoption of AGVs could be driven by the need to replace low value-added operations and costs saving.

3.1 Description of the firms and the production processes

3.1.1 Philip Morris Manufacturing & Technology Bologna (PMMTB

PMMTB is a manufacturing plant dedicated to the prototyping and production of no-smoke tobacco sticks. This stick is burnt using a special heating system called IQOS([4]): the 'HeatSticks' are heated up inside the IQOS and nicotine is released with other tobacco components and flavours for users to inhale. The site is a 'greenfield' plant, funded ex novo in 2016 as a pilot site for the manufacturing of this new product([5]), and it is involved in raw material transformation and product assembly. The plant receives raw tobacco from suppliers and other raw materials for the fabrication of filters and special paper for the wrapping. Raw materials are treated by means of a chemical and mechanical process of transformation in one of the main departments at the plant, known as the 'Primary'. In another department, the 'Secondary', the different semi-finished products (tobacco, paper, and filters) are assembled to form the HeatStick. Lastly, a dock area is dedicated to the packaging of HeatSticks and shipment to national and international markets, while an automatised internal warehouse (High Bay Warehouse) and another external warehouse are stocked with raw materials and finished and packed products. Given the monopoly law regulation of the tobacco product market, the plant hosts a resident office for the government's custom and tax police, which oversees the registration of quantities of products manufactured and shipped.

The workforce operating within the plant (see Table 3.1 below) is deployed by a multi-layered structure of PMMTB which subcontracts to other firms phases of the production processes. Those subcontractors cover different phases and areas of competence. The plant is run by a PMI subsidiary called MTB, Manufacturing and Technology Bologna S.p.A. There are 1719 PMMTB employees (1583 of which under permanent contracts and 214 on a temporary basis) as highlighted in Table 3.1. Focusing on the gender composition of the workforce, 35% of permanent workers are women; their share is even larger among temporary workers (58%), while it decreases among agency workers (20%). The average age is relatively low for all three categories of contracts. PMMTB employees are assigned to the manufacturing processes – the core activity of the plant and one of the core businesses of the PMI corporation ([6]). Another PMI division, PMI Logistics Automation, is composed of 35 employees, most of them engineers who are in charge of supervising internal logistics operations, including the functioning of AGVs.

Table 1. Composition of the PMI workforce at the Bologna site (SOURCE: PMI).

PMMTB (as at 31.12.2021)	Permanent			Temporary			Agency		
	M	F	total	M	F	total	M	F	total
Number	1 172	411	**1 583**	135	79	**214**	278	57	**335**
Average age	34.81	35.40	34.96	34.84	35.01	34.91	31.81	32.62	31.93
PMI Logistics Automation 31.12.2021	Permanent			Temporary			Agency		
	M	F	total	M	F	total	M	F	total
Number	14	15	**29**	3	1	**4**	2	0	**2**
Average age	40.82	36.02	38.34	38.53	41.11	39.17	30.00		30.00

Source: PMMTB

([4]) The system is developed at PMI R&D centres in Switzerland and Singapore and patented.
([5]) Before, PMI, a traditional manufacturing plant, had existed since 1963 in the area of Bologna.
([6]) Although we do not have detailed data on the job structure within PMMTB, we can suppose that a large majority of workers are blue collar manufacturing workers.

However, this PMI team does not run the AGVs directly: the running and maintenance of this technology is subcontracted to a local service provider, SIMIC Automation, with 28 employees at the plant. The basic logistic operations of warehousing, preparation, handling, loading and unloading of AGVs are outsourced to a subcontracted logistics services company, LOGISTA, a Spanish multinational group([7]), which employs 269 workers at the plant, located in the shipment and warehousing areas.

This multi-layered structure generates a complex system of governance for the production process and the AGVs.

The plant layout and the production process were designed for AGVs from the conception of the site. The latter were gradually introduced throughout the progressive establishment of the production infrastructure. During a trial period that lasted several months, production machinery, conveyors and warehousing infrastructure were installed, and AGVs were simultaneously introduced and customised in cooperation with providers.

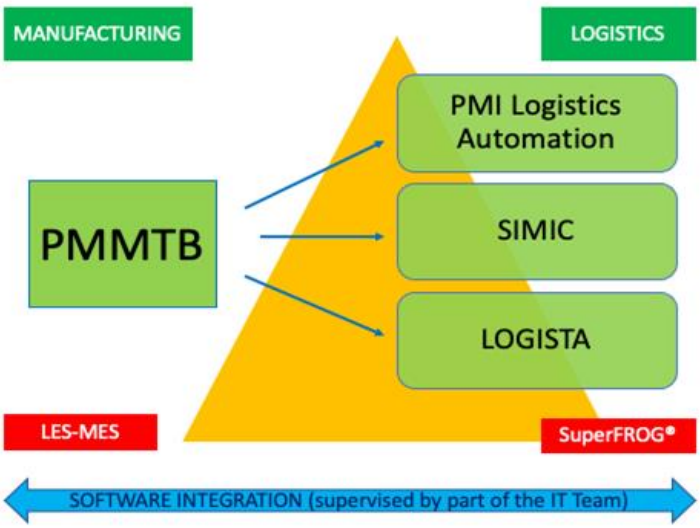
AGVs are produced and provided by Oceaneering International, Inc. corporation, a subsea engineering and applied technology company based in Texas. Nowadays, 34 AGVs operate at the plant. They are connected via Wi-Fi and move following a magnetic line on the floor. Their main areas of operation are the warehousing areas, where raw materials are loaded onto carts by LOGISTA workers, the 'spine' of a long corridor which connects the Primary and Secondary department and the shipment bays. AGVs carry out 80% of the transport operations inside the plant, connecting all the main departments and intervening at all key stages of production. The remaining 20% of transport operations are handled manually with forklifts by LOGISTA operators.

With reference to the informatics management of AGVs, Oceaneering International, Inc. also provides an AGV control system called SuperFROG®. PMI IT teams then deal with the integration of this software with an iMEL LES-MES (Logistic and Manufacturing Executive System).

Thus, AGVs' governance system shows a high degree of integration both in terms of hardware (AGVs intervene in many production phases) and software (AGVs are connected to the plant's central information system in real time).

AGVs are characterised by a general use since they serve most workstations, and workers are trained to handle them according to their specific tasks (see section on work organisation). AGVs primarily support core production activities related to the production of HeatSticks. Figure 1 summarises this complex AGVs architecture and deployment system at PMMTB.

Figure 1. The architecture and deployment of AGVs system at PMMTB Bologna



Source: Authors' elaboration.

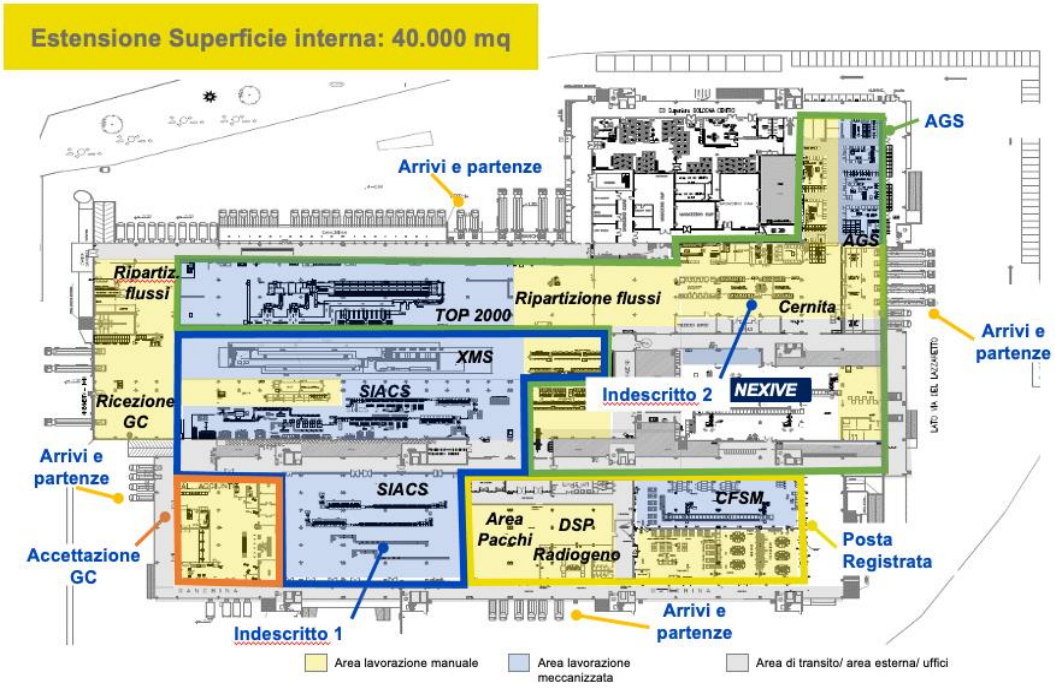
([7]) Historically rooted in the handling of tobacco products.

3.1.2 Poste Italiane Group – Centro di meccanizzazione postale (POSTE)

The site was established in 1995 and is one of the 23 CMPs (Centro di Meccanizzazione Postale) operated by Poste Italiane in the country. CMPs are the core of the country postal distribution network. POSTE was founded by the Italian government after the unification in 1861 to connect its territory to a network of efficient and standardised postal communication. The legacy of this pattern is substantially unchanged today, even if the postal service was formally privatised in the 1990s. Indeed, despite becoming a public company (S.p.A.), POSTE remained within the state ownership since it directly and indirectly holds 65% of the company. In addition POSTE serves as unique contractor appointed by the state for the fulfilment of a universal basic postal service ([8])

The operations carried out by CMPs are the receipt of mail coming from the post box and postal offices; registration, regrouping, sorting; and lastly the shipment of treated mail depending on the destinations within the sphere of CMPs' competence.

Figure 2. POSTE CMP layout



Source: POSTE management

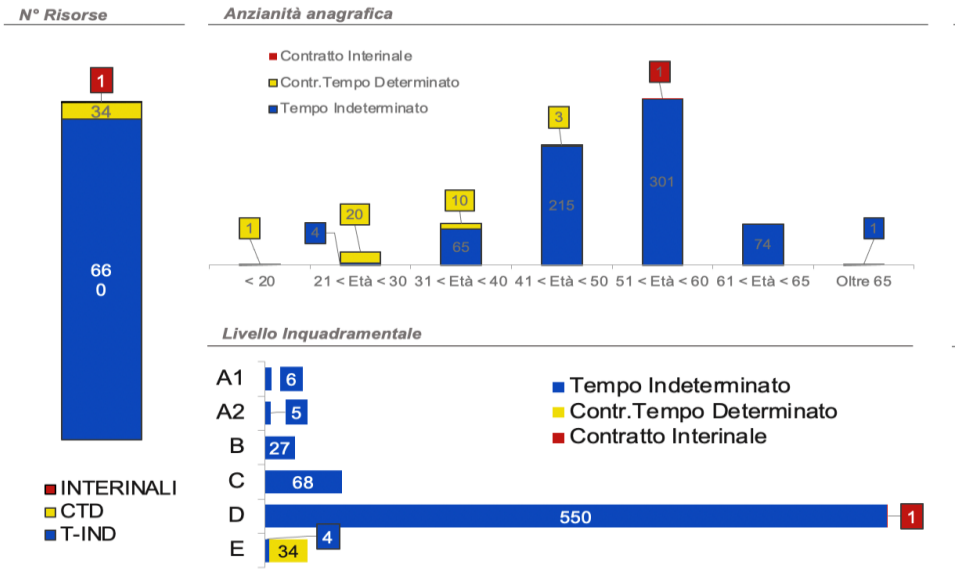
The mail flow at Poste Italiane is divided into two key types: 'Descritto' and 'Indescritto'. Descritto products are the registered and insured items, which are tracked in real time and, given the legal status of registered mail (especially 'raccomandate' that is special mail used, among other things, for formal communication between citizens and administration), undergo special treatment. The rest of the mail flow, known as Indescritto, includes the vast majority of mail shipments, from postcards to commercial communication. Indescritto is in turn divided into two categories: Indescritto 1 handles small items like letters; Indescritto 2 covers larger objects such as magazines, press items or small boxes (called 'voluminoso').

Mail processed at the CMP, however, is not limited to the universal postal service. POSTE started a new business line in 2018 dedicated to the delivery of e-commerce, within the framework of the 'Deliver 2022' business plan. The new strategy includes the stipulation of commercial agreements with big e-commerce players such as AMAZON. POSTE offers AMAZON access to its widespread distribution network, thus allowing the e-commerce company to integrate its logistics network ('postal injection'). The advantage for POSTE is the

([8]) In order to guarantee social cohesion, without discriminating between users, POSTE is obliged to provide the basic (universal) postal service throughout the national territory: collection, transport, sorting and distribution of postal items up to 2 kg; collection, transport, sorting and distribution of postal packages up to 20 kg; postal services relating to registered mail and insured mail.

diversification and possibility of entering a profitable and expanding market([9]). The plan also consisted of two specific collective agreements signed between POSTE ITALIANE and five representative unions (CGIL, CISL, UIL, CONFSAL, CISAL, UGL) – called 'Politiche attive'. In the agreement, POSTE announced the activation of 6 000 full-time job permanent contracts (vis-à-vis a reduction of 15 000 full-time jobs) and agreed with unions on the rules for regulation of the internal labour market. The CMP in Bologna employs 695 full-time staff (including 34 short-term contracts and 1 agency worker([10])). With reference to the employees of POSTE (see Figure 3), 53% are men; 74% of employees are between 41 and 60 years old; and 84% of employees are at the bottom of the pay structure (Levels D, 79%, and E, 5%); 94% have a permanent contract.

Figure 3. POSTE CMP workforce composition



Source: POSTE management

Focusing on the role of AGVs, in 2016 POSTE started planning, together with the Italy-based company SCAGLIA-INDEVA, the introduction of robots to carry out internal trolley movements. The provider designed and realised four AGVs with magnetic markers specifically for POSTE for the pilot plant in Bologna. Two years later, in 2018, POSTE decided to extend the solution nationally, adding a total of 60 INDEVA AGVs to 10 CMPs throughout Italy. The investment is about €1.9 million([11]). In the Bologna CMP, a total of 8 AGVs have been introduced. AGVs are used for automatic handling of objects and the towing of trolleys (6-wheel trolleys, Pally & Lid and Roll containers). They are provided with three sensors to detect the presence of a band positioned on the floor. Charging stations are placed along the route, consisting of two copper contacts on a plastic base, on which each AGV (also equipped with two copper contacts) lingers to keep itself constantly charged.

With reference to software and computer control, AGVs are not informatically integrated with remaining technological infrastructure but they are linked to POSTE's IT offices at the headquarter. Unlike PMI and AMAZON plants, designed and built to host a fleet of AGVs, the Poste CMP in Bologna was operating without AGVs for a long time – almost 30 years. Moreover, and maybe consequently, the number of AGVs is also lower: 8, compared to the 34 AGVs at the PMI plant or the dozens of AGVs at Amazon FC([12]).

AGVs accomplish both general and auxiliary functions in relation to the rest of the processes and machinery. The general use of AGVs implies that every workstation and every machine can be served by AGVs, and every

([9]) It is important to notice that so far e-commerce delivery service has been offered by SDA, POSTE's courier/express subsidiary. This opens up the question of overlapping and possible intra-firm competition.

([10]) Plus 25 NEXIVE employees (former TNT POST, acquired by POSTE in 2020; it operates in e-commerce delivery and on the private postal service market).

([11]) https://www.indevagroup.com/news/indeva-agv-for-mail-sorting-plant/.

([12]) We have not yet received information about the exact number of AGVs.

worker is trained to use them. However, given the relatively reduced number of units and the low degree of digital integration, their role remains auxiliary in relation to the global workflow.

3.1.3 Amazon FCO1 Fulfillment Center

The last case study refers to the AGVs that operate at the Amazon Fulfillment Center of Passo Corese (FCO1), near Rome. Like PMI, and unlike POSTE, the site is part of a US-based multinational corporation. More precisely, the site is run by a subsidiary of Amazon.com Inc., Amazon Italian Logistics S.r.l., which oversees the management of all seven Fulfillment Centers established in Italy. A Fulfillment Center is the main knot in the AMAZON logistics network: a large warehouse in which e-commerce products are received, stored ('stowed') and prepared for shipment, i.e. picked, packed and loaded onto trucks. Fulfillment Centers (FCs) are part of AMAZON's logistics network for the storing, shipment and delivery of e-commerce sales. Orders registered on the website arrive in real time, items are picked, packed and shipped to sorting centres, where they are directed to delivery stations for last-mile delivery. FCs store and process three kinds of items: items owned, sold and shipped by AMAZON; items owned by third-party sellers, sold on AMAZON website and shipped by AMAZON logistics services (Fulfillment by AMAZON, FBA); items owned by third-party sellers, sold on third-party websites but shipped through AMAZON logistics services. This multi-channel strategy turns AMAZON into a platform for e-commerce and logistics services, as well as for data collection.

Like Poste Italiane, and unlike PMI, which is a tobacco manufacturer, AMAZON is a 'pure' logistics player. However, despite similarities (AMAZON logistics subsidiaries are registered as postal operators in Italy) and recent partnerships (postal injection), differences between Poste Italiane and AMAZON remain huge in terms of ownership composition, business model, diversification, the integration of business lines and, in addition, the deployment of AGVs.

AMAZON AGVs move shelves (called PODs) allowing for faster stowing and picking([13]). Each robot is about 75 cm long and 60 cm wide and fits underneath a Pod that measures roughly 1x1 m. It is 30 cm high, weighs around 110 kg and can lift 450 kg. It has a speed of 5 km/h. AGVs are provided by Amazon Robotics, AMAZON's division for research and the manufacturing of mobile robotic fulfilment systems. Amazon Robotics is the former Kiva System, a Massachusetts-based company that AMAZON acquired in 2012 specifically for developing in-house robotic technology for its FCs. Thus, unlike the other two cases, AMAZON is one of the few companies able to in-house developing AGVs technology.

The FCO1 plant opened in 2017 and was designed, from the beginning, to host AGVs. In Italy there are two other FCs that operate using AGVs, one near Turin (TRN1) and the other one in Rovigo (BLQ1). Another one near Piacenza (MXP5) was the first FC opened in Italy and operates in a more traditional way. This means that goods are picked and stowed by humans who push their carts along the aisles of the warehouse following the path transmitted on a handset computer device scanner.

Using Kiva robots, items are stored on portable storage units, while workers are fixed at workstations. When an order is entered into the Kiva database system, the software locates the closest automated guided vehicle (bot) to the item and directs it to retrieve it. The mobile robots navigate around the warehouse by following a series of computerised barcode stickers on the floor. Each drive unit has a sensor that prevents it from colliding with others. When the drive unit reaches the target location, it slides underneath the pod and lifts it off the ground using a corkscrew action. The robot then carries the pod to the specified human operator to pick the items: the picker stands at the workstation (equipped with a computer and a scanner), the computer displays the image, name, barcode and location of the item to pick. To increase the picking speed, a light illuminates the precise bin where the item is located; the picker finds it on the shelf, scans it and puts it in a tote, which is then put on a conveyor system and directed to the packing department. The process is reversed in the case of stowing: the stower stands at the workstation (equipped with a rack for totes loaded with items to stow), the AGV carries the Pod and the stower scans the item and stow it in the bin on the Pod. A camera equipped with artificial intelligence software recognises the location in which the item was stored.

In terms of control and information governance, AGVs' movements are controlled and centralised. A unique Warehouse Management System connects the single AGVs to the website, in order to have real-time transmission of registered orders and inventory updates. This system governs the entire AMAZON network in Europe in order to enable standardised and synchronous storage management. The information technology is

([13]) Picking is the task of taking customer orders from the shelves. Stowing is the task of storing objects on the shelves. Amnesty responder is an auxiliary function, whose task is basic AGV troubleshooting.

provided by the AMAZON IT division and servers are hosted by Amazon Web Services (AWS). AMAZON AGVs are a typical example of the fully internalised introduction and management of automation technology.

AGVs play a key role both from an organisational and spatial viewpoint since they move the storage units located at the centre of each floor to a preferred area. Their role is not simply auxiliary, differently from POSTE, since they allow all operations relating to storage and picking processes. However, they also have limited use since access is reserved to few professional figures such as pickers, stowers and the maintenance/troubleshooting team.

3.2 Deploying automation technologies

3.2.1 Drivers of adoption

There are different kinds of drivers of AGV adoption. In what follows, we highlight those explicitly mentioned by management during interviews, but also those emerging from observational analysis and not necessarily highlighted by respondents. In management discourse, safety is the first driver of adoption mentioned, especially at POSTE and PMI.

> *The big impact of AGVs is on safety. Fortunately, and to our great satisfaction, the use of AGVs will allow the elimination of what are known as man-on-board pallet trucks. So, machines that coexist inside the plant with human operators. Without forgetting all the precautions that we have taken with regard to personnel, both at organisational and procedural level, the coexistence of man and machine within a plant is in itself a source of danger. So, the AGV, when it is fully implemented, will allow us to avoid this risk, which is one of the biggest not only for Poste Italiane but in all the plants with logistics operations.*
>
> POSTE, HR Manager
>
> *The AGVs were immediately an integral part of this project. Clearly it's not that when we started with this building, we already had this structure, this size ... immediately 34 AGVs. Clearly that was an evolution, wasn't it? But in the initial phase [the site] was designed with AGVs in order to give a sign of evolution, automation and innovation linked to the company's growth, and also because, with such vast spaces, this certainly helps us in many ways, in terms of reducing errors, in the transfer of materials and also in terms of safety. Because clearly the operators... we still have a manual part, we have seen it. However, having a large part covered by AGVs certainly helps to mitigate the safety aspect ..., which for us always comes first.*
>
> PMI, Factory Service Manager
>
> *First and foremost, safety. Because any technological handling obviously has much lower, if not zero, margins of error than the potential incidence of safety factors in a manual evaluation ... So this is the first thing. A standardisation of processes. It is no coincidence that Philip Morris Bologna is the 'Lead Site' within the new generation factories, and so what is done here will then be copied and pasted in the other factories that will make these types of products. And obviously the third is efficiency and the ability to have a real-time performance level of the whole flow and not only of the plant. Because if you want to see the performance of the logistics process in supplying the lines, for example, this is given by a manual component plus a technological component. The manual component is the preparation of materials. The technological component is transport. And then already knowing the manual, because you have the people and know how long it takes to make a split of a material, how long it takes to move from A to B, with the technology that is the most impactful, because they are the longest routes and covered by AGVs, you can understand the yield and problems related with interactions that are not compliant with safety, with the ergonomics of people and with everything that revolves around the flow. And so these are the four dimensions that led to the implementation of the technology ... Safety, standardisation of processes, efficiency and then management control.*
>
> PMI, Global Operations Manager

It is followed by the need for standardisation and the reduction of errors, in other words the improvement of quality and monitoring ([14]):

> *[This is a] system controlled and managed in terms of priorities, spaces and on which we can make a numerical analysis because – what is one of the advantages of introducing the AGV: is to have a system that is based on data, that monitors itself continuously and that allows us to make detailed diagnostics for location, for crossing times, for fallibility of the system of areas. So, I can also say to a certain bay, 'your bay has these problems and if we face this project together, or if we do this specific intervention, we can improve the performance of your bay,' and this is measurable.*
>
> PMI, Supervisor Logistics Automation
>
> *When we go to make an analysis or create a discussion, we always work on five dimensions, which are safety, quality, delivery, costs and morale ... as I was saying, having AGVs limits many risks in terms of safety, and so a few examples: if we imagine a company that runs at 45 billion, as we are doing now, made up only of forklift operators using forklifts, the risk of interference, the risk of collisions in terms of safety is much higher than with AGVs, where everything is managed by a system, everything is, if you like, 'tracked', and therefore it is possible to manage the various movements in a much more automated way, and at the same time [the AGVs] are specifically designed to stop as soon as they see an interference, rather than a risk, so... so safety is absolutely one of the first aspects. Quality, because even here, imagine the size of this company and the huge amount of material that is handled: if everything were done by operators, the risk of picking up the wrong pallet and taking it to the wrong area is much higher than if the AGVs allowed us to have everything tracked automated in the system... and therefore much more traceable and possible problems ... So the delivery dimension is also positively affected.*
>
> PMI, Factory Service Manager

A third aspect that emerges, again, especially in the responses from POSTE and PMI management, is the need to reduce dead time and low value-added operations, i.e. internal transportation tasks:

> *So as regards what we call precisely non-value-added activities, those related to handling, logistics loss for instance, we are talking about the walking time of the operators. So just how much the operator moves to go to transport the product or just to go looking for the equipment. So, in the standard work cycle the operator has on their... on their list of activities at their workstation, that of moving to search for the product to be processed or those for managing the trolleys, etc. So, the AGV integrates the current process by replacing the human activity of moving the equipment and, therefore, in this case for the operator who has X hours of activity related to the handling, these tasks are automated through the AGV.*
>
> *[...]*
>
> *The AGS in particular replaces the activity of taking a product weighing an average of 10 kilograms. Then to walk 3 metres to recognise the object, walk 3 metres to the destination and go back. So in that case the non-value-added activity consisted of picking up the object, moving it for 3 metres and then going back to the station and picking up another object. So, the non-added value consisted in moving, let's say, the product as well as the fact that the weight obviously increased the effort for the operator.*
>
> POSTE, IT Specialist

The elimination of value-added activities is absolutely one of the basic reasons on which the technological development of all large companies is based.

> *'Question'. In your case, what are the non-value-added activities that would be eliminated?*
>
> *The transfer of these raw materials from point A to point B is an activity with no added value, in particular, at least for us, we are talking about pallets that exceed 500 kilograms. Ok. The handling of 500 kilograms is another dynamic. Even in the development of raw materials, therefore from a risk-assessment perspective, it must be eliminated. In other words, all activities that involve handling above this weight must be eliminated using any technology within our reach. So, let's say this a bit ...*

([14]) We do not have enough information to talk about the measurability of performance.

there are these pallets that carry raw materials that are quite high, there are at least 3-4 raw materials that are very high. And then I believe that, in any case, this automation of the transport of raw materials has improved the quality of our work.

PMI, Operations Manager

It is important to notice, however, that these three main drivers of adoption can be analytically discerned. Nevertheless, in the practice and discourse of management, these drivers tend to conflate into each other. See, for instance, the response of the manager of PMI Logistics Automation team to our question on drivers of investments in AGVs:

There are certainly many [drivers]. So, first of all, the management of this plant, which I think was anticipated by my colleagues because it is a mantra ... But the idea is to build a factory that is truly projected into the future, that really is and is a bit of a 'lead site' where all the latest technologies are tested with respect to a vision that we have, which is called 'Manufacturing of the future', which envisages a completely digitalised interconnected system of highly automated systems that are governed continuously with a bit of a control-room concept that manages the process in a 'hand-to-hand' manner ... Why do we talk about 'value stream map'? Because it is very important for us to understand that each step, each chain, each link in the chain must work and must be interdependent on one another. This is a vision ... First of all, having an automatic system means that we do not have to rely on human "randomness" due to concentration, distraction, error, etc. ... so anything that is abnormal, as we have seen, perhaps that load had a wheel turned, the sensor has detected something wrong ... so there is ... the human factor of fatigue of underestimating a problem etc. ... So it gives us greater safety in general, greater ergonomics, because a system of this kind relieves anyone going to interact daily with everything that is the load at ergonomic level and fatigue compared to the interaction with loads that, in our case, are also very heavy, and then imagine where exactly the operator of a machine with the pallet truck that moves the pallet – they are 500-600 kilograms, no? Well, we're all capable of moving it while it is running, but to put a pallet truck like that in motion, you need energy to start the movement ... So, from a safety point of view we have both an ergonomic factor and a reliability factor. In addition, a system of this type can manage enormous complexity without ... [before] there is a period of time to get up to speed, but once the mechanisms are oiled up, it allows smooth management, let's say, without any particular problem with complexity, which is important. And it is also a parameter that is obviously technologically much more challenging in terms of the skills required.

PMI, Supervisor Logistics Automation

In other words, safety, quality, productivity and the reduction of low-value-added operations merge into each other. Another example can be extracted from an interview with a POSTE worker who conceives ergonomics and safety as intrinsically entangled in the dimensions of standardisation, order and efficiency:

But in some respects, I think it has been beneficial for the simple fact of order and space. When there is an AGV that has to pass ... it is like the train station, like the tracks. So, if there were no rails in that section, there might have been a house. When there are rails, you know that you have to stay a certain distance away from the rails, there must be nothing in the way. So if you take this example into the company, maybe you can keep things more orderly. Because instead of leaving a trolley saying 'it doesn't bother anyone anyway' ...

'Question'. Did that happen before?

Yes. Now, however, with the AGV, many things have to stay in their own areas, and so it's a bit of a deterrent for those who perhaps had the habit of leaving the basket in the first useful place, because they didn't want to take it into the hold, because they had to walk an extra 20 steps. So they were often abandoned right and left, and then you always needed someone who ... Now, at least there is a limit, because with the introduction of the AGVs, you have to keep the paths clear, otherwise the AGVs get stuck.

POSTE, Worker

Such interdependency between these dimensions is confirmed by the adherence to lean manufacturing principles foreseeing complete integration among 'pillars' of loss analysis, safety, quality and synergies. Despite these commonalities, it is also important to notice that AMAZON diverges slightly from this framework, at least as far as we could understand from interviews. Elements such as safety (or ergonomics) and the reduction of low-value-added operations emerged, but in a less explicit way. This is perhaps explained

by the high level of standardisation and centralisation that characterises the firm. While POSTE and PMI sites were somehow unique, experimental plants, the AMAZON site is one among hundreds of FCs and the decision to adopt AGVs is independent of the specificities of that site. What emerged more clearly in AMAZON interviews, especially according to the HR manager, is another aspect: AGVs are seen as part of a wider set of instruments aimed at improving human and social relations between workers and management:

> *Our technology, which is clearly based on the safety of the workers coming before the [benefit of] organisation, aims to facilitate the relationship between the boss and the operator, the boss and the team, by means of command and recognition mechanisms and feedback that somehow improve quality.*
>
> AMAZON, HR Manager

If the dimensions of safety and ergonomics, standardisation, quality and the reduction of low-value-added activities have been immediately highlighted as the determinants of AGV adoption, other dimensions stand in the background, and progressively emerged during the interviews. The first one is market change. We can outline three kinds of market change that influenced the adoption of AGVs, one for each case study. PMI is a case of market innovation: in the framework of a medium-to-long-term strategy, PMI decided to develop no-smoke tobacco products, including the IQOS technology. This implied the design of a new production process, that of HeatSticks, at the new site in Bologna. AGVs are at the centre of this new production process and are integrated into a digitised and partially automatised organisational environment. POSTE is a case of market diversification. As reported by management, POSTE is facing a dramatic decline in postal traffic and the goal is to find new business lines. AGVs are part of the new 'Deliver 2022' strategy, whose goal is POSTE's entry into the market segment of e-commerce deliveries, a strategy which also includes a commercial partnership with AMAZON. Lastly, AMAZON is a case of market expansion. FCO1 is one of dozens of new-generation, AGV-equipped FCs that AMAZON has been opening in Europe over the last 5 years, in a context of huge sales and operations expansion.

The second dimension, and partially entangled in the first one, is the complementarity of AGV automation with other processes and investments in physical capital (the opening of new plants), digitalisation and software and in other types of automation (such those implemented in packaging and sorting operations). In this respect, our conclusion is that AGVs were not a single driver of the transformation of the business model but quite the opposite: AGVs, along with a general tendency to digitalise and standardise, are the result of the transformation of the business model.

Lastly, there is a third latent reason that emerged as a precondition for the adoption of AGVs, i.e. the rise in productivity and higher spaces of monitoring of the work processes thanks to the standardisation provided by AGV control systems and the incorporation of dead times in the machine system. However, these are standard outcomes of technological innovation in the labour process more than specific drivers of AGV adoption; therefore, they will be analysed in the section discussing the effect of AGV automation on work organisation. Before that, we need to focus on the barriers and obstacles to the adoption and implementation of AGVs.

3.2.2 Barriers to adoption

Four types of obstacles have been identified in the logistics sector with respect to the introduction of AGVs (Gutelius and Theodore, 2019). The first relates to technical unfeasibility: the latter is verified when tasks and operations that AGVs are expected to incorporate (i.e. transportation task previously accomplished by human-carried roll) can by no means be accomplished by a machine. Another obstacle to the adoption of AGVs relates to product and service market instability, especially in the case of 3P logistics firms: in this field, the duration of contracts with clients would be too uncertain and the variety of clients needs would be too large. These two factors would deter companies from the massive investment and rigidities required by automation([15]). The third types are the so-called institutional factors, especially labour law, collective bargaining and trade unions, which are institutions that regulate markets, work and the production process thus, in theory, shaping the firms' choices in embedded patterns of action and, possibly, limiting the introduction of AGV technologies if perceived to threaten employment. However, trade unions might also

([15]) According to the Italian Labour Force Survey data, in 2018 employment in the logistics functions of the economy amounted to 2 376 044 workers in Italy: 40% concentrated in 'Logistics as a service' and more than 31% in 'Industry'. In terms of a time trend, the number of people employed increased by about 110 000 units (+77 000 in 'Logistics as a service'). Given that, it is likely that a further expansion of 3P logistics would occur in the coming years; however, we cannot formulate hypotheses on the impact that this would have on the decision to adopt AGVs.

advise the introduction of robots in order to reduce safety risks or physical strain([16]). The attitude of unions toward automation is anything but unambiguous. Overall, at least in the manufacturing trade, unions have proved to play a crucial role in influencing the implementation of technological and organisational practices (see Jürgens and Krzywdzinski, 2016; Smith and Vidal, 2019, for recent evidence). Finally, there is a fourth set of factors, labour market costs, which could persuade firms to renounce automated processes. For instance, especially in the case of 3P logistics, interviews with key informants suggest that low labour costs and the availability of a flexible workforce could discourage the introduction of labour-saving technologies, which have high fixed costs compared to the low labour costs of a flexible and cheap workforce.

Our evidence is nuanced when it comes to these hypotheses. Given that our findings are based on three cases of relatively successful adoption, we consider these categories as relative obstacles, relevant to understanding the problems that companies faced in the implementation of AGVs.

We collected information about the presence of the first three kinds of obstacles – but no evidence in relation to the fourth kind of obstacles – linked to labour market.

Technical obstacles

The first type of technical obstacles relates to all problems associated with the adaptation of AGV systems to the layout of the plants. This was particularly evident in the case of POSTE, since the Bologna CMP was opened in 1995 at a completely different stage of technological, commercial and industrial development, and in that preventing the adoption of AGVs. This was stressed, for instance, by the union officer we interviewed:

> *'Question'. So, let's say that there were no reasons for disagreement [with management] even on the details of AGV adoption?*
>
> *It is clear that it is a phase that still has to be implemented ... There is a consideration that I would like to say. One thing is to invest in technology in a place that can accommodate all that type of investment that you have in mind, and another is instead to introduce a technology in a location that is already done and working, with unfortunately also its space limitations. This situation has brought some problems, but it was intrinsic in the sense that today, for example, not all AGVs have a very effective functionality specifically because some spaces are occupied by material that does not allow the passage of material because you do not know where to place it. At least not at this current stage.*
>
> *[...]*
>
> *Not completely yet, because there are still some points of the road system where it is not possible for the AGVs to make their route.*
>
> POSTE, Trade Union Representative

This problem was also recognised by the POSTE IT Specialist:

> *So basically the departments were those affected by the main 'arteries' of the plant because we went to optimise the routes with the greatest flow within the plant, so basically we have our 'arrivals and departures' department, which is the most 'objective', let's say, to be optimised, also because it is usually in a position close to the dock, which is then connected to the other departments. And depending on the plant, an INDESCRITTA 1, INDESCRITTA 2 department rather than Parcels has been activated, specifically dependent on the conformity of the plant and on where there is space to implement the AGV.*
>
> POSTE, IT Specialist

According to the IT specialist, the company is already working to a strategy of reciprocal adaptation – a process of standardisation of the 23 CMPs open in the country – and, conversely, a process of customising the AGVs to the specificities of the layouts' transformations:

([16]) According to Lloyd and Payne (2019), conducting a case study on the use of AGVs in services, the way in which AGVs are introduced into the workplace, makes a substantial difference to how workers respond and their subsequent use. In the case of the Scottish hospitals the authors investigated, unions were consulted from the start. Union involvement helped allay concerns and made the introduction of AGVs run more smoothly. Conversely in an English hospital, where there were no guarantees of redeployment, unions were not involved and therefore opposed the use of AGVs, and management failed to take the time to engage with the workforce over their introduction.

We have an industrial plan that also modifies the areas of the plant, and the handling flows will change based on the variation in volumes. Logistics losses are still one of the leading sources of losses nationwide. So, we will certainly proceed to further attack the logistics losses by optimising this technology more and more, thus adapting it quickly to the new contexts … I am talking, for example, of changes in the layout of the plants: based on how you change the plant the AGV system adapts to the latest version of the plant …

POSTE, IT Specialist

Interestingly, a similar problem with layout was detected in the PMI case, in spite of being it a greenfield plant.

Today, AGVs are not completely 100% in charge of handling. Simply because AGVs cannot go in some areas, and in some areas it is not possible to implement an automation system due to layout so on …

PMI, Global Operations Manager

We have narrowed down some spaces and changed some of the machines, which has led to completely different layouts. This means working together to establish the new routes of the AGVs. Now there is an area, for example Bay 3, where we have adopted a new technology that aims to reduce the space inside the production area, and this has led to a re-layout not only of the area but also of the AGVs. Or we did another [re-layout] in Bay 4 to reduce the risk of interference [human-machine].

PMI, Factory Service Manager

In other words, this automation system entails a higher level of rigidity in the organisation of the infrastructure: changes to the AGV system routes can affect the layout and changes to the layout can affect AGV routes.

With reference to AMAZON, we did not find technical obstacles such as those observed at POSTE and, to a less extent, at PMI. Perhaps a similar constraint is caused by the squared layout of the robotic floor. As was explained by one of the operations managers, the corners are a 'discontinuity' in the mobility space of AGVs and this can affect their freedom of movement and, consequently, the distribution of storage units to the workstation:

What we try to do is to keep the load as uniform as possible between operators. What I mean is that we try to give everyone more or less the same type of product mix and quantity. Then of course, because of the layout of the floor itself, there are some technical aspects that may make it easier to lengthen the workload at one station than at another. For example, if I [pick/stow operator] am in the corner, I have a much narrower cone of allocation, and so in theory I will have fewer PODs than the other stations. … Because, of course, corners are always a discontinuity, something where it's hard to understand how the algorithm evolves.

AMAZON, Operations Manager [visit]

The technical obstacles observed so far are linked to the hardware infrastructure of the AGVs. There is a second dimension, which is that of software obstacles, especially those linked to integration. It is well known that one of the main characteristics of current cyber-physical production systems is the fact that they present a very strong integration constraint regarding the technologies that can be adopted. In other words, new technologies can only be adopted if they are compatible with the other technologies and this limits the choice of technologies, unless the decision is made to reconfigure the entire system.

With regard to this aspect, each case provides a specific kind of outcome for AGV adoption. On the one side, AMAZON AGVs showed a high level of software integration – not only into the rest of the ICT infrastructure and the website (via an inhouse Warehouse Management System) – but also did not report any special problem with software integration. As we said, AGVs' hardware and software are developed by Amazon Robotics (with the support of AWS) and this internal governance makes the degree of integration high but smooth.

[We] have a global system that I call the Warehouse Management System, which is basically a kind of database that allows us to link the physical inventory in a warehouse with a virtual location. [When] a product arrives inside a warehouse, it is stored. For example, the moment the product is identified and entered into the Pod, almost instantaneously this information is transferred to this

Warehouse Management System, which updates the databases and the availability of the products almost instantaneously on the website. And then, based on what the customer orders, it can see whether that product is available or not. When the consumer clicks 'I want to buy this pen', this information reaches this WMS, which tries to understand what the most effective way is to distribute and get this product to the customer. Because we don't necessarily ... Let's say that we try to store most of the products nearby [the potential market] beforehand. At the distribution centre you can imagine that the storage capacity is finished, so it could sometimes be the case that the product is not available to the customer. [Suppose] an order for a customer in Rome [which] could be easily moved from the Passo Corese centre, but maybe this product Is only available in Piacenza, or maybe the customer orders two products: one available in Passo Corese and one available in Piacenza. In this case, therefore, what the system does is to understand which is the most effective 'route' to be able to take the two products. If, for example, a product is in Piacenza and one is in Rome, the system also tries to understand whether it is better to make two single shipments or whether it is more appropriate to unite and reconsolidate the product so as to make a single shipment to the customer and to be more environmentally sustainable by having a single package. In this case ... the system does [redistribute] the inventory between certain centres. For example, the Piacenza centre could ship a product from Piacenza to Rome. At this point, the product arriving in Rome is then consolidated as a single product and from there it is packaged and shipped to the customer.

> *'Question'. So ... there is a single piece of software that links the web to the warehouse. Is it a single program that does this or are there several?*

Let's say it's a system made up of various software services that talk to each other. So there is a software service that perhaps takes care of the storage part, one that takes care of the inbound part and all these services, as we call them, talk to each other and then move as a single system.

> *'Question'. So in practice the warehouse has no autonomy, the individual warehouse, in deciding whether to ship this product or that product. If, for example, I have an empty space with a lack of work, today in this warehouse could I decide to unblock some products and have them sent autonomously.*

It works like a network. So there are many nodes of a structure and there is a system that tries to balance these nodes in the most appropriate way, so if there is a shortage of inventory in a certain node of this network, the system tries to restore this balance in a proactive way or in a reactive way just as in the case I mentioned before in which the customer placed an order for two products and one of these products was not available in that warehouse. In that case, there is a reactive way of intervening.

AMAZON, IT Specialist

On the other side of our analysis, AGVs at Poste Italiane show a relatively low degree of integration. AGVs are connected, via Wi-Fi, to a central system that monitors AGVs in all of the sites where they operate. However, as management confirmed to us, they are not connected to other machines deployed in the plant. Lastly, the case of PMI is an example of a high degree of integration but quite complex in terms of software. Indeed, it should be noted that respondents reported massive efforts in terms of continuous improvement in ICT integration. This is due to the (digitalised) manufacturing nature of PMI activities which makes the integration more difficult if compared to a pure logistics plant such as that of AMAZON. This is also intensified by the choice of outsourcing the management of AGVs and their use to two subcontracted companies at the plant. The AGV system is governed by a customised software (SuperFROG®) provided, like the hardware, by Oceaneering International, Inc. This software needs to be customised and then connected to the software that governs the manufacturing process (a LES-MES system – 'Logistics/Manufacturing Execution System' – called iMEL). Integration is a delicate and crucial aspect in the entire production process:

> *It is necessary to push the suppliers towards integration ... Many suppliers arrive with very static proposals, i.e. 'I have this, this is my integration, I can do no more than this.' Some suppliers have told us, for example, 'this software of mine, you open your software, you write from that location to that other location, and then my AGV does it, it does it better than others, it does it faster than others, etc.' and we immediately told them that there was no value in a human being spending 24 hours a day opening the orders to be made, copying them into a system that received the orders to be made, sent them, and returned to the system, which then told me 'I have sent the signal now, sooner or later you will see it,' etc., etc. Why? Because banally the person who is on the floor and scanning with the scanner says, 'I want my transport with the glue in 20 minutes, 30 minutes or even immediately,'*

they need feedback. That is, they want to know: 'has my order been taken care of?' Just like if you call the pizzeria or go to order coffee, you see that the barista is turned and you do not see their face, you need them to nod and tell you, 'I understand, I'll prepare it for you, wait a minute.' And this needs to be said often, because so many of these Italian or foreign companies come with their own idea of integration. So, there are several universal standards and many of these companies remain tied to initiatives and skills from the 1980s and 1990s, while in reality what must be done is the complete opening up of the system's functionality to other pre-existing systems at the customer's home and then saying, 'Look, you want an integration where you put all the software as in our case, it costs X.' Or, 'You don't have a complex system, your system is very difficult to modify, you have an Oracle that is locked up and you can't touch anything; we'll make you the logic to take the glue that expires first. But I ask you for X plus 1 000 X + 2 000 X + 100 000.' And this is often not seen as added value by the integrator, which is basically what the suppliers, the car salespeople, are doing. They ask you, 'Do you have all the cash? Well, I'll sell it to you and then you take care of it,' instead of saying, 'don't you worry about the tax stamp, don't you worry about anything. I'll take care of everything, but it'll cost you a little bit more,' and that's what most vendors find so hard to say ('I can sell you something, or I can turn it into a service') and say, 'Not only do I sell it to you, but I maintain it, I put your data and the system in the cloud and I do everything' ... Trivial example: Tetrapak sells you packaging machines and tells you, 'Some pieces of logic I will never expose to you; I make them, and I don't give them to you.'

[...]

You don't pay for this level of flexibility now, but in 2 month'' time, when the Project Manager says to you, 'Ah, you need to put a stamp, you need to put a card, you need to do a check before welding a wire or closing a milk carton,' you pay for it in, 'Eh, this machine cost EUR 2 million but it doesn't do this extra thing.' we have to ask them will they ask us for EUR 300 000 and will it be a custom version so that every time we call to check the technical support only one of their technicians knows what it is because it is a custom variation.

PMI, IT Specialist/Manager

At PMI, we identified a final type of technical constraint. During interviews with a PMI global operations manager and with the manager of the logistics automation team, respondents explained to us that there is a sort of "physiological" threshold of task substitution that AGVs cannot exceed. At PMI, the transportation task carried out by AGVs does not exceed 80%. The rest is accomplished by a fleet of forklifts run by workers hired by the subcontracted logistics company. What are the reasons for this self-imposed limit to automation?

First, AGVs can be too standardised to handle non-standardised products; human-driven forklifts have enough versatility to take charge of this kind of material. Second, because AGVs rely on a sophisticated and complex electronic and information infrastructure some redundancy in case of errors or stop of the software infrastructure is needed. In that, forklifts are a sort of buffer that provides business continuity in case of sudden crash of information in the AGVs:

At the moment 80% of the movements to and from the warehouse are covered by AGVs ... The reason for this is that by switching to 100% you don't increase the efficiency of handling to the point where you can justify having other machines inside, and at the same time you lose flexibility because the day the network goes down or the system crashes ...

'Question'. So there is a 20% buffer, that's what I call it.

It is a buffer that is ... used for non-AGV-compliant handling, i.e. for all handling for which I have packaging or the type of material you carry or the weight of a material you carry does not comply with the transport specifications of the AGV ... And we have them, because some suppliers have not yet adapted, or because they are not able to size the packaging in accordance with our automation, or simply because in certain areas we do not want AGVs.

PMI, Global Operations Manager

AGVs are less vulnerable than other systems. But what happens if I have a Wi-Fi crash ... at that moment, when the whole fleet crashes, having that 20% buffer means that I have operators with forklifts who can bring me urgent loads until the Wi-Fi infrastructure is restored. So this marginality is also functional for us, not just a question of cost benefit. The fact that we have to adapt any type of load unit, from the smallest to the largest, to automatic transport ... Especially with only one family of

one type of AGV. But it's also about being ready to react to always having that cushion of operators who can take over operations at manual level to ensure continuity.

PMI, Supervisor Logistics Automation

Market instability obstacles

What regards to market instability, this dimension seems to play an important role in the implementation of AGVs, especially in their diffusion and ability to completely replace human-accomplished tasks.

As we anticipated in the previous section, market instability includes the duration of contracts, especially in the case of third-party logistics, but also variation of demand, both in quantity and quality. This is a common aspect across all three cases and pushes companies to limit the extent of AGV implementation within the plants. With reference to qualitative variation and how it affects AGVs, POSTE management expressly reported that the variation in size of mail and parcels is considered an obstacle to the diffusion of AGV systems:

For example, we have our container, which we call a box containing postal items, which must be placed on trolleys. The task of arranging this box on the trolleys requires millimetric detail with respect to the positions, so that the boxes stacked one on top of the other fit together well and do not create security risks. For example, this is one of our activities that is challenging to automate. Or to process objects that make it difficult to identify a standard size and also difficult to recognise what the address is. I give the example of objects from the Asian market which can be from one millimetre to half a metre in size. Given what is the variety of the product and what are then specific millimetre details. It's an activity that is still too difficult to automate … Because obviously the more technology gives you a solution that is variable, the more it costs you, and therefore the more the product costs.

POSTE, IT Specialist

On the other hand, there is also a problem of quantitative market variations, i.e. peaks and troughs in demand. As we stressed in the introduction, all three companies operate in a regime of legal monopoly (POSTE) or de facto oligopoly (PMI and AMAZON). This implies a certain control on demand, higher than in purely competitive markets. However, demand seasonality and unexpected shocks such is the pandemics remain and AGV automation does not provide the degree of flexibility required being introduced to serve a Just in time production process. Therefore, also at AMAZON, management did not replace all internal logistics operations with AGVs, but maintained a share of them under human governance and execution. At AMAZON this is called 'Pallet Picking':

Then there is a task that we call 'Pallet Picking', which would always be picking up a customer's order. But they are not [items] placed inside the PODs. We do it manually, a bit like they do in Piacenza, let's say. These items are mostly a bit big, a bit heavy, and it's difficult to accommodate them in the PODs. Or during peak periods when there are lots of goods. We pick up these items manually.

AMAZON, Worker pick/stow

As explained by this worker, a relatively small area of the plant is dedicated to manual stowing and picking. The configuration of this area is similar to the old-generation warehouse, like that of Castel San Giovanni (in northern Italy) mentioned by the interviewee: in this configuration there are aisles formed by lines of shelves, each one with its code, which contain bins, each one also with its own identification code. The picker and stower walk down the aisles with a cart and a handset scanner with a screen that tells them which product to pick (or to stow) and where to pick it (or to stow it). Two kinds of articles are stocked in these shelves: large articles that cannot been handled with AGV-led storage units because of technical obstacles (called PODs); small articles stored in this area as a reserve stock in case of a peak in demand that cannot be fully supplied through the AGV system. In both cases, management decides to maintain a manual picking (and stowing) area to maintain the pace of production and avoid disruption.

Institutional constraints

With institutional constraints we identify both formal and informal regulations that may alter the adoption choice of AGVs for the firm. First of all, institutional barriers to adoption might be represented by labour laws, collective bargaining and trade unions. With reference to trade unions and industrial relation, we can distinguish, on the one hand a previously state-owned company, the case of POSTE and, on the other hand two private giants, PMI and AMAZON. POSTE was, for decades, a state-owned company with workers assimilated to government employees. In the 1990s, the company was privatised and turned into a public company, but the state remained by far the largest shareholder, POSTE remained a strategic company and

kept the monopoly as universal postal service deliver. This allowed the previous system of cooperative industrial relations to survive in the new phase. This characteristic influenced the way in which unions react today the introduction of AGVs. Unions and POSTE were by no means in contrast with respect to the adoption of AGVs. They supported it:

> *We from the CISL represent the workers but we also represent the company. We believe that a thriving company that is capable of managing development, efficiency, safety, health, but also worker'' rights, is a company that should be helped in some way. And, based on this assumption, we have a special relationship, to the point that, if there are problems that cannot be resolved [the managers themselves] ask us for help.*
>
> > *'Question'. So there were moments of confrontation and information. Do you make this distinction between information and then afterwards the final decision?*
>
> *The company absolutely ... On the organisation of work, we manage the fallout ... With respect to the idea of innovation. I would say no. Let's say that [the adoption of AGVs] was welcomed, I would say, by all the [trade union] unions. And I remember that famous national meeting, I remember the national secretaries also seemed dazzled by what [the new technology] was ... When a company invests in technology there is a risk of a downturn in employment. But right from the start we had a different perception, like it's a technology that can help improve safety workload points, and it's a technology that's not so far-reaching that we'll lose jobs. That was the perception we had. And after 3 years I feel I can say that it is confirmed because it is true that with a certain type of work we may have three [employees] instead of five, but the other two who no longer work at that workstation will not only allow those workers to rotate more on the workstations considered to be a bit heavier, but also that they will take care of other types of work where we perhaps previously had difficulty, purely manual work. ... In my opinion, as far as design is concerned, I would say no ... We found it as it is [the AGV]. Let's say that the details are not related to technical aspects of the installations. Clearly we can't do anything about that other than to say: 'There's a problem.' But I would say that, as far as the initial phase is concerned, it was all a company initiative.*
>
> POSTE, Trade Union Representative

The reasons for this support, however, were not uniquely the previous history of cooperative labour relations. This was a necessary but not sufficient condition. Unions foresee benefits from the adoption of AGVs, because being an investment AGVs represent a commitment by the company in the expansion of its activities. Unlike expectations, unions did not see a threat of labour substitution in AGVs. Instead, they saw the possibility of increasing the total amount of employment at the site and within the company. Another reason exposed by the trade unionist was the significant improvement in safety provided by the AGVs and the substitution of most forklift handling. At the same time, it should be noted that the choice of whether introducing AGVs or not was not really a matter of discussion, as is admitted by the union representative (see the second half of the quote above) and confirmed by a worker when they were asked whether, according to them, unions intervened in the implementation of AGVs:

> I don't think so ...
>
> > 'Question'. How do you say ... Was it was a decision from the top, but not like it was negotiated with the union? ....
>
> Absolutely. In my opinion eh ... Maybe it was him [the union representative] who said, 'These girls are struggling,' ... But in my opinion, no ...
>
> POSTE, Worker

The Italian model of labour relations – and POSTE's in this case – do not give unions a specific way of intervening in the matter of technological innovation, and this is well understood and confirmed by the trade unionist when saying that they 'manage the outcomes' of automation. When we asked whether, during the implementation of AGVs, they had the opportunity to intervene, the union official mentioned the issue of job rotation for workers with disabilities: according to unions, the fraction of workers at POSTE with disabilities and task limitation range between 30-40%. The introduction of AGVs abolished some of the heaviest tasks and thus allowed for greater job rotation. The union official said:

> *Back in 2003, and I'm not ashamed to say it, I was the initiator together with a safety manager. We decided to create reference indices, station by station, so that we could assign the staff. In other words, the fact that I had a problem, say in an arm or in my back, did not mean that I was unfit to do*

anything, but through the analysis of the repetitiveness of the work, of the workloads to be borne, etc., etc., we were able to map all the workstations in such a way as to say that, if I actually had a problem, through the competent doctor I had a reference, an index, and on the basis of that index I can then be assigned to that workstation or to another. And also thanks to technological development, the possibility of assigning the partially suitable ones has increased, because the workstations have become more manageable and therefore the handling of loads has improved considerably.

POSTE, Trade Union Representative

At the same time during our interviews, we found out that the introduction of AGVs created some resistance among the workforce, especially those who were assigned to forklift-handling tasks who were reluctant to abandon this job, which is a typical issue when automation is at stake. However, this form of resistance was not endorsed by the unions, remained latent and, at least as far as we know, never generated conflict.

At PMI and AMAZON, we did not find any special role played by the unions. This is partly due to the different labour relations prevalent in these companies. Both are US-based multinationals careful to maintain a certain level of standardisation and homogeneity across national subsidiaries. They tend to manifest unilateral decision-making and disintermediation in terms of relations with workers and unions. Indeed, we did not have the opportunity to interview unionised workers or union officials during our visit, despite union representatives existing at both plants. That said, what we acknowledge is that the process of planning and adopting AGVs was not discussed with unions. This is partly explained by the fact that both are greenfield sites, where the large part of the workforce had not yet been recruited at the time of the AGV introduction. With regard to the incremental implementation of AGVs, we do not have evidence of union interventions. In the case of PMI, negotiations with trade unions may occur in relation to changes in job descriptions (this possibility was suggested by the global operation manager).

With regard to AMAZON, in a very similar fashion with respect to low trade unions involvement, the only exception is the introduction of surveillance devices. The HR manager told us that the introduction of technological innovations that involved the possibility of surveillance of workers was submitted for the approval of the labour inspector, in conformity with labour laws. The respondent told us that AGV workstations (which are equipped with artificial intelligence cameras) were not affected by this procedure.

Another type institutional obstacles might arise from market regulation, like at POSTE. During the briefing, managers explained to us that AGVs could not cover the handling and transportation of registered mail. This is regulated by specific formal rules that guarantee the protection and tracking of the shipment because they carry legal communications (public administration, judiciary administration, etc.). This implies the presence of human agents validating the integrity of the shipment process for registered mail. AGVs, at least under the current procedures, cannot perform this task.

Institutional factors of this kind (linked to the special legal regulation for the product or service performed) may also play a role at PMI, since the company has the legal monopoly of the distribution of tobacco([17]). To illustrate this, bear in mind that the plant hosts a resident office for the government's custom and tax police, which oversees the registration of quantities of products manufactured and shipped. The interesting fact is that the constraint seems to work not against automation, like at POSTE, but in favour of it:

But consider that this warehouse is under custom jurisdiction and this commodity is therefore substantially more delicate than that which can be found elsewhere, and we have a 'Guardia di Finanza' office inside, and a monopolies administration office. Therefore, the less the manual intervention by operators, the greater the security and the easier the work of the monopolies' office and the Guardia di Finanza, which oversee custom control. When I said, 'Do not bring in the sticks,' it is because there is a random check on exit. They can check whether you have taken out something illegally. If you walk out with a packet of cigarettes, you are basically charged with contraband. That's the concept. So the less manual handling there is, the more it helps us …

PMI, External Relations Officer [visit]

Finally, market regulation does not seem to affect AGVs or, broadly speaking, the process of automation at AMAZON.

([17]) This element cannot be considered as a main driver/constraint in the process of automation since there is not a formal requirement by the state or the company prescribing the use of machines or robots given the specificities of the product.

Labour market obstacles

With reference to the fourth type of obstacle, we did not find any evidence associated with the competitive advantage of cheap labour costs compared to the introduction of labour-saving technologies such as the AGVs. The main reason is, of course, as we have already stressed, that we are studying three cases of relatively successful adoption. However, as we illustrated in the paragraph on unions' reactions to AGVs, we found out that, at least in the case of POSTE, AGVs partially alleviated the problem of workers' task limitation due to disabilities, suggesting that (internal) labour market issues and firm-level automation strategies can be entangled in very unexpected ways.

> *The new machine we have put in, the TOP 2000([18]), is a machine that already has several workstations where staff with disabilities can work on it. So the tendency is to move towards the automation of machinery that can allow me to carry out activities that, today, some cannot do because they have restrictions, derived from physical problems, which prevent them from being used 100%. This will probably allow us to recover the productivity of those employees over time.*
>
> POSTE, HR Manager

3.3 Work organisation, job quality and task content

In this section we discuss the impact of AGVs on the organisation of work, that is, how work is planned, organised and managed; decision-making processes, workflows, quality controls and standards; monitoring and controlling employees; job definition and its content.

This section is divided into five main subparagraphs aiming to: (i) illustrate how workers operate with the AGVs and therefore discussing the hypothesis of reorganisation; (ii) highlight issues of job quality such as working rhythms and ergonomics; (iii) explore changes in autonomy and control of work, including the forms of monitoring and evaluation. In the last two subparagraphs we shed some light on the following topics emerging from interviews and largely related to work-organisation issues, such as wages, occupational classifications, career paths and workforce re-composition. The final section is dedicated to workers' considerations on the whole AGV implementation process, including their relationship with supervisors, and forms of resistance.

Jobs and task reconfiguration in relation to AGVs

Although the three firms included in the AGV case study differ from each other, we could state that the introduction of AGVs was not abrupt but, to some extent, 'incremental' and progressive.

Therefore, a low impact in terms of work organisation has been registered at POSTE, where the introduction of AGVs did not require any special reorganisation of the workflow. The latter remained the same also because of technical problems with the layout – mentioned in the previous section – and the low number of AGVs. Sometimes, as workers declared, there are not even enough AGVs to fulfil the requirments of workers. As we already discussed, AGVs at POSTE display the features of a rather complementarity and low-level integrated technology. A further aspect highlighting the low impact of AGVs on the global organisation of work is the fact that workers can choose whether to use an AGV or not. Despite the low impact, it is important to stress that workers reported some micro-changes occurring within the workflow that relate to the movement of carts, which we will analyse in depth in the section on ergonomics.

At PMI, the impact on work organisation has been very modest since AGV integration was planned from the beginning and the labour process designed accordingly. However, the new plant was in some way a spinoff of the older PMI site (a few miles away) and, in fact, the first workers hired by the new company – PMMTB – previously worked for the old tobacco manufacturer. The comparison with the old plant allowed us to formulate some hypotheses on changes in the labour process linked to the introduction of the AGVs. The latter significantly affected the jobs of forklift drivers (with respect to the old manufacturer) as well as production workers who now deal with AGVs in the execution of their tasks. Of course, considering the new

([18]) TOP 2000 is a sorting machine introduced in 2019.

plant – PMMTB – AGVs have been implemented by forecasting and anticipating the increase in production volumes([19]).

Lastly, new teams were constituted to govern the AGVs, such as the logistics automation team, whereas the maintenance team was outsourced to SIMIC. Another important aspect to keep in mind is the incremental introduction of AGVs. As was stressed by the operations manager and the IT specialist, the AGVs were introduced gradually over 3 months.

Amazon FC is also a greenfield plant, even if by no means a unique plant. There are dozens of warehouses of this kind in Italy and Europe that use AGVs. Nevertheless, during interviews we were able to assess the impact of AGVs in comparison to the traditional pick-and-stow process that is adopted in the old-generation warehouses and in a specific section of this plant called Pallet and Picking (see the section on market obstacles). Therefore, also in this case we detect a sort of stratification of non-AGV work processes that allow us to understand the impact of AGVs. Compared to POSTE, and even compared to PMI (where AGVs remain assigned to an auxiliary manufacturing function), AGVs at AMAZON have had a huge impact on work and on the global organisation of the production process. Work activities characterising the job of pickers and stowers are reshuffled entirely and new professional figures have been introduced, like that of Amnesty Responder. The increase in productivity is so high (+25% units stowed per hour, according to an interviewed line manager) that the limitrophe processes and departments have also been affected (receive, pack, ship). To sum up, we could say that POSTE, PMI and AMAZON represent examples of the low (POSTE), medium (PMI) and high (AMAZON) impact of AGVs on tasks and jobs. Such a qualitative difference mirrors a strong heterogeneity in the number of artefacts introduced (POSTE deploys 10 AGVs, PMI 34, AMAZON dozens).

Which jobs and tasks have been affected and reshaped by AGVs and how do workers interact with and operate them? What impact do they have on rhythms, ergonomics and safety?

At POSTE, as we said, virtually every worker can use the AGVs. 'AGV specialisation' is at a very low level and there is no rigid division of work prescribing who can and who cannot have access to them. In general, the technical division of work within the site is not extremely developed and rigid; AGVs serve most areas, and workers enjoy much more autonomy in the use of this technology if compared to AMAZON or PMI. This is also made possible by the relative simplicity and accessibility of AGVs. Operators use terminals equipped with a display to move AGVs or, better still, to programme their route. In this sense, potentially all workers should have very basic digital skills and perform very simple analytical intellectual tasks when deciding to use AGVs.

> *'Question'. I saw downstairs ... There are displays on the wall where you call and basically programme the AGVs ... So, you do that?*
>
> *Yes, absolutely.*
>
> *'Question'. And it's you who decides when it's time to call [the AGV] and how to programme it? Let's say that the programming, if you want to call it that, is done by you?*
>
> *Yes, because then there are actually two buttons.*
>
> *'Question'. OK, perfect, but do you decide to make a complete round trip? Because I've seen that there are two functions: 'stay there empty', that is, stationary, or 'go back', you decide ...*
>
> *Yes, I can ... Basically, if I insert what are called multiple tasks, it can make several trips within the same mission, while, if you give one mission at a time, you have to give the command again each time.*
>
> POSTE, Worker

POSTE workers are also trained in basic troubleshooting and in the event that an AGV stops, they can intervene on the machines with simple manipulations (all workers are allowed to provide such an initial intervention). If the problem persists, they phone the technical support of an ad hoc team:

> *If there's a problem with the AGVs, we usually handle it ourselves – we know the machine well by now. If there is a problem that is technical, we have a phone number that we call and tell them the problem. For example, "The Soly 11-83 has stopped, but it's beeping or not beeping at all, I've tried*

([19]) The introduction of AGVs did not involve the replacement of workers. On the contrary, the total number of workers has grown in recent years. However, in relative terms, specific professional figures such as those of forklift drivers have decreased, suggesting a reconfiguration of work following the introduction of automated machines such as AGVs.

switching it on, I've tried changing the batter'' – because we change batteries, every Soly has batteries …

POSTE, Worker

Although they recognise having only a low level of intervention – basic troubleshooting – some workers express satisfaction for this relative skill improvement:

I certainly feel more educated, I have some more skills that I did not have before. I also feel a little more responsible. However, these are more skills that I certainly have, compared to before: using a tool, a machine, alone, I try to intervene alone, to solve, it is the 'problem solving' … I sometimes try to solve a problem before calling the technician, it's not that immediately, as soon as I sense a problem, I call them, no: I try to think about it for a moment. Then they are simple instructions, very simple problems, but in any case, I try to solve them by myself. So, anyway, I think I have got some minor skills, an extra set of skills …

POSTE, Worker

The technical team is composed of workers from POSTE and some external companies contracted for the maintenance of the machines. More specifically, training is implemented for external workers, supervisors and instructors who, after receiving training, are in turn authorised to provide training to other workers. Since AGVs serve the area but are not digitally connected to other systems/devices, this gives more discretion to workers, who decide whether to use them or not. Of course, this does not mean that workers avoid using them. Indeed, workers explained to us that sometimes there are not enough AGVs to cover the needs of all workstations. In this case, workers cooperate and decide which one of them can use the AGV for a specific operation. This is done autonomously and through horizontal organisation not involving direct intervention from a supervisor:

'Question'. OK. Perfect. While on the other hand, with respect to the issue before … that issue of the sort of compatibility of use between you and your colleague that … Can this also lead to time problems? I mean, in the sense that you have to wait, or you have to do it in another way. What happens when …?

I don't know. I avoid taking a fourth [AGV] if I can, maybe. I'll go … if they don't use it anymore, I'll set it up so it can be moved by hand … There is a special setting for moving it by hand; I take it, I put it in my home station, I set it with those parameters and then I use it …

'Question'. OK. But that didn't happen before because you were pushing … or did it?

Eh, no. Before (laughs) it didn't happen …

'Question'. You mean that with the AGV the coordination between you and your colleagues is more delicate?

Yes, it's more delicate, yes … Even if I tend to use it in the morning when it's calmer, it's a quieter part of the day, so …

POSTE, Worker

Most jobs and tasks are mail sorting operations, executed using other machine systems (SIACS, TOP 2000, AGS, etc.): workers continue to operate with these machines in the same way. Before the introduction of AGVs, when they needed to transport sorted mail to another area, workers called forklift operators or even transported carts on their own. With the introduction of AGVs they can use them instead of moving their own carts or calling for a forklift driver. However, these two last options have not completely disappeared. Workers reported that sometimes they are even forced to use manual carts on their own because there are not enough AGVs to serve all of the workstations:

'Question'. Like you in your department, reception, how many people use it, all of them? Or do some people use it, and some don't use it and why, i.e. is it up to each person to use it? And then if you don't use it, how do you send the mail, do you push it?

Yes, in fact I use it because before we were forced to carry everything on foot, and in any case to push, because SIACS 4 is a department where access is prohibited to both electric pallet trucks and chariots, those with a person on board.

'Question'. Why? For safety reasons?

Yes

'Question'. So you can go there, i.e. you can get there either with the AGV or ...

On foot, pushing a cart.

'Question'. When do you decide to take the cart [instead of the AGVs]?

When they're not ... Because we have several containers: the train, the car of the train is always the 6-wheeled trolley, and so if I use the AGV I have to have a 6-wheeled trolley because it is the one designed to be towed. Sometimes we don't have them ... however they are ... You have to look for ... We have rolls, the classic roll, and then ... On which you can easily load, eh ... they are allowed containers, but clearly the train cannot tow them and so we go on foot.

POSTE, Worker

The relatively soft impact of AGVs on the organisation of work emerged from interviews with workers not reporting any special change. It took several attempts to get some information about micro-changes in their work. The extract of an interview with a worker from the 'Receive' area ('Accettazione') provides us with interesting elements on task relocation. Before the introduction of AGVs, cargo was dispatched by the 'sender' according to the bay of destination; in fact, the sender used to push (or drive a pallet truck) the cargo to the bay (say the SIACS 4). There, they used to leave the cart at the exact unloading point. The introduction of AGVs has reshaped the process since the sender now programmes the AGVs according to the destination and remains at their workstation. AGVs do not specifically reach the bay but stop at an equipped station. Now it is the receiver who has to place the cart at the right point:

Example: When ... I used to push the carts and carry them on foot ... I would put the trolley ready in the hold. SIACS 4 is quite big, so there are several bays: mail of a certain type, tracked mail, untracked mail. So I already knew where it was going and positioned it [in the right SIACS bay]. Now, the AGV unhooks the two trolleys in a single position and the SIACS operator therefore finds If with two unhooked trolleys, one of which is, for example, bulk mail that goes in one corner, the other another type of product that goes in another corner, so they clearly have to take and position the trolleys in the different holds.

[...]

The SIACS operator, who finds an AGV arriving and unhooks two trolleys and has to remove them quickly, because then the AGVs must come back to me and I send two more ...

POSTE, Worker

This task relocation between the sender and the receiver of AGVs and, especially, the fact that carts are to be moved manually from the AGV station to the precise point has ergonomic consequences, as is stressed by some workers. We will focus on this in the following paragraph on safety and ergonomics. If the task definition of workers involved with mail sorting was slightly affected by AGVs, the introduction of this automation technology had a strong impact on the forklift driver category. This was one of the goals of the introduction of AGVs, as forklifts are considered one of the key causes of accidents in the warehouses.

At PMI there are at least four categories of workers who interact with AGVs in executing their tasks: manufacturing workers (employed by PMMTB), logistics operators (employed by LOGISTA), technical-maintenance operators (employed by SIMIC) and logistics-automation supervisors (employed by PMI Logistics Automation).

'Question'. What do you mean by 'machine conduction'?

We now have to distinguish the four actors that deal with the AGVs. First, all of the passers-by. Then there are the production operators, our blue-collar MTBs, the guys in Tiffany shirts that we saw in Secondary and Primary, and when I say they 'operate', they are 'conducting', they troubleshoot the machine: if the machine stops, they restart it, they clean it, they carry out visual quality inspections, etc., etc., etc. So these are the actors. Then there is LOGISTA, which interacts for loading and unloading in the logistics areas, where we have seen the Control Room, all of that area there. All of the interactions with the AGVs are performed by LOGISTA, and then we have the final actors, the SIMIC operators from my team who only do the troubleshooting. So, we saw the guy resetting the AGV that couldn't take the load. In that case, that's an AGV-management activity for me ... but that's SIMIC ... because that's a technical reset for a technical problem with the AGV. If the AGV doesn't go on to alarm, it delivers and then the production department will handle the load. Conduction tasks require very basic training to be able to carry out problem solving and techniques that only require

removing the obstacle, e.g. arranging the load and basic reset. But we have done induction training to explain what the safety sensors are, what the conditions are for handling a load, what the AGV sees and what its safety equipment is, also in terms of driving. So every operative is trained on this ...

PMI, Supervisor Logistics Automation

In order to understand how these jobs were affected by AGVs, below we present an excerpt from an interview conducted with a global operations manager:

What really changes is that the transport is no longer manual but automatic, so the activity that the operator used to do was to take a pallet, prepare it so that the forklifts can pass through and go up ... They still do it. The only thing that is a plus is that they have had to increase their capabilities. Because in order to prepare a material, they not only have to do a physical activity but also have to understand how to manage a system so that the pallet is picked up.

[...]

The driver opens the mission on the system and says within our Warehouse Management System, 'I operator Alberto, who is working at Packer 45, need a pallet of packages." This information, which is obviously digital information, is managed through a barcode reader and generates a mission. The mission is transferred to the AGV management software, which aims to find the first free AGV closest to the picking station and then bring the pallet to the operator within the set time. The logistics operator, on the other hand, receives the same information on their buffer reader and says, 'I must also prepare this pallet within X minutes at that pick-up location so that the AGV can come and pick it up and take it there.' I don't know if you have noticed those green, yellow and red columns that were present where the LOGISTA operators prepared the materials for AGV picking? That visual is used to say whether ... because that visual is not there to just look nice but it is there to make the operator understand (without being there to look at a panel or to look at the barcode reader) whether the flow that they're managing is still within the times and then the operator must also understand whether the AGV that is coming to pick it is coming on time and, if not, then the light bulb turns yellow. This calls for a reaction by the automation team to understand why the AGV does not arrive.

[...]

The need for the vehicle to have a compliant load introduced the need for us to have a certain awareness and prepare the loads in a certain way and be able to do basic troubleshooting. So it's a small change, but it makes the operator feel the need to work better in order to have a better service, because the operators are very aware of the fact that if they leave a vehicle stationary and do not intervene, etc. – the factory being huge – we cannot wait for the SIMIC support to arrive and decipher the problem. They can already operate alone because they have an initial level of intervention. Understandably, with some classes of problems they cannot intervene. For the classes that require an adjustment of the load or removal of the obstacle and a single reset, they can do it by themselves, so let's say that it is a small change, but for them in terms of capability, however, they are trained, so they have some extra elements ...

'Question'. So they are required to intervene up to a certain level?

Yes, it is clear that if there is something blocking – for example, there is also a problem on the machine, etc. – the SIMIC operator will arrive and fix the problem. SIMIC operators can monitor the situation remotely. So, for some classes [more complex] of alarm, the SIMIC operator is already a little more experienced and knows that for the typical error for an obstacle in the middle of a lane, someone is potentially manoeuvring, and therefore does not run to intervene, they let it, allow me to say in quotes, 'mature' for a moment, because the operators in the bay are able to manage some problems independently.

PMI, Supervisor Logistics Automation

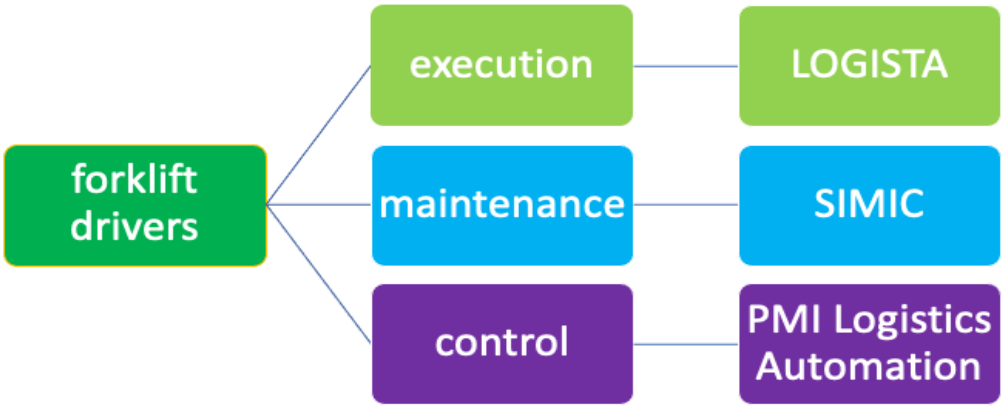
However, tasks and jobs are not affected in the same way by AGVs. First, some required sets of tasks changed and almost expired, such as those performed by forklift drivers. At the same time, management

insists on a positive outcome for subcontracted logistics workers, i.e. the improvement of their skills, as they are trained to deal with robotic technology([20]):

> *[Logistics workers] must be people who have a minimum level of induction training because they have to deal with management software, which is [written] in Java ... They have to deal with SAP, they have to deal with Teams, they have only digitalised documentation. So, our department is one of the most digitised entities in the factory.*
>
> PMI, Supervisor Logistics Automation
>
> *The new capability of the logistics operator is also to understand – using the barcode reader, or using that visual system and also those super PLCs that were placed behind him – how the missions are going. Whereas, previously, basically the classic forklift driver's task was pick up, load, unload, go. Now there are very few people who drive the truck as you have seen ... Above all, those who still exist have additional training in the use of automation systems. Because they do the first level of debugging ... if an AGV doesn't arrive, it's not that one of SIMIC's support staff comes to check, 'gee, this one's stopped.' Because otherwise he/she wouldn't be occupying his/her time properly, would he/she? Because this gentleman/lady at the same time is supposed to be doing maintenance ... So the conduction phase is very critical in this sense, a reason why the appropriate training is done ... It's training, for those of LOGISTA, of a user nature: I give you an iPhone and I also teach you what the functionalities of the iPhone are and what you can do with it. Whereas the training that the [SIMIC] provider must have is 'I give you the iPhone and in addition to knowing how it works, I must also know how to fix it if it gets stuck'.*
>
> PMI, Global Operations Manager

Two new groups of professional figures were created for the management of AGVs while forklift drivers almost disappear (see Figure 3.4 below). The first is the technical and maintenance worker who monitors the AGVs (employed by SIMIC) on the ground and from the control room. The second is the Logistics Automation team at PMI also monitoring the AGVs and the performance of SIMIC at a higher level. Compared to LOGISTA workers, SIMIC technical workers have more proactive interaction with AGVs.

Figure 4. The relocation of internal logistics tasks from forklifts to AGVs at PMMTB



Source: Authors' elaboration

With reference to professional skills, while Logista workers carry out less skilled work activities for which it is not necessary to possess specific skills, the SIMIC team is mainly composed of technical workers with high-school technical education and the PMI Logistics Automation team is mainly composed of engineers. Lastly, the fourth group of workers whose tasks were affected by AGVs are the core workers, those employed by PMMTB in the manufacturing departments (Primary and Secondary). As explained in the interviews quoted

([20]) It is important to highlight that we do not claim any causal relations between the introduction of AGVs and the outsourcing of logistics functions, since many logistics operations were already externalised before the adoption of the AGVs at the new plant.

above, these workers receive the AGVs that bring them raw material (Primary) and semi-finished products (Secondary). Therefore, they are trained to use AGVs and also in basic troubleshooting they can order a replenishment of material using a software tool (iMEL LES-MES). The order is transmitted to the AGVs via the SuperFROG® logistics software, connected to the iMEL. The AGV is loaded by the logistics operators and transports the cargo from one area to another. When it reaches the destination area, it stops at an equipped AGV station, unhooks the cargo and starts another mission. The manufacturing worker is informed by the software that the cargo has arrived; they therefore leave their workstation, arrive at the AGV station, get the cargo (which is on a cart) and push the cart to its workstation. This is a configuration not dissimilar to that described at POSTE, where the AGV does not leave the cargo in the workstation for reasons of technical unfeasibility and for safety risks. It is up to the manufacturing worker to reach the cargo and manually transport it to their workstation. Thus, like at POSTE, the automation of forklift tasks is not total but partial, somehow entailing a relocation of residual logistics tasks, those that the AGVs are not able to accomplish, now under the responsibility of who receives the AGV.

PMMTB workers receiving the AGVs in the Secondary department highlighted that the introduction of AGVs has simplified and eliminated a vast series of mainly physical activities. Among these activities is the loading and unloading of material:

> *Before (10 months before the introduction of AGVs) the materials arrived via personnel, let's say logistics operators, on tracks and then were placed in a buffer zone, and from there were then transported manually, that is, with non-motorised hand pallet trucks inside the cells because the logistics operator cannot have access with a vehicle, let's say an automatic vehicle, however motorised, inside the perimeter that delimits the production area for the operators, specifically for safety reasons.*
>
> *This obviously led to a whole series of inefficiencies, both in terms of time and in terms of the priority of calls ...*
>
> *Today, however, what happens is that the operator selects the material from the panel and visually checks that the machine's stock of reels is decreasing, and the call automatically goes out from the panel and takes the material to the station inside the cell.*
>
> PMI, Operations Secondary

AGVs also save workers' time production, since they perform an automatic replenishment of depleted materials or they can perform ancillary functions, not strictly necessary to the production process, such as emptying bins with discharged materials once activated by the operators (by scanning barcodes). Before the introduction of AGVs, this operation needed phone coordination between workers:

> *... before there was no priority route there was no automated system to track needs, but it was a phone call that could then fall into oblivion rather than needing x reminders from the person.*
>
> PMI, Operations Secondary

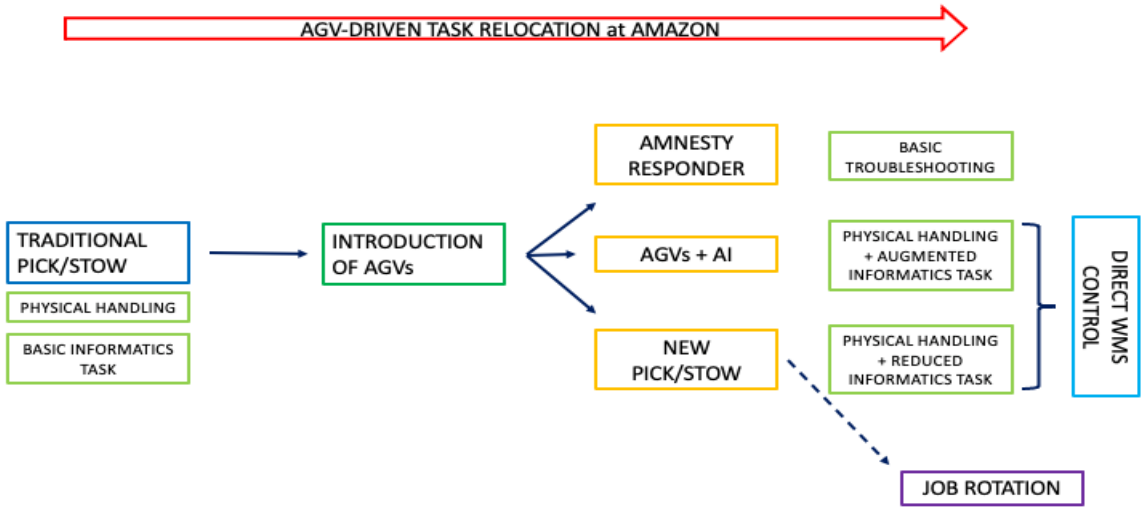
Therefore, to some extent the introduction of the AGVs has reduced social interactions between colleagues of different departments, while it has increased interactions with colleagues within the same workstation. Overall, the introduction of AGVs has standardised work activities by reducing work time spent in low-value-added and non-core activities. Physical tasks have been significantly reduced, although new physical activity has been introduced – such as the scanning of barcodes of the materials needed – whereas social interactions with colleagues in the logistics areas have decreased.

At AMAZON, AGVs contribute to the reshuffling of the pick and stow tasks, leading to the introduction of new jobs, such as that of Amnesty Responder (maintenance worker) or that for technical robotics maintenance, but their introduction did not lead to the disappearance of forklifts, like at POSTE and PMI, because these positions were already marginal in the pick and stow processes.

With regard to pick and stow, AGVs, as we saw, move PODs (the storage units) between pick and stow workstations across the robotic floor. Pickers and stowers do not control the movements of the AGVs, which are centrally managed by the Warehouse Management System. When the operation of pick or stow is completed, the AGVs move the pod away to another pick or stow workstation. Amnesty Responder is a new position introduced for troubleshooting on the robotic floor, which is a fenced area off limits to human operators. Only specific positions have authorised access, and only for maintenance tasks. The Amnesty Responder initially intervenes when one or more AGVs stop – this human intervention is allowed when an item falls down from the storage unit to the floor. The AGV sensor detects an obstacle in its path and stops,

emitting an alarm. The Amnesty Responder receives the alert on their digital tool and is trained and allowed to enter the floor, certifies the problem and tries to fix it (collecting the fallen object and resetting the AGVs). Sometimes the problem is more complicated, and the maintenance team is expected to intervene. In each case, workers entering the robotic floor are equipped with a special vest which projects a magnetic cone detected by the AGVs. Amnesty Responders are few and fulfil a support function ([21]).

Figure 5. The relocation of tasks at AMAZON



Source: Authors' elaboration

Working rhythms, ergonomics and safety

With regard to working rhythms, ergonomics and safety, we found nuanced evidence that prevents us from drawing unilateral conclusions.

At POSTE, working conditions have partially benefited from the introduction of AGVs. This was particularly stressed not only by management but also by the union official. From both parties' point of view, the most important effect was the reduction in human-driven forklifts on the floor and in the pedestrian transit zones. This reduced 'promiscuity', as was defined by the union official, and the occurrence of safety risks:

> *In short, it's clear that promiscuity in a centre like ours, in a confined space between manual work and working with forklifts passing by ... I can only say that in terms of safety, if I were director of CMP in Bologna, I would sleep better. Unfortunately, there have also been serious episodes, not at this centre, but in other plants.*
>
> POSTE, Trade Union Representative

Another important benefit stressed by management, union officials and by workers, too, was the reduction of tasks involving the handling of heavy loads, which are supposed to be assigned to AGVs. However, the picture is more nuanced for this topic. Interviews with workers gave us evidence of a possible increase in heavy loads handling for workers, as described in the excerpt above. AGVs can now move heavy loads across the warehouse, but the final manoeuvre in the cart's approach to the workstation must be accomplished by the worker:

> *Then in some operations obviously yes [there was a change].*
>
> *[...]*
>
> *In my opinion, they could be studied in a better way. Personally, I already do it now, I do it with my feet: I take the lever from the bottom with my foot, so I don't bend every time ... So maybe you could*

([21]) We do not have precise information on the exact number of Amnesty Responders at work at the Amazon plant.

also add a mechanism where a person can lower it with their feet ... So they don't have to bend 90 degrees or go down on their knees.

POSTE, Worker

Working with the AGV, let's say that towing and pushing were introduced in order to be able to attach a trolley close to the AGV, and that wasn't there before. You have to do some towing and pushing.

'Question'. And as a type of operation, is it tiring?

Let's say it's tiring if the load is large. Even if the pallet to be moved weighs anything from 400/300 kilos, we can imagine that in any case, moving it requires a certain amount of force to get it going. Perhaps the weight is not felt while you are in motion, because there is the wheel system, but when you start moving it there is a certain [effort] ... A certain resistance.

[...]

Previously there was someone who was in charge of handling. They arrived with the forklift, picked up the pallet, took it from point A and brought it to point B. There was no manual handling. Whereas now, with the AGV, you have to take the truck, pull it and put it next to the AGV to hook it up.

POSTE, Worker

With regard to working rhythms, the introduction of AGVs does not seem to have caused an increase in working rhythms at the POSTE plant. Management did not report anything about that. The union official told us that they intervened in a problem with excessive workloads on the TOP 2000 machine, but not on AGVs. When we asked workers about a possible increase, they did not explicitly associate AGVs with a special increase in rhythms and not even work routinisation.

At PMI, no specific changes in working rhythms have been detected by managers and supervisors. With regard to ergonomics and safety, we could formulate the hypothesis that the task relocation and the introduction of AGVs that could have opened the door for new types of risks for operators (due to the cohabitation of vehicles and pedestrians) seems, instead, to have led to greater compliance with safety provisions (according to the board of PMMTB), as 'it reduced the chances of human errors related to bad practices'. This has also been confirmed by the interview with the manufacturing operator working in the Secondary department.

Similarly, with regard to working rhythms, we were not able to track any increase or decrease; however, the introduction of AGVs seems to have standardised the work activities of manufacturing operators, reducing time spent on low-value-added tasks.

With regard to AMAZON, our interviews with management and workers did not report any special increase or decrease in working rhythms. Of course, there is a bias, due to the greenfield nature of the plant and the impossibility of asking workers and management about changes. However, on the basis of evidence from the fieldwork and indirect data from scientific literature on AMAZON (see Massimo, 2020a; 2020b), there are some provisional conclusions that can be formulated. Comparing the new-generation sites, like that of FCO1, to old generation (such as that settled in Piacenza), changes brought about by AGVs can have consequences on pace of work and safety. With the introduction of AGVs, pickers and stowers no longer walk from one shelf to another to pick and store articles. This brings some benefits in terms of safety, as there are no longer dozens of workers moving carts within the same area. Among the safety improvements: (i) the risk of accidents and collisions is reduced (although not eliminated, as transportation activities with pallet trucks remain); (ii) workers do not have to walk for miles during shift work; (iii) reduction of accidents due to workers trying to stow or pick items too high up on the shelves since the AGV-assisted process allows a small stepladder for each workstation (at the old generation sites workers can use stools, which avoid overreaching but have higher risks of falling). That said, there are also new risks potentially appearing. For instance, standing in the same workstation for hours is not a zero risk for safety. Moreover, the fact that workers no longer walk deprives them of the control on rhythms because they do not control the arrival of AGVs and this can bring work-pace intensification. Of course, the implementation of job rotation schemes might attenuate these sort of risks – as stressed by the safety manager we interviewed. Workers confirmed to us that job rotation is widely applied, depending on the production needs, of course. Usually, one half of the worker's shift is spent picking and another half stowing (or on other tasks such as packing). With the introduction of AGVs, pick and pack tasks become much more similar. This was confirmed by one of the operations managers that we interviewed, who said that, 'picking is the reverse engineering of stowing.' Packing is very similar to picking and stowing in terms of movements required by workers. This led us to think that the benefits of job rotation for ergonomic risks should be assessed in greater depth and with further research.

In conclusion, AGVs bring different degrees of task and job reconfiguration. The impact appears higher at AMAZON, where AGVs directly affect the tasks of most workers. At PMI, the direct impact appears less pronounced but still detectable. At POSTE, the impact was even less pronounced. With regard to working rhythms, they do not appear as a direct and immediate consequence of AGV introduction. But of course, they introduce a new constraint for workers in terms of the determination of pace of work: either because machinery continues with informatisation and more monitoring; and because machinery has a pace of work that can be independent of the will of workers. Finally, with reference to ergonomics, AGVs brought about important benefits in general since they reduced major physical effort and allowed workers to concentrate on working on core activities.

Autonomy and control

The dialectic of autonomy and control is intertwined with the mode of governance and the problem of task reconfiguration, but also brings to the surface new material. The first piece of common evidence for all three case studies is the fact that AGVs do not bring any radical/disruptive change. Quite the opposite it is the continuation of previous dynamics of digitalisation and standardisation, which have considerable consequences on monitoring.

At POSTE, the AGVs are managed via a software program which was bought from the provider and is now owned by POSTE. The software is controlled at central national level, as well as on-site. Workers, as we said, can choose whether to use AGVs or not and there is no specialised class of workers with exclusive use. Workers are trained to programme their routes according to their purposes. However, this programming is not particularly sophisticated. At the same time, the introduction of AGVs presents more pervasive control on the transportation task that was covered by forklift drivers in a less standardised and informatised way in the previous organisational setting.

At PMI, the centralisation of control on AGVs is higher with regard to workers at the bottom of the pyramid. At PMI, there is a special team for the use of AGVs, outsourced to LOGISTA, and a special team for monitoring AGVs, outsourced to SIMIC. Given this configuration, workers do not have the choice to using AGVs or not. Procedures are much more standardised and even if 20% of movements is assigned to forklifts, this choice responds to internal management risk. Logistics and manufacturing workers do not have much autonomy, even in the programming of AGVs, as they are trained only on basic manipulations (those assigned by the division of tasks) and on troubleshooting ([22]). In this respect, PMI resembles POSTE, even if the governance structure is multi-layered.

AMAZON instead represents an outlier. Not only is there no choice for workers whether to use the AGVs or not, most workers operating them have no possibility of intervening with their ICT interface. And this distinguishes AMAZON from POSTE and PMI, where even workers who deal with AGVs, including manufacturing workers, are trained on basic interactions and basic troubleshooting. Not only can AMAZON workers in no way intervene on AGVs (except for the Amnesty Responder and the maintenance team) but the AGVs radically reduce their autonomy in setting their working rhythms. This does not seem to be the case at PMI, where manufacturing workers use AGVs to request the replenishment of raw materials, while at AMAZON workers appear to be more at the service of AGVs, which, on top of that, are centrally managed by a Warehouse Management System that operates at continental level. The low level of autonomy was explicitly illustrated by the HR Manager when we asked him if they produced formalised job descriptions:

> *For us, the [unique] role is that of warehouse worker. Given the low level of complexity of each of these tasks, there is no particular requirement associated with the indication of a job description because the autonomy is really low in relation to the decision-making possibility. Really low because the whole process is absolutely guided step by step for the worker and then makes it really simple, so we do not have precise job descriptions. We can see if we have something but I don't think so.*
>
> AMAZON, HR Manager

This POSTE-PMI vs AMAZON divide is confirmed in relation to the forms of monitoring. While AGVs brought an extension in digital monitoring of internal logistics operations at POSTE and PMI, AGVs did not have a particular effect at AMAZON. The fulfilment center was born already equipped with digital and connected tools applied at the hundreds of plants that Amazon runs throughout the world.

([22]) During the interviews, PMMTB highlighted the relevance of other complementary activities that the company offers to employees related to training and learning (these initiatives are mostly established under the OPEN Plus management programmes).

We asked management about the forms of evaluation and performance required for employees, namely the existence of individual minimum rates of production. In all three cases, management reported that the evaluation of performance is carried out using standardised KPIs (key performance indicators) at team level and not at individual level. For PMI, the case is made more complex by the fact that it is legally forbidden to directly monitor and evaluate outsourced employees of LOGISTA and SIMIC, thus they use KPIs to evaluate the performance of the subcontractor and not its workers. At the same time, management at PMI explained that they maintain individualised channels of communication with workers:

> *Absolutely! We have a tool within the leadership pillar called Coaching on the Floor. The CoF has a Personal Score Card within it, and those five areas are discussed on the Personal Score Card and how they contribute to CBN ...*
>
> *[...]*
>
> *That's because OPEN+ has two big numbers that apply everywhere inside PMI and outside, which is 0-100, where 0 is the mentality of just 'zero defects', meaning 'I'm never satisfied; 'I'm trying to find the standard to raise the bar is 100% involvement, because we know the results, if people aren't involved, committed, they don't get it ... We're not going in the same direction ...*
>
> PMI, Global HR Manager

At AMAZON, HR and operational management reported that workers do not have an individual rate of production; this apparently seems to contradict previous evidence from literature (Delfanti, 2021; Massimo, 2020a, 2020b). However, during an interview it emerges that workers have some productivity standards to accomplish but, quite interestingly, they did not know the value of the productivity rate. Lastly, the safety manager explained to us that, at least in terms of respecting safety rules, forms of 'coaching' and 'auditing' are put in place for workers who do not comply with the recommendations of management.

The last sections of this paragraph are dedicated to the effects of AGVs on: (i) career improvements, job descriptions/classification, workforce composition; (ii) forms of relations with supervisors, forms of resistance and to the workers' overall impressions of the technological transformation.

<u>Career improvements, classifications, and workforce composition</u>

With regard to career improvements, classifications and change in the workforce composition, the introduction of AGVs entailed the need for new jobs, new skills and new training programmes for workers in order to interact efficiently and safely with the machines. However, in no case have these improvements opened the door to collective bargaining negotiation on pay scales, classifications and, consequently, on wages.

At POSTE, the union official told us that this was not a priority for the unions:

> *From that standpoint ... In short, we haven't ... noticed anything ... there are no variations in level, neither negative nor positive. ... No... we claim training as a conditio sine qua non, so that a worker can have the same opportunities as others, but it is not that, because one has been trained more, then the level increases ... The considerations are on other aspects.*
>
> POSTE, Trade Union Representative

At AMAZON, the HR manager excluded the possibility of recognising the new skills, for instance, those of the Amnesty Responder or problem solver, with higher levels on the pay scale:

> *For us, [workers] are all 'Associates' and they are all to be, like, say, using contractual terminology, Warehouse Operators. Regardless of the process, of the task that they accomplish.*
>
> *'Question'. And this is not a point of friction with the unions?*
>
> *No, and why?*
>
> *'Question'. Because of the recognition of professionalism, of the fact that I am multi-skilled, maybe I want to be paid more than someone who only knows how to do one thing.*
>
> *But the point is that recognising, how to say, the officer in charge of warehouse operations who does different tasks, these are all tasks of the operator in charge of the warehouse job, then the fact that a person ... That is, we tend so that everyone knows how to do all the processes, okay? To facilitate job rotation among people, but there's no constraint like 'I know two processes so I should do them' because the other person probably knows two processes, but they're different, so how could we distinguish who knows more than who? So I don't ... this problem has never been posed.*

AMAZON, HR Manager

Even workers with supposedly higher skills, such as the Amnesty Responders, have the same pay-scale level of pickers and stowers (they are enrolled under the fifth contractual level, and after 2 years they obtain the fourth level of the collective agreement for the logistics sector). This is linked to the issue of job rotation which seems to be largely applied according to both workers and managers. As explained by HR, management trains workers to perform multiple tasks; however, skills associated with these new tasks do not need to be recognised in terms of classification and pay scale.

At PMI, job rotation is much less improved than at AMAZON or POSTE. This is due to the rigid formalisation, through inter-firm lines, of the division of work. Each category of workers belongs to a different organisation, and this does not allow multiskilling and job rotation. With regard to career improvements, the improvement of skills demanded by the introduction of AGVs was not translated on the pay scale, as was explained by the global HR manager. At PMI, like at AMAZON, job descriptions are subject to relatively rigid standardisation across national subsidiaries, and this is a further element that impedes local arrangements in terms of adaptation to the specificities of local contexts. The only major opportunity for career improvement – as explained by HR – concerned PMI employees of the former Bologna site who had the opportunity to enter the new plant and cover team lead and supervising positions.

Relations with supervisors, forms of resistance and overall impressions of workers

What are the workers' impressions of the transformations that we observed at workplace level? Did the introduction of AGVs trigger some forms of conflict? Or, instead, was the adoption of this new technology met by indifference or approval?

In the case of AGVs, forklift drivers are the category most likely to be threatened with replacement. Indeed, our research found evidence that confirms this hypothesis in the case of POSTE and, slightly more, at PMI. It is not casual, as at both plants, unlike at AMAZON, AGVs have an auxiliary transportation function, and this was a function traditionally carried out by forklift drivers. We could not interview forklift drivers during our fieldwork, but other respondents mentioned the issue. At POSTE, the issue was discussed by HR who said:

> *So the impact on the staff is psychological on two fronts: the first in regard to innovation. There's always a reluctance towards what may be new technologies or otherwise innovation in general. The second is that the work that is developed on forklifts and pallet trucks is a job that people enjoy. So it is a job that is appreciated by the staff and therefore the difficulty in implementing the AGV is determined by this, by the general human reluctance on the subject of new technologies but also with respect to those who currently use pallet trucks and forklifts. The most important thing, however, was that when we used this form of innovation and automation, but also the other form that you will presumably see in the departments, which is the AGS, there was no perception either on the part of the union or of the employees of the loss of work.*
>
> *[...]*
>
> *The forklift driving task has been there since before I started working... but not only in POSTE: in all logistics companies, which handle material. So it is something that is part of people's professional background and there is therefore also this aspect that should be considered: losing an activity that one likes. An activity that, however, is part of ... like for an account clerk to put a stamp ... that is, they are activities that became part of the DNA of people and we can say the same for the handling carried out with mechanical means. Now where is the fundamental step that we have made and will continue to make with regard to resistance to change? The fundamental step is that of involvement in explaining, and Lean Management is giving us a big hand in this.*
>
> *[...]*
>
> *By talking to those who use the tools, they have understood and are understanding. And this is certainly... let's say ... The fact that we've given the staff space to make suggestions. When you went through the departments, I don't know if you saw, we put up a suggestion board, so we gave the staff complete freedom. We also had suggestions that were immediately implemented, such as one in the Indescritto 2 area, where an employee spontaneously suggested changes that we made immediately. So this is really giving us a huge hand in getting even the strongest innovations through. I must say that we have also had good cooperation from the trade unions, which historically in Bologna, but especially at our plant, have been very open to innovation, let's say in the whole region of Emilia-Romagna. The mentality is thus very open to change and this has meant that most of the*

experiments carried out in relation to the plants have been carried out in Bologna, which is often the pilot plant for innovations.

POSTE, HR Manager

The argument of innate resistance to change was also used by the union official and by a worker that we interviewed:

In some situations, there is a certain adversity … It is just a question that a human being is a little adverse to change.

POSTE, Worker

Certainly, for some the change, especially for those who were used to it, right? Because it's a job that you can like, right? That of a forklift driver because you are alone, you are used to doing it and maybe not everyone was so happy with the change.

POSTE, Trade Union Representative

However, this argument is weakened somewhat by the fact that not all workers oppose technological and organisational changes. We interviewed workers who operate using AGVs at POSTE, and they provide a positive overall assessment on the impact of the AGVs on their working conditions (although they reveal some potential issues to solve in terms of ergonomics related to their work practices). We could not interview forklift drivers, which would have been an opportunity to further investigate their subjective point of view on the issue. Anyway, as far as we know, no evidence of open and collective conflict was reported and unions did not consider the issue a matter of discussion and claims in front of management.

At PMI, we did not have the possibility to interview forklift drivers and union officials either. However, through discussions with the global operations and the HR manager we understood that possible tensions concerning the conversion of forklift drivers' and, in general, issues with the adaptation of workers to the new digitalised and automatised environment tasks were expected:

It is the same thing within the production departments. Previously, the manufacturing staff in the production department were used to seeing a forklift arrive with a person on board, ok? At a location that was very close to the manufacturing machine. Now, instead we see the AGV arriving, leaving the pallet at the station, therefore relatively far away … This is the safety point … And at the same time the production operator does not have to do anything, except to have the task of going to take the pallet and put it close to their machine. Ok? This is another concept of behaviour. So all of these things are behaviours that must be fully understood by those who are at the plant … So adapting such a community to a new technology was, in my opinion, the biggest obstacle because, first, the Italian mentality, as you said before, and second, however, it's something new … No?

PMI, Global Operations Manager

There are two things to consider. The first aspect is how much of the already foreseen AGV technology has been implemented from the very beginning, it is obvious not.

[…]

What I can tell you from our point of view, because I would have known, is that there have been no traumas from the use of AGVs and from the increase in both the quantity and quality of use of the AGVs. If it had happened surely there would have been a trade union alert and surely I would have known it … Then another aspect that you have to consider, in my opinion, on the sidelines if you have not done it, is the aspect of working side by side with the AGVs in terms of safety, so what are the safety aspects that AGVs pose …

PMI, HR Manager

Comparing PMI with POSTE, it is interesting to note the relationship between automation, safety and difficulties in the adaptation of the workforce to the new environment. At POSTE, the introduction of AGVs was seen almost unanimously by respondents as the solution to many safety problems associated with material transportation at the plant. This is evident from the excerpts that we presented in the previous paragraphs. At PMI it is quite the opposite: the interview with management revealed that the introduction of AGVs may eventually generate new problems for safety, namely the dimension of the cohabitation between pedestrians and vehicles. In this respect, such a new problem demands surplus attention – in terms of training, rules and monitoring – on the adaptation of the workforce to the presence of AGVs.

That said, PMI and POSTE appear quite distant from AMAZON on the issue of resistance. Respondents, whether manager or workers, did not report any information about resistance and conflicts following the introduction of AGVs (or the decision to increase the number of AGVs). Although both PMI and AMAZON were born as greenfield investments, their histories are different. The PMI site was the result of a restructuring of an old manufacturing site producing standard tobacco products towards a new product investment, and it was conceived to be a unique plant for the whole multinational, located in an advanced productive area, in Bologna. The AMAZON site, although of a new generation compared to older fulfillment centers, was opened in an economically depressed inner and rural area. Here, the arrival of AMAZON was welcomed by workers as a blessing ('la manna dal cielo') and also as the ultimate result of technological progress:

> *Let's say that for this area, I live near here, 20 km from here, it was a godsend. And so I tried to get recruited; it went well. I first started with a contract with a temporary agency. We almost all started like this, apart from the leads and managers who had already been converted into permanent ones. And I remember, from the first day we entered my department, RSP was specifically the robotics department. The impression I had the first day I entered, when they put us in front of these little robots, the KIVA, I was really amazed because it is very fascinating to see this little robot that approaches you and that knows exactly what you need.*
>
> AMAZON, Worker pick/stow

Workers were recruited individually, and they did not have previous work experience in the logistics field as at POSTE and, in a more minor way, at PMI. Moreover, there was no professional category, such as the forklift drivers, which was replaced by AGVs. AGVs, as we said, change the work of pickers and stowers, but did not replace other categories. These factors contribute to shaping the attitude of the workforce towards acceptance more than resistance.

The impact of AGVs in terms of working conditions, tasks and content, autonomy and control can be summarized as follows.

At POSTE, the introduction of AGVs brought about the replacement of most forklift drivers and, consequently, the disintegration of their tasks. Some (the physical task of transportation) were incorporated into the AGVs, others were assigned to the workers operating at the sorting stations. These tasks included a certain amount of physical handling of the AGV carts, as explained above, but also basic manipulations and very basic programming in order to send the AGVs to the intended destination (analytical/intellectual type of tasks). The management of the AGVs, and the intellectual tasks that this involves, therefore appears to be horizontally disseminated among the blue-collar workers.

At PMMTB, similarly to POSTE, AGVs replaced the large part of the functions previously run by forklift drivers – even if, as we saw, about 20% of the handling remained assigned to subcontracted forklift drivers. However, the relocation of these tasks was much more hierarchical: handling tasks plus basic problem-solving tasks continued to be assigned to subcontracted logistics workers and to manufacturing workers in the assembly lines; maintenance and more complex troubleshooting to subcontracted technical workers; the overall monitoring of the hardware and software integration to an internal and specialised PMI Logistics Automation team. The model adopted fosters a rigid division of tasks among teams of workers employed by different firms and throughout the organisational hierarchy.

At AMAZON, the level of centralisation is even higher, given the standardisation of operations required by the AMAZON business strategy at all logistics facilities. The difference with POSTE and PMMTB is that AGVs did not replace forklift drivers, but directly captured part of the physical and intellectual tasks of pickers and stowers, as we saw above. Thus, AGVs incorporated the walking task of these workers, increasing working rhythms, routinisation (the pick, stow and pack tasks becoming much more similar now, as testified by the large application of job rotation practices) and managerial control, because control of AGVs is centralised in the WMS. The introduction of AGVs also created new professional positions, namely that of the Amnesty Responder. The latter deals with basic troubleshooting. Interestingly, this is an indicator of a high level of centralisation and strengthening of the division of work, compared to other cases where basic troubleshooting tasks are 'distributed' among blue-collar workers.

3.4 Discussion and conclusions

This chapter aimed to provide evidence on drivers and barriers/constraints to the adoption of AGVs in selected companies as well as shedding light on impacts on work organisation and the quality of work. More specifically, we resorted back to a selection of findings in three main conceptual streams.

The first is that of drivers of adoption. Drawing on empirical results, we built a typology of factors that pushed for the introduction of AGVs: market and business strategy factors (innovation, diversification and extension); standardisation and digitalisation; improvement of safety and ergonomics.

The second stream refers to the barriers that impede the adoption of AGVs in our three case studies. We assessed and verified our hypotheses. We confirmed the importance of classical typologies of barriers: technical, market- and business-led, institutional and, only in part, labour-market-led factors. We also identified an explicit limit to automation adoption in order to ensure redundancy and respond to the flexibility requirement that AGV automation cannot guarantee in one firm.

In the third stream we investigated the impact of AGVs on working conditions, namely on task reconfiguration, autonomy and control, routinisation and possible forms of resistance. We illustrated common processes of safety and ergonomics and job/task relocation. We also found important differences regarding the dialectic of autonomy and control. In terms of conflict, no open phenomenon of resistance was detected but we tried to identify forms of latent tension generated by the introduction of AGVs.

4 Professional cleaning robots

In this chapter we focus on **professional cleaning robots** that can be used by firms operating in a wide range of sectors. Since there are few cases in Italy of the direct adoption of these artefacts by firms (whereas cleaning robots have more likely been used by companies operating in the cleaning sector) the research team has primarily focused on the cleaning sector in order to identify companies using these artefacts (primary users) and eventually providing cleaning services to other companies (end users). End users of the technology can be warehouses, industrial plants, airports, universities, hospitals, while primary users are firms whose main business sector is cleaning because they sell cleaning-related activities on the market.

The cleaning sector has seen growing trends in occupational statistics because of the process of outsourcing the 'less value-added' phases of the production process, and the growth in the casualisation of work, temporary and on-demand contracts. In this respect, intermediaries, such as temp agencies and cooperatives, now manage cleaning services ([23]). While labour-saving trends attributable to the adoption of professional cleaning robots are still not clearly emerging, the sector is quite interesting and worthy of study in terms of the changing nature of work activities supposedly higher in terms of standardisation and poorly characterised by learning regimes.

This sector has been put under enormous stress during the COVID-19 pandemic. On the one hand, this type of work is clearly not executable from home and is considered to be necessary for the sanitisation of related 'essential activities' (mainly hospitals but also manufacturing firms). On the other hand, those cleaning services carried out mainly in hotels, restaurants, theatres, cinemas, but also in universities, were suspended because of closures and restrictions. Therefore, our analysis uncovered potential contingent issues related to the reorganisation of work as a result of the pandemic.

The cleaning sector shares some features of both logistics (Chapter 3) and healthcare (Chapter 5). Indeed, as the logistics segment is considered to perform low-value-added tasks, it is characterised by cascades of contracting and subcontracting procedures, generally short-lasting contracts. It also relies on a cheap and abundant labour force and is clearly disconnected from the producers of technology. The actual distance between technological developers and the limited interaction with retailers represents a major obstacle to develop tailor-made solutions which are indeed required when a single service provider covers diverse final users, such as hospitals, stations, warehouses.

On top of the obstacles related to the disintermediated value chain, there are a series of technical feasibility problems that need to be overcome before the adoption can become standardised. While the presence of dealers actually alleviates the acquisition by means of leasing contracts, the dealers are hardly able to meet final client needs in terms of technical appropriateness and feasibility.

According to literature and preliminary evidence based on interviews with stakeholders and key informants, the use of professional cleaning robots faces a series of obstacles that can be attributed to four reasons:

- highly unstructured workplaces to be cleaned, which require fine, precise, agile and fast intervention relying on dexterity and fluid mobility;
- a need to operate in human-less environments. These robots cannot be used in densely populated spaces but can generally only be used during night shifts since their navigation is still not apt to cope with the presence of humans;
- service delivery time. Professional cleaning robots (currently available) require much more time with respect to human activity to clean the same square-metre space;
- physical obstacles to allow access for still relatively bulky robots;

([23]) Outsourcing and contracting have a direct impact on employment practices and working conditions. As discussed by Grimshaw et al. (2014), procurement is often driven by the lowest price, and this puts outsourcing firms under pressure to tender a bid and deliver cleaning services at the lowest cost possible. Outsourcing firms can try to reduce their costs and improve their profit margins by reducing pay rates, increasing work intensity, reorganising work or creating a more flexible workforce (Equality and Human Rights Commission, 2014).

— short-lasting contracts which do not favour physical investments in such technologies (in the case of subcontracting/outsourcing cleaning services to an outside company);

— price-based competition and low level of importance attributed by clients to the use of state-of-the-art technologies.

If COVID-19 has brought some pushes towards the substitution of humans with humanoid robots also in this sector, some of the procedures and cleaning protocols required by the COVID-19 regulations have preferred the use of more traditional cleaning systems when compared to those based on the UVD Robot®, which uses ultraviolet light to clean hospitals (Sostero, 2020).

The status of the technological adoption of professional cleaning robots can be summarised as follows:

- technological adoption is almost absent in cleaning activities. There are few exceptions concerning the development of in-house solutions; similarly, there are cases of 'failed adoption', that is, the introduction of robots has subsequently been abandoned by companies performing cleaning activities due to the existence of several barriers;

- obstacles to adoption are deep and diverse. They range from technical unfeasibility to a lack of in-house technologically developed solutions;

- cheap and abundant labour force performing labour-intensive activities which are relatively hard to automate inhibits technological, risky investments.

Ex ante expected impact of cleaning robots on work, working conditions and business models

The interactions with key informants and contact persons of firms that have been engaged in the testing phase or adoption of professional cleaning robots have revealed a very rare use of these artefacts. Cleaning services are often outsourced as low-added-value types of activities. There are few cases in Italy of the direct adoption of professional cleaning robots by the final client (such as in the case of Nestlé Acqua Vera). More often there are third parties – such as companies engaged in cleaning and facilities management activities – that provide the cleaning service to the final client (both machines and cleaners). Key informants indicated that software for the navigation of existing cleaning robots is well developed and efficient in terms of navigation; however, the programming part concerning the path that the robot should follow is not able to match the needs of businesses. In fact, there are just two/three types of options to fill in the areas, and these are not adaptable to different workspaces. In this sense, it is difficult for end users to customise the robot to their needs. The area is covered by random movements by the machines, requiring a lengthy time span, which is inefficient for the firm/cooperative that is engaged in that specific kind of task. While cleaning machines are not aimed at optimising the operation execution time in a domestic environment, the industrial application of these artefacts requires time optimisation to be cost-effective and valuable. So far, companies have not found these machines useful / of service / beneficial or, in the case of outsourced cleaning operations, several factors need to be considered before including their use in the technical offer for public tender.

Barriers to adoption range from organisational and structural features (need to reconsider the organisation of spaces) to institutional elements (the inclusion of specific clauses in calls for tender). Key informants reveal that the participation in public tenders – which constitutes about 80-90% of the total revenues of large companies working in the cleaning sectors – poses several constraints on the number of employees to be contracted. The institutional background affects adoption decisions (Art. 4 National Collective Labour Agreement for cleaning and integrated/multi-service companies). Furthermore, among the challenges of adopting professional cleaning robots, there is the need for adequate spaces and structures. So far in Italy there have been few warehouses suitable for deploying these machines. New airports, universities (the case of the University of Naples Federico II, specific departments), hospitals and shopping centres may be suitable for the application of cleaning robots; each structure needs to be carefully evaluated before planning their use ([24]).

([24]) One component in the successful use of cleaning robots involves the design of community-creating facilities in a way that accommodates robotic cleaning. 'At the Sumitomo Building in Osaka city, Japan, the building itself was modified to maximize the efficiency of the robot cleaner and to allow interfacing between the building and the robot: optical transmission devices were installed in all the elevators, and a compatible device was included in the cleaning robot, allowing it to summon an elevator and choose a floor, and allowing the elevator to communicate with the robot, telling it when it has reached its destination' (Services Magazine).

Overall, according to the interviews with stakeholders – performed in the initial phase of the project – the layout of the places and specificity of the existing machines (i.e. Adlatus) do not permit their adoption; specifically, the navigation software of existing machines should be customised jointly by dealer/developer and client.

Against this background, the interviewees note potential benefits stemming from the use of these artefacts and that can reshape the business model of adopting companies such as: (i) substitution of all low-added-value types of activities (even for outsourced companies); (ii) automation of very simple tasks ('while cleaning an empty corridor can be an easy task to automate, cleaning patients in hospital beds requires much more attention'); (iii) upskilling for employees involved in complex operations. The adoption of professional cleaning robots can open up new market opportunities, expanding the set of services offered to final clients. The availability of cleaning robots on the menu also has a 'reputation' effect for the company ('despite tenders encouraging these types of innovation, most of the time, once on-site we acknowledge that the cleaning activity can be more fruitfully carried out by the operators with no need for the employment of machines. It is more a reputational choice rather than operational').

In terms of the impact of adopted technology on occupational structure and task reconfiguration, companies note that the number of workers required to carry out cleaning tasks would not change immediately; they do not foresee any short-term changes in employment due to the adoption of cleaning robots. In fact, institutional factors play a crucial role for companies offering cleaning services, while direct adoption by manufacturing firms or shopping centres appears, to date, a remote perspective ([25]). However, as emphasised by the interviewees of Coopservice – one of the three companies in which the fieldwork has been carried out – even for private tenders, where the social clause does not apply, the labour-saving effect of existing artefacts is negligible. The outbreak of COVID-19 may accelerate the adoption of cleaning robots in offices where employees are still working remotely ([26]).

We hypothesised the following among tasks more likely affected by the introduction of cleaning robots before running the fieldwork.

Tasks performed by cleaners

Creation of a new task concerning the supervision of the machine (with specific time span).

Specialisation of cleaners in selected types of cleaning activities (where machines cannot be employed).

Tasks performed by administrative units of the company (operating within the cleaning sector)

Ability to elaborate a cost-benefit analysis concerning the use of the cleaning robot in a specific space (of the final user).

Cost-evaluation analysis concerning the use of the machine in a specific case (inclusion of the robot service in a tender).

Tasks performed by workers along the assembly lines in a factory (in case of direct adoption)

Creation of a new task concerning the organisation of the workstation so that it can be cleaned by the robot moving along the lines.

4.1 Description of the firms and the cleaning robot adoption process

The companies selected by the research group in cooperation with the JRC team in which professional cleaning robots have been implemented are: (i) Dussmann Service, a case of in-house innovation, which developed its own prototypes to overcome dissatisfaction with existing market solutions; (ii) Nestlé Vera, a case of vertical adoption, that is now employing two cleaning robots at its San Giorgio site in Bosco (Padua) thanks to the long lasting relations with their dealer of IT technologies; (iii) Coopservice, a case of failed adoption, which abandoned the technology since it did not bring any significant improvement and amelioration to its services.

([25]) In the United Kingdom, the Hefter Robot Cleaner is currently employed in the cleaning/maintenance department of both Manchester Airport and The Queen Elizabeth II Hospital.

([26]) On this topic, a web magazine advertised their use during the pandemic crisis : https://www.theverge.com/2020/11/18/21573053/cleaning-robots-autonomous-covid-19-coronavirus-uv-foggers-offices-breezy-one.

4.1.1 Dussmann Service S.r.l.

Dussmann Service S.r.l. is a provider of integrated facility services for healthcare, business, education, facilities for elderly people, the military and transportation companies. It is a division of the German Dussmann Group and, as such, is part of an international service network for public institutions and private companies. It counts almost 17 700 employees.

The company started a pilot project in 2018 to overcome some of the technological limitations perceived in cleaning robots available on the market, which it deemed uncompetitive in terms of cost and productivity with respect to human labour. As a result, it promoted a project with the Research Centre 'E. Piaggio' at the University of Pisa, Autognity and Proxima Robotics for the development of two prototypes of autonomous scrubber dryers customised on the basis of its specific requirements. Contact was established with the help of Warrant Innovation Lab S.r.l.

After the development phase, Dussmann looked for a producer identified at RCM S.p.A, manufacturing and distributing industrial and urban cleaning machinery. Currently, the newly developed cleaning robot NEXBOT has ended the pilot phase and it is now fully integrated at Milan Malpensa Airport (where the fieldwork has been carried out). It can be used in both manual and automatic mode. The arrival of the pandemic favoured the testing phase in a complex space: the possibility of having several almost human-less available areas within the airport was unprecedented and it sped up the testing. Up until now, there is only one machine operating during night shifts since it requires no moving objects nearby, whereas during the other shifts the flow of people prevents profitable functioning. With respect to a semi-automated washer dryer, it is equipped with an autonomous navigation system based on digital maps of the site and with both an ethernet connection and internal router. Internet access is not used to geolocalise but to ease remote updates of the software and automatise the delivery of a digital report at the end of the activity.

4.1.2 Nestlé Vera

Nestlé is part of Sanpellegrino S.p.A., which operates in the food and beverage sector. Nestlé bottles water and soft drinks to supply restaurants, shopping centres, bars and supermarkets. It counts about 200 employees and is headquartered in San Giorgio in Bosco (PD). Nestlé uses two cleaning robots at its San Giorgio plant: the newest one operates in the hallway between the automated warehouse and the end-of-line production site (3 m x 20 cm); the other covers another hallway in the production area. The former commenced operations during summer 2021, while the other was introduced by the outsourced company in charge of the warehouse in 2017.

4.1.3 Coopservice

Coopservice is a cooperative society based in Reggio Emilia that provides healthcare and professional cleaning, security services, logistics and moving services, energy and facilities management and COVID-19 safety services. Such services are mainly supplied as outsourced activities to public entities (60% of total revenue) all over Italy.

The Coopservice Group is made up of subsidiaries and associated companies active in various business areas that are contiguous or complementary to the lines of services provided directly by the parent company Coopservice. It counts 16 149 employees overall.

4.2 Deploying automation technologies

4.2.1 Drivers of adoption

Drivers of adoption reported by the management of all companies include cost reduction and path optimisation. For Coopservice and Dussmann, adoption was also a matter of reputation: being leaders in the cleaning sector requires keeping pace with state-of-the-art technology through continuous scouting activity on the market. In addition, the digital integration played a crucial role by allowing performance tracking and fast reporting to the client and to the provider. Lastly, a possible reduction in turnover due to physical fatigue and deterioration of the workforce has been argued as an important driver, although not sufficiently addressed by existing solutions. This constraint has been particularly stressed by Coopservice.

Starting with Coopservice, the major managerial driver for automation was clearly cost-effectiveness, insofar as the potential removal of the operator driving the semi-automated cleaning machine during night shifts, paid more than a daily one, would have represented the saving of money. However, as will be understood in the following pages, the potential labor-saving effect does not occur since operators have been dedicated to the control and monitoring of the machine which is not autonomous so far.

In addition, automated vehicles optimise cleaning routes while ride-on machines do not guarantee such time optimisation.

> *We purchased the technology on the market, I do not know if through a dealer or directly from the manufacturer.*
>
> *[…]*
>
> *Night workers are costly and the main reason for integrating cleaning robots was the automation of the cleaning service on night shifts. In fact, with such a solution I can be sure that the route for cleaning is optimised, … that is something impossible to assess with ride-on cleaning machines. This also allows you to minimise the amount of detergent and correctly predict charging time … Besides this there is an additional advantage for the client since you avoid the invasiveness of the man-on-board machines passing near to people.*
>
> COOPSERVICE, Chief Operating Officer

In addition, the growing diffusion of cleaning machines within the sector and subsequent competitive pressure played a role.

> *I don't think we have many years to take advantage of any resulting image advantage. Today it would certainly be a qualifying element of the offer but in certain contexts, at least, it is that you almost do have to consider it. I believe that in 5 years this will no longer be an element that can differentiate us.*
>
> COOPSERVICE, Chief Operating Officer
>
> *We include such technologies in tender projects for marketing reasons and to be in line with competitors. The tender commission would take a rather dim view of you not including cleaning machines in the project … we are leaders in the sector and we have to keep up with new technologies especially because most of the time we deal with big clients in the industry that expect this kind of innovation.*
>
> COOPSERVICE, IT Specialist

A second potential driver is turnover reduction. In fact, the physical strain on cleaning operators leads to a frequent need to replace workers. Automated cleaning machines could have helped in reducing the intensification of turnover; however, generally the technological solution does not directly address such a need. The HR manager reported that:

> *The incidence of physical pains among our workers is high … we have several employees who required deskilling or a reduction in working time due to physical strain on the job. … and machines could help workers reduce routinised and exhausting tasks.*
>
> *[…]*
>
> *Overall such a purpose is not properly addressed by existing digital technologies.*
>
> COOPSERVICE, HR Manager

Another driver is the digital integration and the data provision of such machines. Coopservice has taken advantage of the funding provided by the Industry 4.0 plan foreseeing fiscal incentives for companies introducing a specific set of devices. Coopservice had access to the fiscal plan due to the introduction of technologies able to receive and process remote instructions and to send back information of different types. Semi-automated vehicles are now indeed able to store and deliver data on the performance and to receive commands to direct the navigation, such as the maximum speed or the tolerance versus obstacles, or the magnitude of collisions prior to a preventive shutdown. Given this performance tracking allowed by the digital component, reporting to the client become more straightforward and feasible.

> *In the public sphere, especially, the reporting process is often cumbersome, that is to say that every day I should get the OK from my interlocutor that I have done that service, that is, the head nurse at*

the hospital or the facilities manager at the airport. Then I should collect this documentation every day and attach it to the invoice for payment. If I set up a block-chain system that detects that I entered that room at 10 am, left at 10.30 am and the work programme included half an hour of cleaning, then the service could be automatically considered carried out and this notification could be sent directly to the client.

[…]

So for us it is a saving of paper, time, crazy reporting processes. … this technology, irrespective of being integrated on autonomous or semi-autonomous cleaning machines, makes things transparent. We provide portals through which the customer can see the progress of the service but above all we share a process of reporting and certification of the service rendered. Consider how many disputes might be avoided. … this software system for real-time data collection of the performance has been developed with the financial grant from Industry 4.0 that allowed the discounted purchase of the scrubber dryer.

COOPSERVICE, Chief Operating Officer

These projects of automation and data reception from the field were basically born for two reasons: the first trend is that in tender specifications more and more reference is made to traceability, so it is the client that wants to know where and what our workers or machines are doing. The other trend that really gave the biggest push was Industry 4.0 because we are talking about very expensive machinery. We therefore buy machines that are equipped with control units or black boxes capable of receiving some instructions remotely and from the field, such as how many square metres it has cleaned, how many bumps it has suffered as well as the position at a given moment. … a machine is part of Industry 4.0 if it is able to receive instructions. So we have machines that can get instructions from software solutions that tell them to clean a given area, at this speed, with the brushes spinning at this speed, and so on.

COOPSERVICE, IT Specialist

Dussmann Service instead developed the technology in-house. The project required an initial investment of EUR 140 000 and another one of EUR 260 000 to bring the robot to its full potential. The tax credit covered 50% of the first tranche and 25% of the second.

The most important managerial driver was the reduction in hours worked to contain labour costs. In the medium term, the machine should allow for the complete automation of flat-surface cleaning and the reallocation of operators to the deep cleaning of bathrooms, handles and keypads.

Dussmann brought its expertise and productivity requirements for building up a solution to be used in the facilities sector since available machines do not meet the needs of companies. In fact, the project started 4 years ago with Research Centre 'E. Piaggio' at the University of Pisa, Autognity and Proxima Robotics and resulted in the development of two prototypes. At the end of this phase we looked for companies willing to take charge of the project financially, and we found RCM. … both navigation and cleaning systems for the machine have been patented and we gave the relative ownership rights to RCM.

[…]

We have not actually invented anything new; it is just a compromise between existing technologies. We wanted something highly productive, easy to programme, with a given size and features.

DUSSMANN, Head of the Planning and Control Department

The main objective remains to increase productivity. Given the constant increase in labour costs, we need to reduce working hours and to achieve it I need to mechanise cleaning services with low added value … operators should perform only those activities requiring human dexterity and precision such as cleaning toilets, keypads and handles.

[…]

It works in gradual stages; when you win a new tender you cannot naively halve the working hours of the operators. For now we just want the operators to get familiar with it and start reorganising the work.

[…]

We also expect to implement the technology in other structures; we are indeed discussing which hospitals and airports where we won the tender could adopt it.

DUSSMANN, Head of the Planning and Control Department

Furthermore, the gains from adoption in terms of cost reduction and the visibility gained at the most important sector trade fairs are expected to bring significant improvements in reputation and market share, therefore potentially overcoming competitors. This gain in reputation is also linked to the 'green' motive, that is, the reduction in water and detergent used with respect to standard technology.

Now we are the only one on the facilities management market with an automated cleaning machine that complies with high productivity standards. […]

At ISSA PULIRE fair that took place in September 2021, I gave a speech in which I presented the machine. I would say it received relevant positive feedback: there have been articles in sector magazines and other facilities management companies contacted RCM for information about the technology.

[…]

Between April and May there will be another important fair in Amsterdam and there should be a further push for the commercialisation of the machine.

[…]

This project gave us great visibility on the market and the hope is to foster Dussmann's reputation as a solid company able to offer innovative services to clients.

[…]

Also, the management of Milan Malpensa Airport is interested in the adoption and upgrading of the technology. We included it in the last proposal and now they are asking for feedback. They probably see it as a way to get advertising.

DUSSMANN, Head of the Planning and Control Department

Classic washer dryers consume much more water than the automated ones. They therefore require the operator to flush dirty water and refill it more often. The robots can work continuously nearly 6.5 hours and consume little water, more or less 60 litres or 70 litres for 6 hours of work, corresponding to eight or nine thousand square metres. The running time of the classic model is on average 3 hours.

DUSSMANN, IT Specialist

Nestlé Vera is almost the opposite case. The nudge for adoption came from the provider of IT solutions, Ica System, already supplying the company with semi-automated washer dryers and eventually proposing the testing of a fully automated solution. Interestingly, the complementary technological adoption of technologies occurred together with a site restructuring. The technology was in fact adopted shortly after the introduction of automated guided vehicles for the warehouse: the company was rearranging internal logistics and decided on the automation of the cleaning service whenever possible. The purpose was to redeploy cleaning operators to other activities with a higher value added, a typical case of combined product, process and organisational innovation. Given the maturity of the adoption process, some other plants of Sanpellegrino S.p.A. are considering its integration for cleaning services.

According to the supervisor of logistics automation for the San Giorgio in Bosco plant:

I would not say that the cleaning robot is part of a comprehensive strategy of digital transformation for the plant but we certainly had to reconsider the internal logistic fluxes and at that point it made sense to automate some cleaning activities as well.

[…]

Our provider of semi-automated solutions often came here to the San Giorgio plant … and started asking whether we would have been interested in experimenting with a robotised solution. They were looking for a place to test it and pushed for starting the pilot phase here since we knew each other quite well.

[...] *We wanted to automatise those activities with low value added and relocate the operator to more complex tasks. This is the main reason. Plus its size is perfect for the area we need to cover, which is indeed narrow for standard washer dryers ... as far as I know there are other Nestlé plants that are considering adopting cleaning robots for internal areas.*

NESTLE, Supervisor Logistics Automation

4.2.2 Barriers to adoption

Barriers to adoption reported by all companies include the upfront investment cost, the technology not being completely autonomous and still requiring daily maintenance by the operator and the high space and environmental standards to be met. Besides an initial scepticism, resistance from workers did not constitute a real problem after adoption.

Spatial and environmental constraints were considered very important by Coopservice, which provides services within the healthcare sector or in offices, which are highly unstructured workplaces that require fine, precise, agile and fast intervention relying on dexterity and fluid mobility, preventing the standardisation of the service. Similarly, Dussmann had to confine the use of the cleaning robot in Milan Malpensa Airport during night shifts given the need to operate in human-less environments.

For instance, if there is a leakage of biological fluid I cannot say to the nurse to wait for the machine to come from the warehouse ... I have to remove it as soon as possible and only the operator is able to provide an immediate response.

[...]

At conferences, at trade fairs, I note a lack of contact between the producer and whoever manages the service. There was great enthusiasm and then I asked them if they ever went to a hospital. That is, have you seen what hospitals are like?

[...]

When we tried automated cleaning solutions in hospitals or at logistics sites of large-scale distribution, even the client, who hadn't let himself be enthralled by the great innovation for his own pride and personal visibility, began to notice that maybe the machine works for an hour and then needs to go on charge, that maybe that spot cannot be cleaned by the machine and so on.

[...]

Including automated solutions in projects for public tender is nearly always a good idea. However, most of the time we agree ex post with the client to avoid them since they do not necessarily mean added value to the outcome of the cleaning service.

COOPSERVICE, Chief Operating Officer

First of all, consider that we do not innovate products, we just buy products and try to insert them into a work flow because ours is a labour-intensive company, therefore 70% of the cost is made up of personnel costs. Also consider that ... hospital works mainly with frightening access flows in the morning and then significantly reduces the activity in the afternoon. In common areas such as hospital lobbies where automatic solutions could be used today, the machine would stand still to protect the personnel. There are also architectural constraints, in fact, the hospitals in Italy today date back to the 1960s.

[...]

For example, in the hospitals we have to clean under the wardrobes because there could be dust accumulation and subsequent creation of bacterial strains and automating this service involves rethinking the structural part of the hospital but also of the furniture, beds, headboards and so on. ... for these reasons we are more interested in wearable devices for operators that indeed do not affect manuality and allow us to track their performance, or mini loads for medicine.

COOPSERVICE, Chief Innovation Officer

During the day the airport is chaos ...] and the machine would not even be able to start the cleaning activity. Plus, there would be the risk of collision and subsequent repair costs.

DUSSMANN, IT Specialist

The technology employed by Nestlé Vera requires the area in question to be flat and unobstructed, since the possible misalignment of its sensors would require intervention by the provider to restore the correct position, but can still operate in the presence of moving objects and humans. In fact, the sensors allow for the proximity of moving objects around the robot. Safety is a leading concern in the deployment of the machine: it proceeds at walking speed, causing no harm to humans and vehicles nearby. In fact, the technology is used for 3 hours every day even during daytime.

Automated solutions employed by both Dussmann and Nestlé also require daily intervention by the operator to refill the water and the detergent, drain the dirty water, clean the filter and charge it at the end of the activity.

> *The operator should take care of daily maintenance; there is no automation in this sense … overall the technology is pretty costly, around EUR 70 000 or EUR 100 000 , and sensors are much too sensitive to any minimal obstacle on the floor. Even the tile is a problem for it; the floor has to be super smooth otherwise it stops working. Plus its daily functioning on the site lasts 3 hours and it requires 5 hours on average for a full recharge.*
>
> *[…]*
>
> *Fortunately, it is not susceptible to the presence of people and it keeps moving. Overall I would say that if it was cheaper, with lower requirements for the surface to be cleaned and equipped with a battery that lasts longer, its use would be much more widespread*.
>
> NESTLE, Supervisor Logistics Automation
>
> *At first we had to calibrate the sensors to make it as safe as possible, and this stage required time. Then we improved the resolution of the camera. Besides these minor problems that are typical of the start-up phase, the adoption was pretty smooth. … on the workers' side, they were somehow sceptical about the technology and during the training we had to stress the fact that the machine is there to help them and not to substitute their work. … however, operators that use the robot give me daily feedback and I would say they are now at ease with it. Indeed, they also made proposals to improve the technology, for example, they asked to integrate an option for slow acceleration in the initial moving phase. They eventually felt involved.*
>
> DUSSMANN, IT Specialist

Coopservice reported that its clients attribute importance to the presence of automated and semi-automated cleaning machines in the offer submitted, although most of the time the applicability is classified as not necessary by the cleaning operators once the tender has been won (more often public procurement types of activities). Therefore, it is more a signalling strategy rather than actual deployment of the technology:

> *Paradoxically, the public sector encourages these types of innovation… but once on-site we acknowledge that the cleaning activity can be more fruitfully carried out by the operators with no need for the employment of machines. … in other cases, in which the service has to be done in narrow spaces or it requires precision work, we do not even propose the use of semi-automated solutions. … I would say that most of the time it is more a reputational choice rather than operational.*
>
> COOPSERVICE, IT Specialist

Furthermore, according to Coopservice, the inclusion of such machines in the project does not have relevant implications for the number of operators to dedicate to the specific site or to the budget, since the labour-saving effect is compensated by the cost of an operator dedicated to the control and monitoring of the machine. In this sense, the social regulation adopted by public entities that ensures the maintenance of the entire workforce from one tender to another is seen only as a partial constraint on the automation of cleaning services. Technical and physical constraints related to the configuration of the cleaning surface and the general environment in which machines should operate are considered to be far more binding. Binding to the extent that an IT specialist reported that, in their opinion, the future of cleaning services does not reside in automated solutions.

> *When we write the projects for tenders, the number of workers does not change as much if we decide to include automated washer dryers. Of course, given the nature of the sites in which we operate, it is never the case that only autonomous machines are implemented … it was most often a mix of the*

two [autonomous and semi-autonomous] thus the labour-saving effect was not such as to make the social clause binding.

COOPSERVICE, Chief Operation Officer

In the future I think that only the number of hours worked could be reduced. But I am not sure since this would open the way to trade union matters; it is delicate… so far the change in hours worked in the budget of a tender with cleaning machines with respect to one without automation is irrelevant.

COOPSERVICE, IT Specialist

'Question'. when you prepare the tender and you include the cleaning robot, does it require a reformulation of the amount of internal staff involved?

No, because it is true that they are robots but they are not autonomous. They do not actually have a productivity to be effectively considered autonomous and we often propose them because they appeal from a marketing point of view and they maybe help to save a little bit in terms of hours. However, they cannot replace a work shift.

COOPSERVICE, IT Specialist

I would say that that the trend of automated solutions is now on the decline according to what was presented during the last cleaning sector fair. There were very few automated solutions compared to the previous two fairs, in which automated solutions seemed to be the future of cleaning services.

COOPSERVICE, IT Specialist

4.3 Professional cleaning robot systems and relations with providers

The Dussmann case is a textbook case of the development of technology involving a supply chain from the actual research and development stage to trialling and testing, prototype and industrialisation. Dussmann internally promoted the development of its own prototypes with the involvement of Research Centre 'E. Piaggio' at the University of Pisa, Autognity and Proxima Robotics. RCM S.p.A., a leading expert in the manufacturing of cleaning machines, located in Emilia-Romagna, built the machine and now owns the patents to the washing system and the navigation system. Magris S.r.l. is the official dealer and provided the training for operators.

The inadequacy of available automated solutions brought Dussmann to seek external partners for the development and production of its own machine. This process has been supported since the beginning by the consultancy of Warrant Innovation Lab, a subsidiary company of the Tinexta Group, that offers business consulting services for innovation and digital transformation.

We are currently renting the technology from RCM through a dealer named Magris S.r.l., which also managed to organise the 1-week training programme last December for selected workers. These seven/eight operators allowed to use the cleaning robot are those that were already using the washer dryers so they were already familiar with cleaning machines. This selection process has been effected by our colleagues at Dussmann responsible for the tender here at Malpensa.

[…]

The training was done on the job and in 1 week, all night operators had been covered …. RCM does not directly sell or rent to companies: Magris acts as an intermediary and provides the technical assistance and the training of operators. Proxima Robotics mapped the areas and built the blueprints for the ground floor … and Autognity provided the hardware and software, that is, the computer that tells wheels where to turn and so on. It is practically responsible for the navigation system.

'Question'. What if you decide to integrate the robot at another site?

At that point Magris would manage the relationships with Proxima for the new mapping process: we should inform them of the win, deliver the blueprints of the areas of the site to be covered, then the dealer would take care of the rest.

DUSSMANN, IT Specialist

Dussmann relied on a model of so-called open innovation for the development of the technology. That is, a prior step to innovation was the acknowledgement of the state of the art of digital and automated technology in both cleaning and logistics sectors. We have been contacted by Dussmann for a consultation to automatise the manual or semi-automated washer dryers. The first step consisted of brain storming to define the project in terms of needs, budget and feasibility. After that it was clear that the technology they were looking for pertained to the AGV technology and we started scouting for technological partners: software design and prototyping were the work of the Research Centre 'E. Piaggio' in automation, bioengineering and robotics at the University of Pisa. The starting point was the navigation system, that is, how to make a cleaning machine 'smart'.

[…]

We also did what is known as a benchmark activity to analyse existing solutions on the market, but Dussmann's standard in terms of productivity – that is square metres clean per hour, and the ease of programming – were not met. For the latter, the problem was that machines on the market required an engineer for the daily programming phase, that is someone with higher digital competences than the average cleaning worker.

[…]

Once the concept was ready, we patented it.

[…]

The development and initial tests followed; the tests of the very first prototype took place at Milan Bergamo Airport, where Dussmann won the tender for the cleaning service. The subsequent industrialisation process, where we as Warrant Innovation Lab acted as project manager, was instead developed through a collaboration between companies, such as RCM of Modena, specialised in the production of industrial and urban cleaning machines and in the distribution of solutions for professional cleaning. […]

Currently still in touch with Dussmann mainly to support the marketing of NEXBOT [the autonomous cleaning machine] through social media campaigns.

WARRANT INNOVATION LAB, Innovation Manager

According to the management at Dussmann, NEXBOT can work 6 hours in a row with an average productivity of 1 350 square metres per hour. Further improvements – including the increase in speed and optimisation of the mapping to expand covered areas up to 1 800 square metres per hour – are already planned in agreement with partners.

Overall, the pandemic slowed down the schedule and the integration of the machine at other locations, which remains a goal for the following months.

We are 6 months behind in our planning calendar due to the pandemic, but technically it is all set for the upgrade in speed to 1.5 metres per second and for the covered area per hour. The machine should also come into use at other sites … it is an important project for us.

DUSSMANN, Head of the Planning and Control Department

The autonomous scrubber dryer also allows for data storage but, so far, they seem to be more fruitfully analysed by Dussmann and RCM for technical improvements rather than tracking workers' performance.

Technical anomalies are automatically forwarded to RCM, which checks them out in the morning. When they call us the following morning asking for details we are usually already aware of the problem since the operator has already signalled it to the shift manager.

[…]

Magris would eventually intervene to solve the problem.

DUSSMANN, IT Specialist

RCM and Proxima Robotics are in charge of the software updates. The updating of maps is also up to them … Besides this, we contact them in case of malfunctioning. At the present moment we are continuously in touch since the adoption is relatively recent and we are all interested in tracking the performance of the technology. Plus the automated delivery of reports is not yet operational, so we depend on RCM to collect daily reports filled in by the operators.

DUSSMANN, Head of the Planning and Control Department

Instead, Ica System S.r.l., the Italian provider of the automated solutions used by Nestlé Vera in the warehouse and on the production line, customised size and velocity to the client's requirements. At the end of the pilot phase, the company agreed to lease the technology with annual maintenance borne by the supplier. Customisation has been quite important. Since the hallway is crossed by several shuttle buses which move along rails that the robot must avoid, it has been divided into four different parts corresponding to as many cleaning programs for the robot, with the purpose of easing the whole process. The mapping of cleaning areas was developed and embedded in the software by the provider. Several hours with the technical staff at Ica System were sufficient to train the operator.

They came here and tested the cleaning robot on a small area to assess its sensitivity. They also asked questions about daily activities on-site and possible obstacles. However, they already knew the plant quite well. … the leasing contract includes annual maintenance and this simplifies things a lot with respect to direct purchase.

'Question'. So the technology has not been developed according to the specific needs of your plant?

No, it has not been tailored to our demand but its function certainly meets the requirement of the cleaning level and speed of work that we needed for that specific area. … we rented the solution from the provider, who was responsible for the whole process to make the machine ready to use on our site. In fact, their technicians came to map the area and we told them which cleaning program we wanted for each area … there is a relationship of trust with them; they know the company and are familiar with the plant as well since they also supply non-automated cleaning solutions. … Ica System also did on-the-job training for our operators, one for each area.

'Question'. Does the provider ask you for feedback about your experience with the technology to improve the product or even design new models?

Honestly, I do not know if they are developing new versions of the machine, but they are certainly often here at the plant. They want to see it at work and continuously ask about what is wrong and what needs improvement.

NESTLE, Supervisor Logistics Automation

Finally, the IT specialists of Coopservice reported that relations with providers of semi-automated solutions are limited to the budgeting phase, that is, when they need to acknowledge technical specificities and the cost of the machine for lease in the event of winning of a new contract. Software systems are usually supplied by the provider and already embedded in the artefacts, and data collection in the field is used both by providers to inform potential dealers and by Coopservice for the reporting activity to the client. However, it is not uncommon for the internal technical office to integrate further software into the machine to customise the service, adapting it to the specific requirements of Coopservice regarding data collection and visualisation. As claimed by an IT specialist, this information also applied to the autonomous solution.

We as a design office interact with providers only at fairs or at events where the Coopservice purchasing office is also present. Of course, if we need to know the cost and need the technical sheet for cleaning machines for the tender project, we rely on the purchasing office, which in turn asks providers to supply this information.

COOPSERVICE, IT Specialist

Usually the software is already embedded in these machines, whether they are automated or semi-automated. However, we also tried to integrate the software to collect data in the field and store them in the Microsoft Azure cloud platform for the reporting activity to clients. … we receive these data from the machines in the same way as the provider. The provider is, however, interested in showing what happens every day to better sell the machine to a dealer, which, in turn, needs to know how the machine moves to do proper maintenance. We instead work on these data to make them useful for the client; we aggregate them since there is no interest in knowing, let's say, how many times the battery has not been properly charged since we as Coopservice pay for the batteries. … we built our own platform so as to tailor each report depending on the specificity of the client.

COOPSERVICE, IT Specialist

The evidence suggests that providers did not alter the organisation of work on the site where machines operate: Nestlé customised the technology together with the provider, describing the existing flow of people and other artefacts in the area that did not need further rearrangement. No particular dependence on the provider has been spotted in this case, especially considering that the supervisor of logistics automation for the San Giorgio in Bosco plant claimed that the provider comes to see the robot at work on-site and asks operators for feedback.

The management at Dussmann instead temporarily depends on RCM S.p.A. for the daily reports, since automatic forwarding to the internal technical office is not yet operational, but, as claimed by the head of planning and control, it is only a matter of time. Despite this, partners, producers and dealers of NEXBOT do not exert any control over the work process: the steps for technical improvement have been agreed according to Dussmann's requirements, as well as time and manner of service provision.

Lastly, Coopservice implemented semi- and completely autonomous cleaning machines with standard software equipment, which means that whenever they needed to customise the outcome in terms of data collection and visualisation or speed of movement, the internal technical office made relevant modifications and extensions without relying on providers.

4.4 Industrial relations

A system of industrial relations is rather weak in the cleaning sector, and the technological introduction was not a trigger of any evident action by trade unions. For Coopservice, the key interviewee in this respect was the territorial representative of FILT CGIL, the federation for logistics and transport workers of the most representative trade union in Italy, while for Dussmann relevant information has been indirectly obtained via questions to the management and operators. The only interview in the case of Nestlé did not bring any informative content concerning the involvement of unions in the adoption process.

Interestingly, there is seemingly no discussion within FILT CGIL about the technology and its impact on work organisation, safety and job quality. Despite the detection of potential for reducing fatigue and minimising turnover due to physical strain – that is, however, expressed by the interviewee on their own behalf, at the moment the union has not taken any net position on the matter. This might be read as reflecting the negligible rate of adoption of these technologies in the sector.

Overall, operators rely on their representatives whenever there is a change in the company supplying the cleaning service on site, especially to preserve their contract category and remuneration. The adoption was, in all aspects, a managerial decision: unions have never been involved in the process, not even for safety- or training-related matters, and they were informed only when it was all set for the technology to be operational.

> *The automation in cleaning services could represent a great opportunity to reduce the physical wear on operators and limit more trivial and routinised tasks. Unfortunately, unions are scarcely involved in crucial decisions such as performance tracking, retraining staff and human-machine relations … we have never talked about these things here. If we are talking about intelligent robots with perimeter sensors working at night, it is not even a discussion presented […] today, at least in Italy, we do not know this technology.*
>
> *[…]*
>
> *Within FILT, this discussion about the effect of this technology on work organisation and labour substitution do not take place, I say this in all frankness. I can tell you my point of view … I am absolutely in favour of the introduction of technologies and the replacement of physical work and related fatigue within the workplace. I am worried because I do not believe that a worker in the cleaning sector with a low qualification, low level of education, low personality will be moved to another activity. That is, this transition should involve everyone to not leave anyone behind… the workers of Coopservice – like any other company that works in the world of procurement – are mainly concerned with maintaining their contract and contribution at every change in service agreement, besides the change in uniforms. … nonetheless, even the most inexperienced worker understands that there is an intervention that relates to their own condition or their employment.*
>
> *[…]*
>
> *But the central theme is not that; you will never be able to have a real discussion on these topics with those workers. Instead, industrial policy reasoning should be achieved.*

FILT CGIL Union Representative

Clearly when we build systems in IT projects we have a series of steps to pass and one of these is that of privacy and, therefore, in the design phase the Privacy Office already stressed the fact that this information [about the performance of the machine and who is on shift] had to be decoupled … in this case we have also anticipated the trade union part. When we went to present the application the union told us that in this way we could control workers but we replied that only matriculation codes of who is on shift are recorded on the database, thus both us and the client do not know who they are. A secondary inspection had to be carried out, which clearly must come from an alleged dispute about some event.

COOPSERVICE, IT Specialist

When we win a tender the whole training phase can be reorganised irrespective of what has been done by the previous company. While writing the project, you specify the plan for the training and development of operators and intermediate figures. … if the previous company does not give us any training certificate, we must reactivate all the training, even mandatory, even if they have already done it 20 times. All the training that falls within the specifications. […]

> *'Question'. This information could be delivered by trade unions. Do you usually bargain the training process with them?*

No, not really. We interact with trade unions only in cases when you cannot absorb all of the workforce on the site and need to reduce working hours …

COOPSERVICE, Coordinator of Employee Training and Development

In the case of Dussmann, even if the unionisation rate for the cleaning staff of Milan Malpensa Airport is relatively high, no prior involvement occurred. Unions have just been notified of the implementation since the project was developed by Dussmann with no specific site of application in mind. The involvement of workers and their unions in strategic decisions related to innovation technologies can be considered extremely negligible, and no trend reversal seems to occur in the near future given the lack of debate within trade unionists of FILT CGIL.

Workers' unions are present here at Malpensa … they help us, especially when there are procurement changes, which means that you need new suits, you have to preserve your classification level and so on. I also rely on them to fill in the 'Modello 730 ([27])' for my tax return.

DUSSMANN, Worker

They implemented it and then they told us to use it, this is all I know. I am a union member and I know it has not been involved in the process; it is a decision made by the company.

DUSSMANN, Worker

Here at Malpensa there are several trade unions. The unionisation rate is high. … as far as I know, trade unions have certainly been notified of the introduction of this technology but they have not been involved in the design phase.

DUSSMANN, IT Specialist

4.5 Work organisation, job quality and task content

The only available evidence about possible transformations in work organisation due to technological adoption is the Dussmann case. Although the management declared its intention to reduce the total workforce in the medium term, the adoption of the machine did not impact the working pace and left workers' autonomy in setting procedures unaffected. In fact, as for semi-automated solutions, autonomous artefacts need to be activated manually by workers according to Directive 2006/42/EC machinery. Plus, as mentioned before, the robot allows for data storage but, so far, they seem to be analysed by Dussmann and RCM for technical improvements rather than tracking workers' performance. A similar conclusion can be drawn for

([27]) Simplified model for the computation of tax returns of employees and retirees.

Coopservice, which uses data collected by semi-automated solutions in the field to automatise the reporting process to the client rather than monitoring misbehaviours by operators.

> *In particular, we have implemented a software solution that brings together shifts, people and signals from the field. In developing the procedure these data have been deliberately decoupled, i.e. it is never possible to put together the data from the field with the data for the operator's shift if not ex post and knowing how the architectures are made.*
>
> *[…]*
>
> *Clearly if this thing is to be done on a mandate from the personnel office, it can be done ex post.*
>
> COOPSERVICE, IT Specialist
>
> *The machine stores the chronology of washes from which you detect whether the area to be covered has been completed or not. I could ask the operator why the cleaning for that area has been interrupted; however, we mainly use these data and the reports completed by operators to assess how the machine works. In fact, we do not even deliver the reports to SEA S.p.A. [the company that manages Milan Malpensa Airport providing all services and related activities]; they know the technology is in use but no control on cleaning activities is taken by them through the reports.*
>
> DUSSMANN, IT Specialist
>
> *We never had problems; it works smoothly. Technicians at RCM also ask for data about the functioning of the machine.*
>
> *'Question'. You input such data?*
>
> *No, they can be downloaded directly from the software. We start working and they are just collected on the hard disk and then downloaded.*
>
> *'Question'. Do you think the use of this machine could change the way your work is evaluated? If the machine blocks several times or it does not properly cover the area, could all of these be used to evaluate your performance?*
>
> *We did not talk about such things; there is no such problem. Dussmann just asks you about the performance of the machine just to give some information, some data to RCM for further improvements.*
>
> DUSSMANN, Worker
>
> *'Question'. Does the use of the cleaning robot represent a constraint when choosing means and pace of work? Could it be the case that you have to wait for it to finish the work?*
>
> *Maybe it happened at the very beginning since you were unsure about its functioning, but now it does not really affect our decisions.*
>
> DUSSMANN, Worker
>
> *'Question'. Did the cleaning robot impact the work organisation of the other cleaning operators. Did you need to reallocate them to other areas?*
>
> *We just selected an area that was suitable for the robot and asked the operators previously in charge of that area to provide its daily maintenance.*
>
> NESTLE, IT Specialist

Interestingly, the automation and the associated upgrade in relation to clients seems to give more autonomy to intermediate figures employed at Coopservice, such as the contract leader, responsible for the overall management of the specific sites, and team leaders, who coordinate and supervise groups of operators. Paired with the stagnant upskilling of operators, this ongoing process could eventually foster the hierarchical structure, as claimed by the coordinator of employee training and development.

> *There is also the training project 'Coopservice way' for our key figures, such as the contract leader and the team leader. They will increasingly need targeted training to foster both soft skills and digital competences. … contract leaders who were previously adequate today are struggling to keep up with the times. … performing a service today is very different from before because the complexity level of the relationship with the client no longer consists of 'just cleaning' but requires paying attention to sustainability, compliance, quality checks made by the customer, etc.*

'Question'. Overall it seems that this technology, autonomous or semi-autonomous, fosters the position of power of top figures, while instead the lower part of the pyramid seems to contract. Is there a consolidation of this hierarchical structure?

Well, there is a much more advanced technological component. Today, therefore, there is certainly the theme of the professionalisation of these people, so if by 'position of strength' we also mean the level of professionalism and perhaps also their autonomy, yes, because certain characteristics must be met today otherwise the client will consider our service inappropriate.

COOPSERVICE, Coordinator of Employee Training and Development

With regard to job quality, no wage increases nor upgrading of those operators able to use the robot were detected. Moreover, as mentioned before, despite the compelling need to reduce physical strain by increasing the workplace ergonomics, the analysed technology seems not to address such an aim. Interestingly, the cost of the cleaning robot causes anxiety for some night-shift operators at Milan Malpensa Airport who feel responsible for it.

Actually, you cannot leave the machine alone: you always have to keep an eye on it during work since the airport is open, even during the night. You can do other tasks in the meantime but it is safer not to lose sight of it.

[…]

The machine is costly and I am afraid when I have to use it during the shift especially because of the presence of homeless who sleep in the airport at night. It is a great responsibility for us and this is certainly something new.

DUSSMANN, Worker

'Question'. Did it make your job more repetitive?

It did not really change.

'Question'. Is it more stressful or tiring?

At first it is not easy, you do not really know what you are supposed to use, but you simply get used to it. For overall physical effort, I would say that not much has changed.

DUSSMANN, Worker

Also, there is no money reward for those who are able to use the machine, even if I think that they should be upgraded to 'third-level' operators like those who can use the aerial platform to clean the windows and clear the cobwebs. … this would also encourage operators to use it; in fact, if I do not feel confident I would avoid using it.

DUSSMANN, Worker

Besides this, the adoption did not result in the concrete upskilling of workers since the use of the robot requires limited digital skills. However, the selection of the operators to train for such a purpose was top-down and filtered those night-shift workers with positive attitude towards technology.

The selection criteria was the supposed familiarity with digital technologies among those workers operating during night shifts … so they chose those who were already at ease with monitors, touchscreen and so on.

DUSSMANN, Worker

At first it was new for everyone, for a youngster it would have been much easier … however, we just open the window for the positioning of the machine and launch the program. I do not open any other window I am not interested in.

[…]

After all using it is not difficult. You just have to get used to it and it takes a while. If there is 'progress', you just accept it and that is all. … also, the other washer dryers we have are touchscreen so we basically do the same thing.

DUSSMANN, Worker

We kept the machine easy to use, with a friendly user interface and no complex installation procedures. Another weakness in existing solutions is that they require a skilled final user, who most of time you cannot really afford.

DUSSMANN, Head of the Planning and Control Department

Task 'densification' was recorded for all companies considered. Operators now perform more tasks besides the daily maintenance of the machine. For the case of Dussmann, in particular, the maps of the areas to cover are embedded in the software of the machine and divided into cells. Each cell has a starting point marked by a sticker on the floor, and the operator is supposed to place the robot on the marker at the end of cleaning each cell. Correct positioning is crucial since the navigation system counts the metres travelled to assess the completion of a cell instead of relying on geolocation.

The colour of the cell changes from red to orange to green as the cleaning progresses. Once it turns green I move the machine to the starting point of the following cell … it is intuitive and after the first time you are able to manage it on your own.

DUSSMANN, Worker

As the night shift starts I go to the warehouse, touch the screen on the machine and unblock it. Then I move it to the sticker and launch the cleaning program. In the meantime you possibly pay attention to the machine at work, you watch over it, and then take the other [semi-automated] washer dryer; it happens to work in parallel … If it freezes you can unblock the wheels manually and bring it back to the deposit. Of course, you report it to the shift manager and the following morning you write the report. At the end of the shift you flush the waste water and clean the suction tube since the dirt dries out if you just leave it. Actually, it is not really different from old machines [semi-automated machines] since we do this kind of daily maintenance for them too … nor did it change the effort we made in cleaning operations … cleaning the floor was something which we were already using the washer dryer for, it was not done manually. … we use the joystick to move the machine.

DUSSMANN, Worker

While the machine is working, the operator keeps an eye on it and carries out other tasks such as emptying waste bins, cleaning the bathrooms and removing dust from chairs. Since it is kept several inches away from the walls, the operator has to eventually clean those uncovered areas and at the end of the shift a brief report concerning the use of the machine and the correct functioning is required.

The point is that when it avoids an obstacle it does not come back to the portion of floor that has not been cleaned and I am supposed to cover it. Moreover, the machine leaves a margin of 20 cm from the wall for safety reasons. … we usually use the semi-automated machine to clean the remaining part. It is an extra that you have to bear in mind while working.

DUSSMANN, Worker

Some colleagues were afraid of being fired after the adoption of the technology. Honestly, I am not, since the robot is not able to clean the doorknob, to clean the toilet, to sanitise and so on and so forth … you keep doing your job and it just washes and dries the floor in the meantime.

DUSSMANN, Worker

Digitalisation and data entry was more widespread across firms. For Coopservice, even if the implementation of automated cleaning machines has been abandoned, the in-house improvement of semi-automated solutions led to a wide digitalisation of tasks, such as the automation of the report on completion of the service, the storage and analysis of data received by semi-automated cleaning machines on the efficiency of the service. This even required the creation of a group for data collection and analysis of efficiencies, actually seeking new hirings.

There is already a group for data collection and analysis of the efficiencies of our services in tenders as part of the cleaning division … and I know that they are looking for two more specialists to integrate into this unit.

COOPSERVICE, Coordinator of Employee Training and Development

Specific training projects are also at work to assist digital skills development for intermediate figures such as the contract and team leaders. In addition, the subsequent increased amount of information available to the client led to higher standards in terms of quality of the service; the contract leader needs to know how

machines work, whether it is convenient to intensify their use to detect misbehaviour by operators. Overall, the need for quality analysis resulted in a boost in the demand for intermediate figures, such as contract leaders responsible for the implementation and development of each specific tender, technicians, and engineers.

> *It is clear that when I have a service that goes from cleaning everything by hand to a situation in which I have to know how to choose which cleaning program to use, there is already a completely different mental approach. I am therefore looking for people with a different familiarity with technology than before; I have to programme the machine and I need those kinds of people to intervene. I need both site coordinators familiar with the technology and able to choose between different cleaning systems and more technical figures responsible for the software system and the reporting activity to the client.*
>
> COOPSERVICE, Chief Operating Officer
>
> *Every time there is something new, operators show some kind of resistance. … the team leader figure is the one to foster to avoid these problems. In fact, if they know how the machine works and its potential, and if they are convinced the enthusiasm within the whole team of operators would follow.*
>
> COOPSERVICE, Coordinator of Employee Training and Development

Overall, cleaners now perform more physical tasks in line with expectations: they use the joystick to move the machine and place it on the right starting point; they supervise it while in action; and they are responsible for its daily maintenance. However, no further routinisation due to the technology has been emphasised by the interviewees. In addition, the intellectual dimension is unaffected since the digital skills required to interact with the robot are basically equivalent to those of semi-automated solutions; even the digital report that operators at Milan Malpensa Airport have to fill in after use is a quick summary aimed at detecting technical issues. Social interaction with coordinators or colleagues has not been altered, as well as the autonomy at the workplace since data collected by the machine in the field are used by the management and the provider to monitor malfunctions rather than misbehaviours.

With reference instead to the role of administrative units, Coopservice is involved in the evaluation of the relative convenience of including semi-automated machines in projects for tenders on a daily basis. However, they are not proper cost-benefit analyses; the use of cleaning technologies does not really impact the amount of operators required and related budget estimates, resulting in the default provision for reputational motives. We cannot, therefore, conclude that the technology had an impact on their task content or methods of working. On the contrary, key interviewees in the case of Coopservice envisage a greater understanding of the cleaning artefact and its software by both contract and team leaders in the future, with the aim of giving them a higher degree of autonomy with the client and for training operators. In this sense, for these intermediate figures, the cleaning technologies seem to enhance the intellectual and social content of their tasks, as well as their latitude in determining working time and methods of working for the operators on-site.

Lastly, the interviews did not provide evidence about the reorganisation of workstations to ease the cleaning by robots. On the contrary, it seems that for both Dussmann and Nestlé Vera, the technology was implemented in those areas that did not need further rearrangement.

4.6 Discussion and conclusions

This chapter was intended to study the extent of the adoption of cleaning robots, drivers and barriers, technological integration with providers, task reorganisation and workplace changes. In line with *ex ante* expectations, the use and the deployment of automated cleaning machines are at an infant stage with very limited application. The identification of the adopting firms turned into the study of a failed adoption case, lacking other alternative adopters.

Strong barriers to adoption have been spotted by managers and technological specialists, in particular the complexity of the workspace in which the machines have to operate. The most relevant driver remains reducing labour costs, and in some instances turnover. Another relevant driver is the possibility of collecting digital information on performance and errors to therefore improve the quality of the service provided to the client. Quality control via remote information led to the construction of specific 'digital units' even within a cleaning company. The digitalisation of non-digital service companies in the cleaning sector even seems to be already underway. However, this consideration is beyond the scope of the specific adoption of cleaning robots.

An interesting case of in-house technological development and powerful integration among parties of the supply chain was under study. This is the case of Dussmann, a leading German firm providing professional cleaning services, whose Italian division decided to internally develop automated machines in collaboration with a university and other high-tech firms. The prototype was then produced by a machine manufacturer. A supply chain was built for the single technology, a rare phenomenon.

Product customisation has been identified as fundamental to meet client needs. This is the case of Nestlé, whose IT provider proposed and supported the adoption of the machine. Customisation was crucial to define the speed and size of the machine. However, it was quite effective, and several hours of training were sufficient to instruct the operator. For Coopservice, the actual distance between technological developers and the interaction limited to retailers represent a major obstacle in developing effective solutions which are indeed required when clients vary from hospitals to offices and warehouses.

In terms of work organisation and change in activities performed, no significant transformation was spotted, unless the increasing number of tasks performed by operators, who together with visually controlling the machine, have to clean and do the other scheduled work activities. Interestingly, more digitally oriented operators were chosen to operate the machine, the latter being provided with a digital interface. However, the rising standard for reporting seems to demand orderly upskilling of intermediate figures and new tech specialist hirings rather than greater autonomy to operators. Lastly, the physical environment was not modified, and workstations were not changed. However, the Nestlé case represents a combined introduction of automated machines, both in cleaning and in moving objects (i.e. internal logistics), known as low-value-added phases. This multi-technology adoption strategy seems to be valuable and clearly adopted by a leading company in the reference market.

Overall, the analysis confirms the complexity in automating presumably low-value-added phases: human labour remains crucial in conducting activities that require the flexibility, adaptability and reconfiguration of physical tasks as in the case of cleaning. Companies indeed perceive that the number of workers required to carry out cleaning tasks would not change immediately.

In addition, whenever used, such machines might require operation in human-less environments, therefore restricting the scope of application to specific warehouses and spaces, such as airports during the night. Nonetheless, firm heterogeneity was quite evident in approaching the technology, ranging from a case of virtuous in-house development and production giving rise to a dedicated value chain across parties, to a case of adoption driven by the external IT service-and-solution provider, to a case of abandonment of the technology. In contrast, homogeneity was found in the lack of any industrial relations system in place, and therefore of any specific intervention put in place by trade unionists.

5 Health monitoring devices

In this chapter we focus on the adoption of **remote monitoring devices** in the healthcare sector.

In particular, we focus on four different technologies that can be included under the label 'remote monitoring devices', namely: i) telestroke and (ii) remote monitoring technologies for implanted heart devices, both adopted by Santa Maria Nuova Hospital (Reggio Emilia); (iii) remote monitoring devices for cardiovascular conditions and for defibrillation onboard advanced emergency vehicles ('Lifepak 15') adopted by ASUR Marche (Ancona); (iv) devices allowing remote, web-based visits or televisits implemented by Humanitas Research Hospital (Milan).

In the past 10 years, the healthcare system has developed some technological solutions to implement remote patient monitoring. Before the COVID-19 pandemic, all of these technologies under the general heading of telemedicine – i.e. digital communication technologies applied to homecare settings and virtual provision of patient care (Litwin, 2020) – did encounter a series of obstacles, mainly socio-cultural and institutional constraints, but also organisational and technological barriers. However, an ageing and isolated population; the reduction in the number of general practitioners and the quality of territorial assistance; the process of centralisation towards big, multi-purpose hospitals; and the need for continuous monitoring of chronic diseases have led to a gradual reconsideration of more structured remote monitoring programmes, also with the introduction of previously unknown fees and payment systems. The spread of the pandemic has therefore dramatically accelerated the adoption of such technologies.

In terms of occupational projections, the sector is thus expected to keep growing over the next 10 years (U.S. Bureau of Labour Statistics, 2022). In particular, those occupations relating to home health and personal care aides are precisely those whose absolute numbers are expected to grow further, despite reporting the lowest median annual wage compared to other occupations in the same sector.

The state-of-the-art technologies in healthcare remote monitoring include:

- remote monitoring of patients' clinical parameters through various types of sensors and wearable technologies;
- home-based visits or televisits by means of virtual platforms;
- advanced robotics used to replace various activities in working environments exposed to infections and diseases;
- artificial intelligence (AI) providing assisted diagnosis by means of machine-learning algorithms based on large-scale datasets that aggregate different sources of information on patients' clinical parameters.

It needs to be stressed, however, that AI and robots appear relatively less diffused than the devices for healthcare remote monitoring and the provision of televisits.

For the purpose of this study, the term 'automation' refers to the replacement of human labour input by (digitally enabled) machine input for some tasks in production and distribution processes, not only in manufacturing, but also in the service sector (Eurofound, 2018).

With reference to healthcare services, in particular, automation typically implies the replacement of different work activities, for instance, for meal delivery and cleaning within those environments exposed to infection risks and diseases. Most frequently, as we shall see more clearly in the following, it refers to the replacement of those monitoring and diagnosis activities that were previously carried out in person, by doctors and nurses, and which are now increasingly substituted by 'automatic' remote monitoring and diagnosis.

Overall, the status of the technological adoption of remote monitoring devices in healthcare can be summarised as follows.

- The technologies concerned are in an uptake phase, though with a high level of variability ranging from AI and robots, which are relatively less diffused, to various types of devices for healthcare remote monitoring (e.g. sensors and wearables) and for the provision of televisits, which are more widespread.

- Obstacles to adoption are deep and diverse, among them (Litwin, 2020): (i) pricing policies of telemedicine; (ii) difficulties in identifying the pool of patients to be telemonitored; (iii) strong reorganisational needs to rearrange shifts and intra-day working activities; (iv) problem of software integration within diverse units such as central healthcare divisions, hospitals, private clinics, elderly residences; (v) need to massively rely upon caregivers; (vi) digital divide to ensure assistance to patients; (vii) fragmentation between those who

decide to undertake a technological innovation (financial and ownership actors) and those who are going to define whether that technology is actually worthy of deployment (medical and caregiver personnel).

The main drivers of adoption are: (i) the possibility of increasing patients' access to healthcare monitoring; (ii) the need to reduce hospitals' stress, notably by limiting hospital admissions and patient flows, as well as ensuring improved disease prevention; (iii) efficiency and productivity gains.

Ex ante expected impact of remote monitoring devices on work content, working conditions and business models

The application of various forms of telemedicine is considered the fastest-growing area of technological adoption among the three sectors under consideration. However, the process of technological transformation primarily concerns digitalisation rather than sheer automation. This is because remote monitoring devices are primarily digital infrastructures which do not entail proper human substitution, but rather a reorganisation of organisational and work processes as described below. Hence, no direct human substitution has been envisaged during consultations with industry experts. However, if the intention is to bundle jobs as tasks, remote monitoring devices can affect work organisation and impact some specific tasks performed by healthcare operators.

Although the field of telemedicine is far behind in Italy and telerobotics is almost non-existent, expectations concerning adoption are positive compared to initial experimentation projects, also because the pandemic has greatly accelerated the adoption process. As for the impact on the healthcare facility system, it is expected that the adoption and implementation of remote monitoring and televisits may have a huge impact and, if widely adopted, may allow hospitals to lower working loads and significantly reduce emergency admissions.

More specifically, the technologies concerned have several applications, such as: (i) telemedicine, including telemonitoring, which involves the detection of patients' clinical parameters – e.g. blood pressure, respiration and heart rate – and their digital transmission to the reference health centre; (ii) active transmission by the patient, when patients in quarantine or isolation are directly enabled to transmit various parameters regarding their physical condition; (iii) televisits or teleconsultation, when patients use their own digital devices to access remote visits without moving, that is, remote visits carried out at home with information transfer. These latter are mainly used by patients located in rural and mountain areas who have been provided with digital devices for the transmission of parameters to hospitals and GP.

In all cases, the adoption of remote monitoring devices – entailing the possibility of detecting specific patients' parameters and transmitting them to hospitals, or using sensors that directly transmit patients' parameters to health facilities – is expected to affect the following.

<u>Work content and working conditions of doctors</u>

Creation of new physical and intellectual tasks carried out concerning an *ex ante* evaluation of the physical condition of each patient (e.g. risks and benefits) in order to be included in the pool of telemonitored patients. Clearly not all patients can be included in or be subject to remote monitoring. In general, patients with chronic diseases or occasional medical problems, though in good physical condition, are more likely to be included (e.g. young individuals before a small surgical operation).

Suppression or partial reduction of physical, intellectual and social tasks concerning annual routinised visits for medical check-up or in emergency departments.

Changes in work organisation and workloads due to the fact that the implementation of remote monitoring devices allows doctors to be constantly updated about the health status of their patients so that they no longer need to visit them in person to get the information necessary and, thus, can just focus on their in-person visits for the most critical cases. In this specific sense, the technologies concerned entail a kind of 'automatisation' of tasks, with possible consequences also on the 'social content' of the work activities carried out (i.e. regarding the relationship between doctors and patients as well as between doctors and colleagues).

In this specific context, the substitution of nurses for doctors is not quite predictable. However, remote monitoring and all of the activities carried out remotely highly impact hospital organisational structures as well as the work organisation of hospital teams in the entire reference area, implying several additional functions.

For instance, televisits do not entirely substitute in-person visits. Indeed, all activities performed remotely must be done in person if necessary: this means that the system must be able to rearrange the visit from

remote to physical in case of emergency (the waiting list for televisits is the same). The platforms employed range from Skype, Teams and some other professional tailored-made platforms.

Hence, although the professional figures involved in televisits are essentially the same as those involved in traditional medicine, requiring the same competences and functions, the latter should be more strictly linked to the organisational personnel and the related tasks and work organisation. For example, if there is a delay in a televisit, it needs to be communicated. Moreover, at the end of the visit any possible receipts must be provided to patients. All of these activities also represent an additional workload from an organisational perspective.

Work content and working conditions of healthcare staff (nurses) and administrative units ([28])

Changes in work organisation related to hospitals' internal telemonitoring management and increased use of digital tools, which should imply the reshuffling of shifts and a formal inclusion of time frames and schedules to read and study the collected parameters. Likewise, the provision of televisits is expected to entail the need to reorganise appointments.

Creation of new physical and intellectual tasks concerning reading and studying the collected parameters and related to the digital transcription of previous patient diagnoses and parameters (likely perceived as temporary). At the current stage, the sector is still paper-abundant, also because the doctors consider using digital transcription as deducting time from visiting and treating their patients. This has been the case, in particular, during the pandemic.

Overall, industry experts do not foresee a deep transformation of tasks performed by doctors; instead, they expect more changes in tasks carried out by either the administrative units which have the organisational burden, and by the caregivers that have the ultimate burden in terms of transmission and technology adaptation.

Work content and working conditions of caregivers

Increase in social tasks and problem-solving activities related to the provision of social assistance and patient support in the use of remote monitoring devices, notably to ensure the correct application and use of the remote monitoring devices. In this sense, the caregiver mediates the adoption process.

The socio-health dimension is partially managed by the health facilities and by the private care systems. The ASL (local health authority) social service deals with the transition from the health to the social dimension. However, social assistance then passes to local councils and is then contracted to cooperatives or private foundations.

Hospitals' business models

In terms of expected changes in the business models, several elements should be considered: (i) high costs of telemonitoring in terms of activation and management (at least in the short run); (ii) need for more devices, digital infrastructure and longer monitoring times.

In practice, minimal adoption is due to the short-sightedness of pay-back investment rules. Apart from cost amortisation, barriers are very much due to the organisational dimension. Currently, telemedicine visits are unpaid in many public hospitals. This is not the case for private clinics that are currently imposing very costly access rates for televisits([29]).

In terms of patients' acceptance, while the use of wearables is often poorly perceived, televisits are well received since they allow closer and more constant relationships with doctors and avoid physical transfers.

Furthermore, medical devices must be compatible with the local health centre, and must therefore be provided by it. However, there are problems in integrating differentiated software used by hospitals, regional and local health agencies (known as ASL), private clinics and elderly residences.

([28]) The internal division between tasks performed by administrative profiles, nurses, assistants and, more generally, health operators depend on the hierarchical structure of the healthcare centres. Therefore, in some organisations it is likely that nurses are also in charge of more organisational types of activities such as the arrangement of appointments.

([29]) San Raffaele, belonging to the most important private healthcare providers (Gruppo San Donato) has just launched a telemedicine programme with very high access rates: https://www.world-today-news.com/san-raffaele-we-do-not-carry-out-home-visits-for-e-450-only-diagnostic-tests-cost-a-lot-2/.

Against this background, in the medium-long term telemonitoring should reduce admissions to hospitals and emergency cases because of continuous monitoring and prevention, therefore reducing hospital management costs. In this sense, the research team envisages major changes in the business model for healthcare centres concerning infrastructural investments (see also the attention paid by the Italian National Recovery and Resilience Plan – PNRR), training operators, strengthening administrative units.

5.1 Description of the hospitals

5.1.1 Santa Maria Nuova Hospital

The Santa Maria Nuova Hospital is part of the Azienda Unità Sanitaria Locale (AUSL) of Reggio Emilia with the qualification of '*Presidio ospedaliero provinciale*'. It is a public hospital unit with autonomy at management and organisational level, and separate accounting within the AUSL budget. It has become the most important hospital in the whole province in terms of employment and number of hospital wards and several integrated telemedicine services in the last few years, such as televisits and remote reporting systems, besides telestroke and the remote monitoring of implantable devices.

> *Telemedicine is growing a lot. Many other areas could be classified as telemedicine: besides the technologies you are interested in, we also do classic remote transmission with the specialist sending a link to the patient who is at home and performing the visit remotely. As well as remote reporting, that is, the examination is carried out in a certain place in the hospital network or in the network of local services and is analysed and reported in a completely different place. This is quite customary by now.*
>
> SANTA MARIA NUOVA, IT Specialist

The **telestroke** technology was implemented at Santa Maria Nuova Hospital in 2019 and is now fully operational. The initial aim was to connect the whole province, that is, both the northern and southern areas of Guastalla and Castelnuovo Monti, respectively. However, the latter experienced several problems that eventually prevented the adoption. Currently, Guastalla Hospital, as part of the AUSL network with no neurology department, is the originating site while Santa Maria Nuova Hospital in Reggio Emilia stands as the distant site. Castelnuovo Monti was also supposed to take part in the project but in 2018 a clinical research project envisaged the use of telestroke at the site with the testing phase being financed by bank funding. The maintenance office carried out informal scouting of possible providers on the market and at the end of the experimental stage the AUSL of Reggio Emilia published a public invitation to tender that was renewed a second time since no tender was submitted in the first instance.

The technology is now rented with the possibility of redemption, and it is part of current AUSL spending. Initially, stroke telemedicine had to be implemented throughout the province, but due to COVID-19 and organisational barriers, the uptake of telestroke counts only Guastalla Hospital as the originating site. Specifically, in the event of a suspected cerebral stroke, the emergency doctor or the nurse at Guastalla Hospital calls the neurologist, activates the hardware and software support for teleconsultation and physically performs the televisit led by the neurologist, while the latter at the distant site is supposed to leave other activities and give priority to the telecommunication as the call is received. The technology is indeed not active on night shifts since there is only one neurologist in operation at Santa Maria Nuova Hospital, who would not be able to carry out both routine tasks and the teleconsultation via telestroke.

The **remote monitoring of heart devices** is operational at Santa Maria Nuova Hospital since 2014 but the pandemic helped to release the technology's full potential. In fact, the division of the implanted patient's cohort between those whose check-ups can be performed remotely and those who still need to visit the clinic annually has been encouraged due to the pressure on the healthcare system caused by COVID-19. In 2020, the electrophysiology unit at Santa Maria Nuova Hospital started contacting those patients whose devices allowed for remote check-ups and included their names at what is known as the 'virtual clinic' (*ambulatorio virtuale*), while those patients with older devices were still received in person by electrophysiology as an outpatient on an annual basis. The automatic annual check-up report is then uploaded to the digital platform for document sharing used by the ASL and included in the patient's electronic health record. There are now 1 200 patients at the 'virtual clinic'.

5.1.2 Azienda Sanitaria Unica Regionale Marche

ASUR (Azienda Sanitaria Unica Regionale) Marche is the regional public health authority composed, at organisational and functional level, of five units (*'aree vaste'*), which include the 13 ex-territorial units (*'zone territoriali'*). '*Area vasta* 2' is the unit of interest and includes the Riuniti Torrette hospital in Ancona and the three health districts of Fabriano, Jesi and Senigallia.

The technology was first adopted in 2011 (Lifepak 12) by the Osimo Loreto hospital and allowed for transmission between its emergency vehicles and the cardiology hospital unit at Riuniti Torrette hospital in Ancona. Following this experimental phase, the Lifepak technology was extended to the entire territory of *'Area vasta 2'* in 2015 and is now fully integrated. Specifically, the Lifepak was the subject of regional procurement by the Marche region in 2000 and the winning provider later on contacted regional hospitals that may have been interested in the adoption.

The adoption has not required further investments in network or hardware infrastructure unless arranging the station for the acquisition of data in the cardiology department at Riuniti Torrette hospital. The station consists of a desktop computer connected to the Lifepak monitor/defibrillator and once it has been set for one device, the transmission can be extended to all required devices. In fact, the adoption of the technology across the whole *Area vasta 2* after the test phase did not demand further spending. Despite this, Carlo Urbani hospital in Jesi will host another central station for acquiring messages from the Lifepak defibrillators/monitor within the territories to provide logistics support to the Torrette cardiology unit.

5.1.3 Humanitas Research Hospital

Humanitas Research Hospital is a highly specialised hospital, research and teaching centre headquartered in Rozzano (Milan). It is accredited by the National Health Service and manages 50 clinical domains grouped in specialised centres: Cancer, Neuro, Cardio, Orthopaedic, Fertility, Obesity, Ophthalmology, Internal Medicine and Check-up, Pancreas and Duodenum conditions, Chronic Inflammatory Bowel diseases and Immunology. The hospital is also equipped with an emergency department and the outpatient radiotherapy area. It comprises five locations in Italy with a total of 6 500 employees.

The televisit project started in May 2020, independent of the pandemic. It builds upon the Secure Doc Sharing solution, which is software technology the hospital implemented in 2019 to store and share patient medical documents across departments, such as radiographs and test results, as part of the hospital's 'zero-paper' policy. The patient can book the televisit either through the platform or in the standard way by calling the hospital directly, then essential data for the patient are automatically or manually imported by the platform. The day of the televisit, the patient logs into the platform and receives a temporary password to access the video conference via Google Meet. They are also allowed to upload personal documents to the platform to share them with the doctor. In turn, after scheduling the visit, customer service assigns a teleconsultation station to the doctor, which is now part of the clinics' equipment and consists of a personal computer and a webcam.

At the end of the visit, the doctor's report is uploaded and freely available and downloadable by the patient, while stored data are automatically deleted after 3 months. The service is now fully operational in the haematology and oncology departments.

5.2 Deploying remote monitoring devices

5.2.1 Drivers of adoption

Santa Maria Nuova Hospital relies on several telemedicine services, such as the televisit system, tele-reporting and remote monitoring of implantable heart devices. This familiarity with digitalised technology possibly eased the adoption of **telestroke**.

The most relevant managerial drivers mentioned by the interviewees include the reduction of diagnostic errors and the cost of unnecessary transfers to the hub as well as, indirectly, the magnitude of stroke-related disability.

> *The technology is of great help for managing emergencies remotely. It enables us to assess whether the patient can be treated on-site at the peripheral hospital or needs a transfer to Reggio Emilia … prior to that almost every patient with a suspected stroke was brought to Santa Maria Nuova*

because keeping them at the peripheral hospital where no fibrinolysis could be delivered was risky.

SANTA MARIA NUOVA, IT Specialist on the Neurophysiopathology Unit

Our rationale about technology adoption is about time saving rather than labour saving.

[…]

Technology is therefore not seen from the perspective of reducing the number of people who work there. The example of a stroke is even more evident since you should carry out the thrombolytic procedure [administration of the clot-busting drug] within 4 hours from the start of the symptoms … Now if you notice among individuals that have been affected by stroke, there is a smaller number of them with hemiparesis or whichever permanent sign … because there is the possibility of intervening effectively in time consistent with the recovery of the insulted tissue.

Managers of the Castelnuovo Monti and Scandiano hospitals' emergency department

Here in Guastalla there is indeed a neurologist who serves as the doctor for outpatient clinics. We as medical staff of the emergency department tear him out of his role in case of extreme necessity at predefined times, which is normally 1 hour a day, usually at the end of the morning. So the neurologist gives us this availability of 1 hour a day which, for us, is of little significance, especially in the case of a stroke, which is a time-dependent pathology. The need for the immediate support of a specialist [here at the peripheral site] the adoption of the telestroke.

GUASTALLA HOSPITAL, Emergency Doctor

It also helps equalise medical treatment within the territory, an argument that has largely been used by the management to ease implementation in peripheral sites.

With telestroke we can guarantee the same treatment within the same time frame for those who live far from the hub. It is priceless … For a recent study, I took all the strokes registered in Guastalla and Castelnuovo over the previous 2 years and I evaluated the average time before the therapy, which was always 80 minutes longer than those who lived in Reggio Emilia.

[…]

When I participated in conferences to present the technology, citizens of the peripheral areas were enthusiastic about the solution since the geographical inequality in medical treatment is perceived as a real problem by both people and medical staff.

SANTA MARIA NUOVA, Neurologist

Prior to telestroke, the telecommunication between the emergency doctor at the peripheral hospital with the neurologist at the hub was carried out as a phone call, and the probability of incorrect diagnosis remained high, notwithstanding the involvement of a specialist since cerebral stroke detection relies, for the most part, on visual diagnostics.

'*The neurologist never had the opportunity to see the patient … the simple call was sterile: ischemic stroke has several shades and the description with no visual support was useless*,' reported an emergency doctor at Guastalla hospital.

All in all, technologies in use at Santa Maria Nuova Hospital seem to have benefited from a more general strategy for regional administration directed towards the enhancement of telemedicine services in public healthcare.

The telestroke was taken with specific financing from a bank, which is often the case for innovative projects. We usually start with pilots financed in a timely manner, after which the AUSL, when it sees that the technology works and that it is beneficial, finances it in a structural way and it becomes part of the AUSL's current expenditure.

'Question'. Are you planning other similar investments in telemedicine or for the moment it is more a phase of strengthening those already available within the territory?

Telemedicine, in terms of large projects, is in the hands of the region. As far as I know, a regional project is underway to monitor fragile patients with chronicity to equip patients with basic sensors that regularly transmit the data to the healthcare facility that in charge of their care.

[…]

There is also a strong enhancement of televisits and telecontact, such as the dialogue before surgical intervention.

SANTA MARIA NUOVA, IT Specialist

Focusing on the **remote monitoring of heart devices** at Santa Maria Nuova Hospital, the cardiology department pushed for the adoption of the technology, which enables doctors to obtain information from the implanted heart device on an as-needed basis, and hopefully reduce hospitalisations and ED (emergency department) visits.

Now if I need the monthly or yearly heart activity of a patient, it is sufficient to rely on the number and gravity of the alerts received by our mailbox. … it is also true that if something is wrong, it is transmitted no later than the day after . Therefore, the probability of detecting heart anomalies in advance is significantly increased.

SANTA MARIA NUOVA, Cardiologist

The increase in quality of the monitoring service is noted by patients as well:

After implantation of the defibrillator or pacemaker device, patients give informed consent and it is our responsibility to explain, very accurately, how the system works, what it does and what it does not do. We explain that the life-saving system is the one they have under the skin, while the remote monitoring system they have at home is an extra help. … many patients tell us that they feel safer; the system makes them feel more relaxed since they know that if something is wrong, the notification reaches the hospital in real time.

SANTA MARIA NUOVA, IT Specialist on the Electrophysiology Unit

However, during COVID-19, the most relevant driver for further development of the technology was the reduction of the patient flow for routine visits at the hospital. 'COVID-19 has been an opportunity to refine the implementation of the technology since many cardiopathic patients could not come to the clinics for the annual visits. This led us to build up the virtual clinic to keep them controlled,' stated a cardiologist referring to the impact of the pandemic on the implementation of the technology within the hospital in Reggio Emilia.

Something that has also been emphasised by the IT specialist on the electrophysiology unit at Santa Maria Nuova Hospital:

In March 2020 we found ourselves completely blocked, so within 3 months we had a thousand pending checks. It means that they had not been performed and we had to check patient files to assess which patients needed urgent check-ups or the scheduled check-up was simply necessary, and then calling them, summoning them, re-calling them all. It was a huge job. This was the origin of the idea to asking the AUSL to activate what is called a 'virtual clinic', which means no longer seeing those patients with fully automatic monitoring systems … In fact, a secondary reason is that there were too many patients with implanted devices to be visited at least once a year, while the primary motivation is to have a device that works well which sends reliable data.

SANTA MARIA NUOVA, IT Specialist on the Electrophysiology Unit

Turning to the **Lifepak 15 monitor/defibrillator**, the impetus for the implementation came from the emergency unit at Osimo Loreto following contact with sales representatives. As for telestroke and the remote monitoring of implantable devices, doctors communicated with the management directly to nudge the adoption. In particular, Lifepak 15 technology avoids the intermediate step to the ED for those patients that require immediate acceptance to the operating theatre and improves the diagnosis made by the emergency doctor on the ambulance through both the automatic diagnosis provided by the monitor – which is generally considered accurate by the medical staff – and through the remote assistance from the cardiologist based on the electrocardiogram (ECG) and relevant parameters transmitted by the machine.

I would say that I trust the diagnosis the Lifepak provides, which almost always matches mine. If I am convinced and the situation seems to be under control, there is no need to transmit it to the cardiologist. While in other cases the transmission is necessary to prepare the haemodynamic room and arrange it accordingly to the needs of the patient. In fact, the predisposition of the room depends on the therapy to be delivered which, in turn, changes with the diagnosis.

RIUNITI TORRETTE HOSPITAL, Cardiologist

It is considered a time-saving technology with a consistent life-saving effect. Even before the adoption of the technology, the emergency doctor called the cardiologist for medical support, but now the same assistance is based on the share of reliable evidence concerning the patient's heart activity, implying the reduction in incorrect diagnoses.

> *Time is a muscle, as cardiologists say. Every minute saved corresponds to preserving a part of the cardiac tissue. … the adoption of Lifepak goes beyond strict cost-benefit considerations. It allows us to save lives in two ways: the first is that it lowers the probability of an incorrect diagnosis on the ambulance since – in the case of a dubious situation – the ECG and relevant parameters can be transmitted to the hub and, second, it allows for straightforward admission to the operating theatre instead of a long and useless passage to the ED*.
>
> RIUNITI TORRETTE, Emergency Doctor

From the beginning of 2021 to 27 September 2021, the number of ECGs transmitted through Lifepak was 1 350, and the number of direct admissions to the operating theatre thanks to the transmission has been 91: this result accounts for the process of skimming 'false-positive' patients that did not really necessitate direct access to the haemodynamics unit. As reported by an emergency doctor at Riuniti Torrette hospital, 'our data suggest that Lifepak allowed for a strong selection among patients since the amount of transmitted ECGs considerably outweighs the number of those who entered the haemodynamics room for emergency operations … This improves the matching of what the patient needs and the treatment they received, besides time reduction,' eventually reducing costs for the hospital.

As for **televisits** implemented by Humanitas Research Hospital, it emerges that before the pandemic, the adoption of the televisit system was intended to replace in-person follow-up visits after surgery, routine visits and general continuity of care for those patients located in central Southern Italy. Humanitas Research Hospital indeed constitutes a basin of attraction for international patients and health migration from Central and Southern regions of Italy. The functioning of the televisit system was then crucial to reduce transportation costs and improve the quality of post-operative follow-ups.

> *The majority of our patients comes from outside the Milan province. Several patients are international and to provide an adequate service both the digitalisation of the visit and the creation of a cloud platform for sharing medical documentation were necessary steps … it was our medical staff that first recognised the utility of such innovations.*
>
> HUMANITAS, Engineer in the ICT office

During the COVID-19 outbreak, the system was expanded to the majority of medical services to reduce the flow of external people at the hospital as much as possible. The process was eased by the already existing internal digital platform for sharing clinical files.

> As the technician of the ICT office reported, '*The use of the televisit system increased with the peaks in the pandemic since people could not move. However, the technology was meant to be a natural accomplishment of the Secure Doc Sharing platform that was conceptualised and implemented in 2019 before the outbreak of the pandemic*.'

Overall, for both telestroke and Lifepak, the main drivers turn out to be related to time- and life-saving dimensions, both being technologies whose application is strictly associated with time-dependent pathologies. Indeed, both allow remote interconnectivity and time savings through initial diagnosis and the reconfiguration of hospital admission and flows (notably by reducing crowding in emergency departments) in the case of an emergency (e.g. strokes and heart attacks).

Instead, for the televisit systems and remote monitoring of cardiac devices, adoption has mainly been driven by the need to reduce hospital patient flows. In fact, both allow remote interconnectivity, time savings and a reduction in hospital admission and flows (especially by reducing the number of routine visits and check-ups) in the case of chronic diseases or after surgery.

5.2.2 Barriers to adoption

For **telestroke,** obstacles to adoption were expected to be deep and diverse. Among them, we can recall the strong reorganisational needs to rearrange shifts and intra-day working activities; the problem of software integration among diverse units, such as central healthcare divisions and hospitals; and the fragmentation between those who decide to undertake a technological innovation (financial and ownership actors) and those

who are going to define whether that technology is actually worthy of deployment (medical and caregiver personnel) (Litwin, 2020).

The barriers that actually discouraged or limited the adoption are very much related to the organisational dimension. In fact, telestroke is not active on night shifts since there is only one neurologist in operation at Santa Maria Nuova Hospital, who would not be able to carry out both routine tasks and the teleconsultation.

> *The protocol we have for the use of telestroke foresees the activation of the machine only during the daytime since there is more than one neurologist and in the case of teleconsultation, there is at least one colleague who can manage all other duties within and outside the neurology department.*
>
> GUASTALLA HOSPITAL, Emergency Doctor

Moreover, Castelnuovo Monti hospital was expected to become another originating site, but the experimental phase never got started. Firstly, the problem was that from 4 p.m. to 10 a.m. the hospital was not able to guarantee at least two emergency doctors on shift, hence the telestroke could have been used only for 5 hours during the day. They eventually managed to come to an agreement with medical internists to charge them for the telestroke procedure in the case of a suspected stroke in the emergency department. However, the further staff reduction in emergency and internist doctors in the period before the pandemic has prevented the adoption of the technology by the hospital. So, despite a broad consensus about the need for adoption of the technology, staff shortage hindered its finalisation. In this respect, the manager of the emergency department of Castelnuovo Monti and Scandiano stated that:

> *The problem in the pre-COVID era was that we could guarantee the presence of two doctors in the emergency department for only 6 hours, centrally 6 hours of the day. In all other periods, essentially from 4 in the afternoon until 10 the next morning, there was only one doctor who had to cover the needs of the emergency department and the needs of the territory. Under these conditions, thinking of assigning the only emergency doctor with the telestroke procedure was not up for discussion. We then asked the department of internal medicine. … when we developed this new procedure they realised that, for the organisational setting that a hospital like Castelnuovo could offer, having a goal that was shared by all in front of them, that is to reduce the time of fibrinolysis [stands for thrombolysis], internists had to take charge of it and they did it without protest … The adoption seemed ready to go since everybody was enthusiastic and we had found a timespan from 10 a.m. to 4 p.m. in which an internist was available for the telestroke procedure in case of need. However, this situation clashed with a further cut to both the emergency and internist medical staff… Consider that in order to guarantee first aid and ambulance services at Castelnuovo Monti during the COVID period, I practically moved the availability of the Scandiano emergency department staff to Castelnuovo, which was temporarily, and still is, closed due to logistical impracticability*.
>
> Manager of the Emergency Service of Castelnuovo Monti and Scandiano Hospitals

Stroke telemedicine is thus designed to provide neurologist advice within those medical centres with no neurology unit, but its operability is strongly limited in the case of staff shortages experienced by both hub and spoke hospitals.

With reference to possible difficulties in software integration for telecommunication, the adoption required no additional investment for both physical and network infrastructure. The only precondition was to identify, at each hospital involved, where to place the station with a high-resolution monitor and a pivotable digital camera for both the distant and originating site.

'*There has been no need to invest in hardware and software systems; a readjustment of the existing system has been sufficient for the implementation of the technology … also the station for tele-transmission is relatively parsimonious since it consists of a monitor and a camera which can be controlled from both the hub and the spoke*,' stated a member of the clinical engineering unit at Santa Maria Nuova Hospital.

As for the case of telestroke, those who decided to undertake the technological innovation were those able to define whether that technology was worthy of deployment. The **remote monitoring of heart devices** involved only Santa Maria Nuova Hospital, whose management showed full support for the project. It required relevant effort by the whole organisation, from the arrangement of the invitation to tender by the Emilia-Romagna region, to the setup of the supporting technical unit within the hospital. Interviewees also reported that even patients – whose average age is relatively high – did not express significant resistance to the shift from in-person to remote annual visits.

'*It seems easy now that it is part of our DNA, but the remote monitoring technology together with the creation of the virtual clinic required a remarkable effort by the whole organisation and close dialogue with the region,*' said the head of the ICT department at Santa Maria Nuova Hospital.

Besides organisational requirements, the possibility of disconnecting the device from the remote monitoring system is also acknowledged as the main limit of the technology:

> *I'll give you a classic example: the patient goes to the emergency department with an implanted defibrillator device because they were sick the night before. The emergency department staff then call us and ask whether the device intervened to restore the heartbeat. We are not sure that the device has communicated with the monitor on the bedside table because the number of days of disconnection before the problem is signalled to the provider can vary from 3 to 15 depending on the company. Since we are not sure we have to physically interrogate the device and this is a problem for local hospitals: local staff have to send them here with ambulances and organised transport. We check them and then they go back to the provincial hospital. This means a huge commitment for staff and transportation. As far as we are concerned, cardiac devices have this latency which is very difficult to manage because we are not that this is communicating every night with the device that the patient has under the skin. This is the dark side of telemedicine, and this is not manageable by us because the company gives it to us as it is and we have no way of managing it differently*.
>
> SANTA MARIA NUOVA, IT Specialist on the Electrophysiopathology Unit

Major drawbacks of the **Lifepak 15 monitor/defibrillator** include, other than the lack of connectivity on the territory that can slow down the whole process, the weight of the monitor/defibrillator, which is 15 kilograms. Doctors are usually helped by the driver of the emergency vehicle even if they are not required to.

'*It can happen that the modem has trouble connecting, especially in hilly areas. In these cases I call the hospital while the driver moves the ambulance to another spot searching for reception … the driver also helps me when I have to walk up several flights of stairs to bring the Lifepak close to the patient since it weighs 15 kilograms. Even if they are not supposed to, sometimes it is impossible to carry it on your own*,' reported an emergency doctor.

Ultimately, the availability of cardiologists is crucial: since they are supposed to leave routine tasks in the case of tele-transmission, in the case of staff reduction the technology cannot be implemented.

'*The Lifepak had already been delivered but the cardiologist was not willing to make themselves available for the tele-transmission and for the responsibility of remote diagnosis. Since no obligation was applicable … notwithstanding the weakness of technological constraints, the whole process of adoption stopped*,' stated an emergency doctor with reference to Macerata Hospital.

In fact, at Macerata, as part of '*Area vasta 3*', the Lifepak technology has not been deployed since such availability could not be guaranteed.

Finally, focusing on **televisits** at Humanitas Research Hospital, since the decision to visit a patient in person or through televisit is still largely at the discretion of the doctor, at first the medical staff showed some resistance: '*The nudge for the adoption came from the medical staff but some of them were wary about the efficacy of the remote visit to assess the health status of a patient. While the follow-ups shifted to televisit mode relatively easily, for other types of visits doctors took a while to become at ease with the technology*,' reported a member of the technical office at Humanitas.

However, the pandemic and the subsequent spread of video-conference systems seemingly smoothed such a reluctance and eventually eased the adoption process.
Overall, the management drove the adoption with the nudge on the part of the medical staff, but while doctors were left with the possibility of choosing the type of visit to conduct, on the organisational side the impact is not clear in terms of hiring, reshuffling shifts and the change in tasks for such a top-down process of adoption. In this sense, the participation of at least one operator from customer service would have helped clarify the real barriers to implementation of the televisit system ([30]).

Despite a general characterisation of all the technologies as quite demanding with respect to organisational requirements, the only real barrier to adoption points at the staff shortages for telestroke, since a lack of

---

[30] Humanitas Research Hospital did not authorise interviews with medical and administrative staff.

connectivity for Lifepak and the remote monitoring of heart devices, or the weight of the Lifepak itself, are more limits of the technology rather than obstacles to its uptake.

5.3 Remote monitoring device systems and relations with providers

The **telestroke** technology is provided by a German company through an Italian dealer, with regular and extraordinary maintenance carried out by the provider. The relationship with the provider is maintained by the clinical engineering unit at Santa Maria Nuova Hospital and the responsiveness in case of issues related to both software and hardware components is considered more than adequate by the medical staff. The provider also organised the training for the neurologists of the hub which lasted one day.

With reference to customer care from the provider, a technician from the neurophysiopathology unit stated that:

> *The provider is responsible for the annual maintenance, but for any problem I rely on the clinical engineering unit, which contacts the supplier directly. They are very precise and timing… I coordinate the technical department of the provider's company when they come for annual or half-yearly maintenance. When the technician arrives, I take them to the machine and we test the audio, video and software on the machine by checking connections with the spokes*.
>
> SANTA MARIA NUOVA, IT Specialist of the Neurophysiopathology Unit

Both telestroke and the remote monitoring system for heart devices have been acquired on the market through public procurement and then harmonised to the existing technology within the hospital by the internal technical department.

> *Since we are a public company, the acquisition of any equipment in hospitals entails a public tender … The procurement centre can be the individual hospital itself, as in the case of telestroke, where a single provider has won the procurement contract; in other cases, e.g. remote monitoring devices, defibrillators, etc., there has been a large public tender for the entire region, so the procurement centre is the centralised regional purchasing unit, and multiple providers have even obtained the procurement contract for the same hospital. … when the technology is acquired it must first of all be harmonised within the already existing technologies, known as systems integration.*
>
> SANTA MARIA NUOVA, IT Specialist responsible for management of medical equipment and procurement processes

Indeed, for the **remote monitoring of heart devices**, the providers that won the last regional tender for procurement are Medtronic (USA), Boston Scientific (USA), Biotron S.p.A. (Italy) and St. Jude Medical (Canada)([31]). Each provider has access to the data stored by the remote monitoring system paired with their own heart devices, which are both clinical – e.g. the average heart rate or the physical activity of the patient during the day – and technical data, such as the impedance of the battery. Technical data are normally not available to the hospital and they are used by providers to collect information about the technical performance of the technology, such as the rate of disconnection. In fact, each provider has set a threshold of days of disconnection after which it is allowed to contact the patient and restore the functioning of the device; Santa Maria Nuova Hospital indeed authorised the access to sensitive information concerning the implanted patients by providers.

> *We have an excellent relationship with some providers … they have a very efficient technical support service … This means that they take control of calling either the patient or the relative so they have our authorisation of making contact using sensitive data… in the case of technical malfunctioning.*
>
> SANTA MARIA NUOVA, IT Specialist on the Electrophysiology Unit
>
> *There is a co-ownership agreement for the data with the supplier company. They do not use them for the clinical aspect, for which they require specific permissions. … normally they use data only for monitoring the functioning of the devices since they have to know the average running time, the rate of disconnection, etc., they must release them to market by law and the best way to do this is to keep*

(31) Another interviewee gave a different list of providers, which includes Boston Scientific, Medtronic, Abbott, Sorin Group, MicroPort and Biotronik.

track of the data coming in from every patient … the suppliers of these devices also provide decision-support tools that analyse the data and suggest some evaluations to the clinician, synthetised by the colour of the alert received in the mailbox.

SANTA MARIA NUOVA, IT Specialist

For all providers but one the threshold is 15 days, which is considerably high, while for only one the threshold is set at 3 days. Additionally, the tech specialists at the hospital receive alert messages in the case of repeated disconnection and they agree with the provider's technical service on who is going to proceed to restore normal functioning. The drawback of possible disconnection of the device has been addressed by the cardiologist at Santa Maria Nuova by requiring a report from the tech specialists every 15 days on the rate of disconnection of the devices: if it is higher than 4%, devices involved have to be promptly maintained by either the supplier's tech service or by the hospital specialists.

At the time of implantation of the heart device, both a technician on the electrophysiology unit and a specialist sent by the provider are present. Moreover, the head of the electrophysiology division at Santa Maria Nuova Hospital is part of the R&D department of three out of four supplier firms: he participated in the conceptualisation process for the technology since he was looking for a communication system able to replace the annual check-up for implanted patients. He is still collaborating with these suppliers since all of them envisage further advancement of the technology:

I contributed to create such a technology. I wanted a communication system able to give me enough information to avoid routine visits at the hospital… and my collaboration with the providers is ongoing since the system can be improved upon and the advice of who actually employs it is essential … They are now proposing an app that communicates with the monitor and helps the grandson, the daughter or the caregiver to be notified by a pop-up in the case of technical problems with the device or the monitor. It will be useful, especially for my technicians, since potential problems would be signalled directly by the patient.

SANTA MARIA NUOVA, Cardiologist

In the case of the **Lifepak 15 monitor/defibrillator**, technical assistance is provided by Physio-Control. No customisation is stated by the contract. However, the last regional procurement for the supply of such a service awarded another provider, hence, from 1 January 2022, there has been a change in the supplier firm for equal characteristics of the technology.

We maintain close contact with the provider company because then it also takes care of technical assistance. I must say that they have always been very present too.

[…]

And yet it must be said that the Marche region has made a call for tenders where the only winner is another company that will be in charge of the provision from 1 January [2022]. So all of these monitors that we now use will perhaps be placed in other hospital departments and replaced by another machine, which will not be Lifepak technology but will have the same characteristics, that is, it must allow remote transmission.

'Question'. Do you also give any feedback on the machine that can then be accepted by them for improvement, is there a formalised relationship?

No, once the technology is offered they know more than we do about that.

RIUNITI TORRETTE, Emergency Doctor

'Question'. With respect to the management of the software, the ability to programme it, is there a need for something specific, something that is more than technical competence?

No, nothing. Our defibrillators are all programmed in the same way … and we simply have 24-hour assistance.

'Question'. And for the implementation of software development, is there a dedicated technical figure?

No, we cannot do anything directly on this equipment.

Manager of the Emergency Department of ASUR Macerata and Ancona

The **televisit** solution adopted by Humanitas Research Hospital was instead developed internally based upon the Secure Doc Sharing solution provided by Exprivia([32]). It consists of a cloud platform supplied by Google for online booking by the patient together with the standard Google Meet video-communication service for carrying out the visit. The booking procedure as well as the logistics assistance for the patient is provided by the hospital's customer service.

An engineer from the ICT department at Humanitas reported that:

> *… the hospital wanted to implement a 'zero-paper' policy within the hospital and Secure Doc Sharing was the pillar that allowed for the sharing of clinical documents online … For the subsequent development of the televisit we relied on the standard services provided by Google for a friendly booking interface and the Meet system for teleconferencing. However, our customer care service is responsible for the whole procedure and the technical assistance for the patient as well as for the doctor is supplied internally by our operators.*
>
> HUMANITAS, IT Specialist

The training was jointly offered to all actors involved by three different units of the hospital: the technical office explained the functioning of the platform, the medical administration illustrated the protocol doctors have to follow for the televisit and the operational management unit informed about the new customer service tasks.

The overall role of providers in effecting work organisation and working pace is null in all cases considered. The only strong relationship between adopters and providers pertains to the remote monitoring devices, where data are co-owned and regular feedback for continuous improvement of the technology are made official by the presence of a member of the medical staff in the provider's R&D division.

5.4 Industrial relations

With regard to **telestroke**, the initial idea came from the head of the neurology unit and the testing phase was conducted as a clinical research project. Unions have not been involved and other medical staff, such as the nurses in the hub and the emergency doctors in the spoke, were informed about the aim of the project in collegial meetings before the start of the experiment. The neurologist who nudged the implementation said that:

> *We gave the clinical engineering department the idea and it started scouting possible market solutions. When the project had taken shape, we organised meetings with colleagues of both the hub and spoke hospitals … the unions have not been involved in the process, we interacted with the management and the colleagues directly. We had six meetings over the span of 3 months to write the protocols. In the year this project started, we had more than 100 people who participated from all points of view, including nurses and doctors from the various operating units that could be involved. In 2019, we revisited the whole path from start to finish, both the conceptual principles and the operational aspects, after which we started with the operational phase in the autumn of 2019. We wrote the protocol – that is, the specific operational instruction that health management has approved, together with clinical engineering, to all the other health professionals, each for their competence.*
>
> SANTA MARIA NUOVA, Neurologist

Interestingly, these technologies seem, to a larger extent, to be put under investigation by the Italian official association of doctors rather than by unions. An IT specialist at the hospital reported:

> *As far as I know, the implementation of this technology in other Italian and international environments was followed by several queries on legal-medical responsibility from professional associations. In fact, in these cases the lion's share of supervision is done by the medical association*

([32]) The televisit was part of a research project financed by the Italian Ministry of Economic Development from 2017 to 2020 called 'Telemonitoring heart failure patients and radiological teleconsultation', part of the 5G trial with Vodafone and Humanitas. The project involved research, analysis, design, development, and the testing of an innovative telemedicine platform for the monitoring of heart failure patients and radiological teleconsultation.

rather than unions. However, in our case the protocol has been written and adopted without much difficulty.

SANTA MARIA NUOVA, IT Specialist

Similarly, for the **remote monitoring of heart devices**, the whole process, from conceptualisation to the actual implementation after the testing phase, took place without the involvement of unions. The use of the technology was planned to fit into working time and the prevention of overheads for both technicians and doctors has been a priority.

The pilot project and the subsequent adoption has been managed by doctors interacting directly with the management and the IT office at Santa Maria Nuova Hospital, while the role of unions was limited to potential intervention in case of misconduct and unvoluntary rescheduling of shifts.

The union has not been involved but workers have been informed and of course everything must revolve around normal working hours; there must be no work overheads, etc. From this point of view everything is done in such a way that it conforms to normal hours; nursing and medical staff do not do more than they should.

'Question'. However, has there not been any involvement with respect to organisational change?

No, normally there is no communication, sometimes there are questions that the union wants to understand better, but mainly after the adoption.

SANTA MARIA NUOVA, IT Specialist responsible for management of medical equipment and procurement processes

For **Lifepak 15**, the impetus for the implementation came from the emergency unit at Osimo Loreto following contact with sales representatives. Unions and medical staff have not been involved in the decision-making process, which assumed a top-down form. Only the matter of the weight of the defibrillator has been pointed out ex post by the drivers of ambulances to their union representatives.

Healthcare and social-care personnel at the hospital have not been involved in the decision-making process concerning the convenience of adoption … Unions are present but I don't think they are even aware of the adoption of the technology; I would say it is a marginal aspect for them.

RIUNITI TORRETTE, Emergency Doctor

There has been a discussion about the fact that many doctors do not want to carry it [the Lifepak 15] because there is a weight threshold that people of a certain age cannot lift … otherwise you face a job risk. … drivers of emergency vehicles help doctors with the lifting, even if they are not supposed to.
'Question'. Are there union representatives who interface for this issue? I know that there are various drivers who have turned to the trade unions. As far as I know there is still no solution to this problem.

ASUR MARCHE, Emergency Doctor

We have a nursing union here, it is quite widespread, I would say that three quarters of the people are members. If you have any problems, and over time it has happened, they give you legal support. … we are satisfied with the job they do here.

RIUNITI TORRETTE, Nurse

Even in the case of **televisits** for Humanitas Research Hospital, doctors interacted directly with the management to integrate televisits into the services provided by the hospital to the patients. Relying on the only interview available for the case, it seems that no intermediation through unions and medical associations took place at any level.

5.5 Work organisation, job quality and task content

With reference to the hypothesis made in Section 2 about the expected impact of the technologies on the work process and working conditions, the results only partially meet predictions. In particular, cardiologists at Santa Maria Nuova Hospital decided to shift to the 'virtual clinic' only those patients whose implantable heart devices allowed for remote monitoring; therefore, the choice was not based on a medical evaluation of physical conditions. On the other hand, annual check-ups of implanted devices are now carried out remotely

for a large share of cardiopathic patients being treated by the electrophysiology unit at Santa Maria Nuova. Interestingly, remote monitoring required the hiring of a dedicated technical figure, creating a brand-new technical office for the electrophysiology division.

With reference to **Lifepak 15**, contrary to expectations, the technology did not suppress the initial diagnosis by the medical staff since the diagnosis provided by the machine acts only as a support for the assessment made by the emergency doctor or the nurse. However, together with telestroke, the adoption of Lifepak resulted in the relevant upskilling of the nursing staff: nurses on peripheral sites can now carry out thrombolytic procedures as well as transmit an ECG through Lifepak 15 and interact with the cardiologist, although no changes in contract level or pay have followed. Additionally, the increased interaction among the medical staff and between the medical and nursing staff is appreciable.

With regard to Humanitas, the doctor is left with a high level of discretion towards the means by which to carry out the visit, i.e. remotely or in person. In this case, it is reasonable to suppose that doctors decide in advance based on a careful evaluation of the patient's medical history, indeed creating a new task. In line with predictions, the administrative unit seems to play a crucial role in the functioning of the televisit system, with several new tasks for the customer service operators. Unfortunately, it was not possible to interview any member – neither of the medical staff nor of the administrative office – to better assess this hypothesis.

Additionally, for caregivers or family members, who reasonably ensure that the monitor stays on the bedside table allowing the remote monitoring to work or take care of the setup at home for the televisit, the real impact on their work is not clear since the interviews did not involve users of such technologies.

Work organisation

With regards to work organisation, for all of the technologies under study, some relevant changes have been identified in terms of work organisation, both in terms of methods (e.g. at least a partial increase in repetitiveness and standardisation for nursing staff, while possible increasing autonomy for doctors) and tools (i.e. increased use of digital technologies and need to follow specific protocols and procedures to ensure correct functioning).

Interestingly enough, the fact that the Lifepak defibrillator is able to store the timing of actions and makes it available on demand is not perceived as a means of further control by the medical staff; legal complaints are a regular occurrence in emergency environments and the possibility of assessing compliance with the medical protocol is virtually unopposed by the staff. In fact, in the words of an emergency doctor:

> *Checks aimed at verifying compliance with existing protocols are a daily occurrence for us. The fact that the technology is able to register our conduct does not really have an impact on our job*.

Another emergency doctor stated that:

> *Checks on correct procedures generally done, … but I can question the machine in the sense that I take out all the data the machine can give me.*
>
> *[…]*
>
> *But this is done if things go wrong. 'Question'. In this respect, is there a form of resistance from the staff? No, because by the very nature of our work you cannot exempt yourself from doing ex post verification; when you do this work you take on responsibilities.*
>
> RIUNITI TORRETTE HOSPITAL, Emergency Doctor

With reference to the emergency medicine staff at the peripheral hospital of Guastalla, the involvement of the stroke expert enables them to properly diagnose ischemic strokes versus haemorrhagic strokes and recommend the correct treatment. In fact, ischemic strokes require a thrombolytic procedure (also called fibrinolysis) that could be performed only at Santa Maria Nuova Hospital and requires immediate transfer. However, **telestroke** technology and the related improvement in correct diagnosis has encouraged the management of Guastalla to deploy such a procedure internally, resulting in the relevant upskilling of the nursing staff (required to carry out more complex tasks). In this way, only the most severe cases that require more intensive treatment will be centralised to the stroke unit of Reggio, while all other patients will be treated and hospitalised at Guastalla.

> *Now the thrombolytic procedure can be carried out at Guastalla.*
>
> *[…]*

It gave us a greater degree of autonomy. Of course, after the patient undergoes the thrombolytic procedure on-site, the most severe cases are then sent to Reggio for endovascular treatment on the stroke unit … nurses basically learned a new protocol. There is the whole procedure for monitoring patient with a stroke, how to insert the needle for the therapy, the dilution of the clot-busting drug. Basically, they too had to hone their skills to be able to assist in the thrombolysis phase.

GUASTALLA HOSPITAL, Emergency Doctor

The usage protocol written by the Italian Hospital Directorate (Direzione Sanitaria) together with the neurology division indeed allows the nursing staff to use the technology and perform the visit only in the presence of the emergency doctor, even if the option to give greater autonomy to nurses in launching and managing telestroke, as a countervailing measure for the shortages in doctors in emergency departments, is still a sensitive topic.

At the peripheral site, the nurse can take charge of the patient and start the telecommunication with the neurologist and ask for the intervention of the non-specialist physician [i.e. emergency doctor]. I believe that nursing competence can have many areas of development … and I am firmly convinced that these aspects should also be taken into consideration for a question of sustainability and identifying the core medical skills.

[…]

Then you also know the reactions of the Italian official association of doctors … There is a defence category that frankly does not belong to me. … in the case of telestroke, it is not so much the physical execution of some manoeuvres to come to a decision; it is that these are therapies that can have a series of complications and the monitoring of the patient in my opinion must therefore be entrusted to the emergency doctor in this case. … I believe that the relationship must be medical-medical. This is my opinion.

SANTA MARIA NUOVA, Neurologist

Job quality

Major effects on job quality concern the increased workloads, especially for nursing staff and specialised technicians ([33]), and the creation of more collaborative working environments in which nursing and medical staff operate, especially for telestroke and the Lifepak defibrillator, yet the remote monitoring of cardiac devices is also crucially dependent on daily interaction between the cardiologist and the dedicated IT division.

In fact, the use of the **telestroke** requires a relationship of trust between the neurologist – who cannot be present during the visit – and the in-person emergency doctor since the legal liability remains with the neurologist.

The big difference is learning how to work as a team … in the dynamics of traditional first aid, the neurologist arrives and the emergency doctor goes to do something else. Instead, now it is a team evaluation because one is the arm of the other.

SANTA MARIA NUOVA, IT Specialist

Now the neurologist has to trust their colleagues. Initially we were afraid that it could become a case of buck-passing, but eventually it just fostered the teamwork. … The practical advantage is also professional because to prepare this programme we did a very intense training job. … now the staff of the peripheral hub have not only entered into the logic of evaluating a patient with the right times and methods but also that of sharing the final decision with neurologists. So there is involvement in the diagnostic and therapeutic process for a stroke that was not there before.

[…]

This was positive because it has spread knowledge and now the medical and nursing staff of the spoke also have an exact idea of what it means to do thrombolysis, that is, to do a time-dependent therapy for a patient with a stroke.

([33]) In this respect, partial constraints to technology implementation related to competence and human resource availability at this level have also emerged.

SANTA MARIA NUOVA, Neurologist

With the adoption, emergency doctors have become a bigger part of the process and neurologists have learnt to trust colleagues and guide them to make all the relevant assessments for a correct diagnosis.

SANTA MARIA NUOVA, IT Specialist

Additionally, the **Lifepak** seems to exert a positive influence through the creation of additional opportunities for interaction and collaboration between colleagues at different levels of the work organisation.

Our interaction with cardiologists is now at a high level and I must say that it represents an important learning opportunity since they support you throughout the visit and explain why they choose to do a specific action or treatment.

[…]

However, the proper understanding of the ECG trace requires upskilling for our category. In fact, I paid for a private course on that on my own, even though I would say that experience plays a decisive role and after several months your on-the-job training would be sufficient.

RIUNITI TORRETTE, Emergency Doctor

The remote consultation with the cardiologist acts as a psychological support for the entire staff on the emergency vehicle, whether it is an '*auto-medica*' with a doctor on board or an '*auto-infermieristica*'.

The transmission of the ECG to the cardiologist from the ambulance gives you a psychological support … when you are not sure about the diagnosis, interacting with a specialised colleague helps you to see things more clearly.

RIUNITI TORRETTE, Emergency Doctor

When you are outside on the auto-infermieristica, being in contact with the cardiologist is of great help … The collaboration between cardiologists and nurses is facilitated by this transmission system and is also much more reassuring in the sense that the operator who is on the territory sometimes feels a little abandoned … In addition, maybe you are on a nursing emergency vehicle with no doctor on board and this becomes even more fundamental because you have telephone contact with a specialist doctor, after the transmission, who tells you exactly what to do.

RIUNITI TORRETTE, Nurse

Hence, all the technologies under study seem to exert a positive influence in this respect through the creation of additional opportunities for interaction and collaboration between colleagues at different levels of the work organisation.

Indeed, along the same path as the virtuous rise in more collaborative working environments, productivity in terms of the number of **implanted devices with a remote monitoring system** increased and the technical unit is supposed to welcome a third specialist within the coming months. Such a technical unit within the electrophysiology division was created *ex novo* for the remote monitoring of implanted heart devices, and since they work in close contact with cardiologists, the overall interaction within the department increased due to the technology.

Our productivity has increased; our numbers have increased a lot, in fact, a third technician should be coming to work with us. The number of new implants of cardiac devices per year is more or less about 250-300 implants, but the patient continues to use it for years. There is no turnover but an accumulation of patients, a constant growth.

SANTA MARIA NUOVA, IT Specialist on the Electrophysiology Unit

The management of the devices is far easier now. I must say that technicians do a great job. Other than the routine tasks related to the technical maintenance of the devices, the relationship with providers and the daily monitoring of relevant alerts, I asked them to report to me on the amount of disconnected patients every 15 days.

[…]

We collaborate on a daily basis; we are continuously in touch.

SANTA MARIA NUOVA, Cardiologist

On the other hand, few possible negative impacts on workers' health and safety have been detected, represented, for instance, by the weight of the Lifepak and the related fatigue that emergency doctors, together with drivers of ambulances and nurses, have to face when reaching patients' houses:

'The driver also helps me when I have to walk up several flights of stairs to bring the Lifepak close to the patient since it weighs 15 kilograms. Even if they are not supposed to, sometimes it is impossible to carry it on your own,' reported an emergency doctor.

Moreover, no career improvements or changes in wages related to the adoption of such technologies have been detected.

Task content

With reference to **Lifepak**, as for **telestroke**, emergency doctors and nurses are both the most highly affected in terms of task content.

All in all, besides a partial reduction of physical, intellectual and social tasks carried out by doctors (especially those in emergency departments), relevant changes in terms of task content for the nursing staff have been detected, with an increase in physical, intellectual (i.e. information processing, monitoring and problem-solving) and social tasks (i.e. increased interaction with doctors, teaching and training activities). Indeed, both technologies lead nurses to perform more tasks (of different types) without the presence of doctors.

For instance, based on the call the emergency department receives and the corresponding severity level, the doctor decides whether to bring the Lifepak on the emergency vehicle or not – generally, it is part of the standard equipment in case of heart attacks or respiratory deficiencies. Once on site, the doctor or the nurse enters the name and the gender of the patient, applies the electrodes and generates the ECG. If the tracing of the electrical activity of the heart is clear and the diagnosis matches the automated one provided by the machine algorithm, there is no need for transmission to the hospital unit. In some other situations, the remote support from the cardiologist is needed to clarify the nature and severity of the disease and to prepare the operating theatre, if required.

> *The placement of the dots is then generally done by the nurse ... we first enter the patient's name so that if we have to transmit the trace to cardiology they already see the patient's name on the monitor and it is easier to identify it ... you generate the ECG and the monitor gives you a diagnosis ... I try not to look at it, I make an evaluation myself first but it is usually very similar. I have never noticed anomalies and inconsistencies with a diagnosis that I may have made or even that the cardiologist made by phone viewing evidence on the computer ... at that point normally the nurse sends it to the cardiologist through transmission.*
>
> RIUNITI TORRETTE, Emergency Doctor

Additionally, the adoption of both technologies seems to lead to relevant upskilling, particularly in the field of digital competences, but also in the form of expanded knowledge and 'learning through interaction' with other colleagues and medical equipment as well as with technology providers and tech specialists.

The emergency doctors, for instance, save time related to useless transfers and dedicates more time to the diagnostic phase for the stroke patient, while the neurologists seem to have experienced a densification of tasks, although the number of centralised patients in the hub is now reduced. Moreover, the accuracy of the diagnosis is crucially dependent on the harmonisation of medical language between the non-specialist and the specialist doctor to ensure effective communication of the patient's symptoms. This led to gradual on-the-job upskilling of emergency doctors.

> *'Question'. So, on the part of the neurologist, is there an intensification of the working activity? Yes, in the midst of their activities, which are already quite hurried now, there is also the teleconsultation, ... but the amount of centralised patients sent by the peripheral [hospital] is now lower. 'Question'. But for you as an emergency doctor, there is no intensification, right? The telestroke added the diagnostic phase and took away a lot of useless trips. I spend more time on targeted diagnosis ...*
>
> GUASTALLA HOSPITAL, Emergency Doctor
>
> *We as emergency doctors had to improve our medical vocabulary to interact with neurologists. For example, for me there is just one type of aphasia, while for neurologists there are thousands of different shades of incapacity to speak of and in order to answer their questions we needed to refine our language and how we perform the visit.*

GUASTALLA HOSPITAL, Emergency Doctor

However, the upskilling of nurses (especially in the field of medical knowledge) is a bit controversial: some of the medical staff take a dim view of the Lifepak being used by nurses regardless of the presence of a doctor, while others consider it an unavoidable solution to the shortages in emergency departments that many regions have already overcome through the enrichment of the tasks carried out by nurses.

For example, in the Emilia-Romagna region, nurses can deliver pharmacological therapy, hence they can perform the whole treatment process for the patient: from the arrival on-site to the operating theatre in the hospital. However, there is no upgrade in the level of contract or in nursing staff remuneration.

> *Even if some colleagues do not accept it, the role of nurses will increase in importance in the coming years. … there still are relevant differences between regions about what nurses can or cannot do, but I think that the opposition of medical associations will not last long given the reduction in the number of emergency doctors we experience every day … now nurses can only transmit, they cannot do the therapy … there are some realities in Italy where the nurse in front of, let's say, in front of certain patients who have certain symptoms interfaces with the doctor on the basis of what is said by the nurse, the central doctor authorises them to give certain drugs, to carry out or do therapies in the within the field. Here it is not possible.*
>
> *Manager of the Emergency Division of ASUR Macerata and Ancona*

Likewise, for other involved operators such as the technical specialists of the Neurophysiopathology unit, it has emerged that they perform a daily check-up on the machine, even if this has not required further training and the acquisition of precise digital skills:

> *Every morning I turn on the computer, check that connections with the spokes are working and that is it. In an emergency, the machine has to be ready to use … the neurologist gave me this task almost 2 years ago before the pandemic since he knows that I am familiar with computers and general digital technology … I am the only technician responsible for this … there has been no training for me in this respect, I follow the protocol to keep track of potential problems in connecting the hub to the remote sites; basically I report on how the daily check went. … if something goes wrong, e.g. connection is weak and responses are delayed, I call the clinical engineering unit which contacts the supplier directly.*
>
> *'Question'. Did your job become more demanding, intellectually speaking? How did it change after the adoption of telestroke?*
>
> *Actually it is just another machine to check; I am passionate about computers so it does not require any specific mental effort.*
>
> *SANTA MARIA NUOVA, IT Specialist on the Neurophysiopathology Unit*

In both cases, technology adoption does not seem to entail relevant changes in the overall level of occupation. The Lifepak 15 monitor/defibrillator, for instance, seems not to demand new hirings, as it (at least partially) responds to the lack of emergency doctors by providing nurses on emergency vehicles with a reliable technology for accurate diagnosis. However, the technology requires that at any moment in time, when the call that warns about the following transmission is received, the cardiologist should leave the ongoing activity and reach the station that acquires the information and bear the responsibility of the diagnosis.

With reference to the **remote monitoring of implantable cardiac devices and the provision of televisits**, relevant changes in terms of task content concern the tech specialists and the administrative units, with an increase in physical, intellectual and social tasks. Relevant upskilling, especially in the field of digital competences, can also be detected. For the **remote monitoring of implantable cardiac devices**, the tech specialists on the electrophysiology unit at Santa Maria Nuova Hospital are in charge of checking the mailbox every morning and frequently during the day, and to evaluate the priority of the alert. In the case of low priority, intervention by the cardiologist is not needed: the tech specialists contact the patient and set an appointment in person to restore the functioning of the device. In the case of medium-high priority, they address the cardiologist to decide upon the urgency for convening the meeting with the patient; sometimes the visit is carried out by the tech specialists, while some others that require a more detailed clinical examination are held by the cardiologist. The call from the tech specialists is crucial since the patient does not receive any direct warning from the device in the case of anomalies.

> *Our main activities are based on the control of the remote monitoring system; it is one of our priorities. So every morning from Monday to Friday, one of the first things we do is to check the*

mailbox to see whether any alert arrived from the remote monitoring systems that patients have at home … one of our tasks is the technical evaluation of the type of information we receive: if the alert is a priority and deserves immediate attention we inform the doctor … and the clinical decision is up to them; it is their responsibility. If the alert needs further investigation, we call the patient and arrange a visit in person: the patient is then received in our clinic by us technicians and we do a preliminary check of the device. After that, if it is the case, the cardiologist intervenes and finalises the visit, but it is also possible that our technical check-up is sufficient to solve the problem. … we actually do a frequent check of the emails even while I do other activities. … we follow the patients even if they do magnetic resonance imaging, if they undergo radiotherapy cycles or special therapies … our profession is also required in the operating theatre when the device is implanted.

SANTA MARIA NUOVA, IT Specialist on the Electrophysiology Unit

The IT specialist on the electrophysiology unit also emphasises remarkable professional enrichment due to continuous updates concerning the functioning and applicability of the remote monitoring technology.

At least half, three quarters of our time is dedicated to the technology and related tasks. From a professional point of view, it was certainly a great advantage, we as technicians also gained a lot because these remote monitoring systems are demanding and require constant updates so we keep ourselves updated along with our devices, leading to remarkable professional enrichment. … the total workload has increased since the total number of patients has increased … you used to see many patients once a year, now you follow them every day so potentially there is much more work to do.

SANTA MARIA NUOVA, IT Specialist on the Electrophysiology Unit

On the contrary, cardiologists were not really impacted by the implementation of the technology since almost the entire workload – except for carrying out the visit in the case of the most severe or controversial alerts – is maintained by tech specialists.

With reference to the **televisit** technology, patients who undergo a televisit can contact customer service at the hospital to receive assistance in case of problems with the platform, i.e. they are not able to log in since they forgot the password, they do not succeed in uploading relevant documents, they are late or need to postpone the appointment and so on. In this sense, the operators of the call centre need to cover technical assistance for the patient and they also assign the station to the doctor for carrying out the televisit.

At the end of the televisit the doctor is supposed to leave a comment for customer service about the outcome of the visit, and in case of unsatisfactory results, the patient is appointed with another free-of-charge reassessment in person. Generally, their time schedule has not changed much and they essentially converted some in-person visits to remote teleconsultations.

Certainly, the way the doctor gets ready for the visit has changed. With televisit it is no longer the patient who brings relevant paper documentation, but they are supposed to upload it on the Secure Doc Sharing platform in advance and someone – typically a non-medical person – is supposed to download and deliver it to the doctor. Therefore, the doctor gets access to the patient's clinical history in advance and is able to arrange the visit accordingly … the biggest change was on the organisational side. The customer service now supports patients from booking to the moment of the televisit, as well as communicating with doctors on logistics arrangements …. The medical staff made a significant upgrade in digital skills since now they are able to manage the visit via Google Meet on their own.

HUMANITAS, Engineer in the IT office

The nursing staff mainly approached the technology to hold those meetings prior to hospitalisation to outline basic instructions to the patient and relatives: now nearly all of them are carried out through Google Meet.

Overall, the digital competences of all actors involved have been fostered by the adoption of the technology. However, the role played by caregivers in mediating the adoption of the process remains unclear.

5.6 Discussion and conclusions

This chapter aims to offer new insights into the patterns and consequences of adoption of remote monitoring devices in healthcare. Specifically, we provide a summary of the main findings stemming from the company interviews carried out in three selected hospitals – namely, Santa Maria Nuova Hospital, ASUR Marche and Humanitas Research Hospital – in relation to the adoption of four specific technologies: respectively, i)

telestroke; (ii) remote monitoring technologies for implanted heart devices; (iii) remote monitoring devices for cardiovascular conditions and for defibrillation onboard advanced emergency vehicles (Lifepak 15); (iv) devices allowing remote, web-based visits or televisits.

All in all, the information collected only partly supports our *ex ante* expectations regarding the main drivers of and obstacles to the adoption of such technologies and, especially, their impact on and consequences for work, work organisation and tasks.

With reference to the main drivers, both the need to ensure improved health assistance (e.g. by avoiding incorrect diagnoses and reducing time before treatment in case of emergency) and that of cutting costs and increasing efficiency (e.g. by reducing the flow of patients going to hospitals for routine visits and, thus, hospital overcrowding) have clearly emerged. It is also clear that the COVID-19 pandemic has dramatically accelerated the process of adoption and implementation of these technologies.

As for the specific barriers, the main obstacles highlighted refer to the organisational dimension and, in particular, relate to the difficulties of rearranging shifts, working activities and tasks. However, any open resistance, opposition or reluctance from workers or patients has not been identified.

With specific reference to the hypotheses developed in Section 2 on the impact of the technologies on work processes and working conditions, the results only partially meet our expectations.

As far as doctors are concerned, there seems to be no complete suppression of tasks related to in-person medical visits and check-ups (at the hospital or at home) and initial diagnoses. Indeed, the technologies in question appear more complementary rather than substitutive, in the sense that they provide better support for the tasks performed by the medical staff, though never implying their complete substitution or, to some extent, 'automation'. This becomes particularly evident with respect to an initial diagnosis.

Turning to nursing staff and administrative units, as expected, we do find evidence of an increase in workloads, also with consistent task enrichment and relevant upskilling, particularly in the field of digital competences.

With reference to caregivers, in light of the information collected, we can further note that their role is crucial for mediating and, thus, indirectly fostering the adoption processes, especially by ensuring the correct application and use of the technologies by patients. Nevertheless, the real impact on caregivers' tasks and their overall burden is still not clear since the interviews carried out have not involved technology users.

6 Conclusions

At the time the research project "Case studies of Automation in services" started, the scientific and public debates were dominated by techno-optimist and techno-pessimist views, both largely sharing a strong deterministic perspective on the unfolding of technologies within sectors of activities, companies and their impact upon labour. Massive unemployment scenarios or, alternatively, narratives on man and women's liberation from hard labour have demonstrated to fail a deep understanding of economic processes in which technological changes are rooted.

As times goes by, even mainstream economists - used to see in the long run the emergence of a new equilibrium through self-adjusting forces and pay rising/falling according to the tasks required by the new technologies – opened the door to uncertainty. '*Traditional economic optimism about the beneficent effects of technology for productivity and welfare has eroded as understanding has advanced. Fundamentally, technological change expands the frontier of human possibilities, but one should expect it to create many winners and many losers, and to pose vast societal challenges and opportunities along the way*' affirmed David Autor in one of his very recent papers ([34]). Is this the case?

In this work we have explored the main changes occurring at workplace level in relation to automation technologies intended as technological devices aimed to *automate* work processes, and specifically automated guided vehicles in logistics, cleaning robots and health monitoring devices in the health sector. Indeed, the novelty of the study has been to focus on service industries instead of manufacturing. While the massive introduction of robotized work has certainly characterized the manufacturing sector over the last decades, with robotic devices able to substitute for repetitive and "routinized" activities, only more recently, automating technologies have become increasingly relevant in services. Therefore, this research project has aimed to empirically assess through the adoption of a qualitative type of analysis based on the realization of case studies: i) the main drivers and obstacles behind the adoption of technological artefacts supposed to *automate* specific phases of work; ii) the main processes of work reorganization occurring at the workplace level potentially affecting the distribution of tasks among workers and eventually leading to job displacement or, conversely to the creation of new professional figures.

The qualitative analysis - based on an intense fieldwork activity lasting about one year for a total of 57 interviews - has been inspired by the evolutionary theory of technical change and the capability-based theory of the firm, following three main principles.

First, the non-neutrality of technological change with respect to the capital-labour (and gender) relations. New and old technologies are nested in complex political economies, ranging from the division of labour and power at enterprise level to legislative, fiscal and demand-management policies (Dosi and Virgillito, 2019). If this is the case, technologies as such are not good or bad since their use and application need to be contextualized in capitalist economies, where conflict over labour processes, income distribution and power are structural features.

Second, we have considered technology as an ensemble of recipes, consisting of both codified and non-codified knowledge. Therefore, the space of human intervention on the production process has to be understood in relation to organizational routines, namely the ensemble of conditions occurring among the members of a given organization (Dosi and Nelson, 2010). Therefore, the routine/non routine dichotomy poorly explains which tasks are ex-ante expected to be substituted or augmented because one should also account for organizational practices. This is what we aimed to explore in continuity with previous research on the Italian metal industry (Cirillo et al., 2021; Garibaldo and Rinaldini, 2021) inspecting technological and organizational changes as simultaneous forces reshaping production processes.

Third, this study relies upon an anti-deterministic perspective on the role of technology with respect to jobs and tasks, as also recently developed by Fernández-Macías and Hurley (2017) and Fernandez-Macias et al. (2022) focusing on division of labour and role of institutions. From this point of view, this research project has intended to study the unfolding of technology inside firms in terms of organizational practices and routines regulating the work process and, therefore, considering technology not as a datum but as a choice.

([34]) Autor, D. (2022) The Labor Market Impacts of Technological Change: From Unbridled Enthusiasm to Qualified Optimism to Vast Uncertainty (No. w30074). *National Bureau of Economic Research*.

Bearing in mind these three principles, we can assess our first finding. So far, there is no evidence of labour displacement due to the adoption of automation technologies. From this point of view, most radical changes have occurred in the logistic sector since the introduction of the automated guided vehicles (AGVs) has reconfigured the execution of certain tasks previously performed by forklift drivers, of course with high heterogeneity across plants – depending mainly on the level of integration of the AGVs in the work process. For instance, in the case of PMMTB, two new groups of professional figures were created for the management of AGVs: (i) the technical and maintenance worker who monitors the AGVs on the ground and from the control room; (ii) the Logistics Automation team at PMI also monitoring the AGVs and the performance of SIMIC at a higher level. The execution of specific manual tasks before in the hand of forklift drivers has now been outsourced to an external company, named LOGISTA. At AMAZON, AGVs contribute to the reshuffling of the pick and stow tasks, leading to the introduction of new jobs, such as that of Amnesty Responder or that for technical robotics maintenance, but their introduction did not lead to the disappearance of forklifts. AGVs at POSTE operate as an 'auxiliary' technology whose introduction did not massively affect the organisation of work and the tasks of workers. Before the introduction of AGVs, when POSTE workers needed to transport sorted mail to another area, they called forklift operators or even transported carts on their own. Now workers can use AGVs instead of moving their own carts or calling for a forklift driver.

Overall, while in POSTE, AGVs remain a technology *in support of* the human functions, also implying substitution of forklifts, in AMAZON they are a technology *leading* the human functions which are required to adapt to the pace and rhythms of the centralised software management system regulating the movements and the speed of the AGVs. The hybrid case of PMI represents a strict divisional attribution of tasks to oversee the logistic function during very specific phases of the production process. Workers and their functions are neatly distinguished in terms of responsibility and even employed by different firms.

Such heterogeneous outcomes of the very same human-machine (AGVs) relationship result from both the final product/service produced but also by the techno-organizational capabilities of the firm and the type of strategic orientation versus technological adoption. Exemplary is the case of POSTE vs AMAZON FC, both operating on the distribution segment but characterised by profound diverse attitudes toward technological adoption, with total in-house development and integration in AMAZON contrasting with a total technological dependence from external supplier in POSTE. The conception and management of technologies than clearly maps into the way in which the work process is organised.

Focusing on the cleaning sector which shares some features with logistics – it is considered to perform low-value-added tasks, characterised by cascades of contracting and subcontracting procedures, generally short-lasting contracts and relies on a cheap and abundant labour force – the introduction of cleaning robots did not lead to workers displacement either. In fact, the adoption of the machine did not impact (at the Dussmann Service) the working pace and left workers' autonomy in setting procedures unaffected. Conversely, the introduction of cleaning robots has increased the number of tasks performed by operators, who together with visually controlling the machine, have to clean and do the other scheduled work activities.

Similarly, in the health sector the adoption of remote monitoring devices did not lead to workers substitution. For instance, at Santa Maria Nuova Hospital remote monitoring required the hiring of a dedicated technical figure, creating a brand-new technical office for the electrophysiology division. With reference to Lifepak 15, contrary to expectations, the technology did not suppress the initial diagnosis by the medical staff since the diagnosis provided by the machine acts only as a support for the assessment made by the emergency doctor or the nurse. In some cases (see Humanitas), the doctor is left with a high level of discretion towards the means by which to carry out the visit, i.e. remotely or in person. In this case, it is reasonable to suppose that doctors decide in advance based on a careful evaluation of the patient's medical history, indeed creating a new task. The healthcare sector is the one most characterised by a technology-disease nexus: the technologies under scrutiny were diverse across them but also employed in particular wards of the hospital under analysis and with reference to very specific treatments. Two aspects remain crucial in explaining the results in the healthcare: the space of action of the public, whenever hospitals are public and of regional policies, and the race toward telemedicine accelerated by the pandemic, which quite probably will deeply affect the sector in the near future, particular private hospitals.

Overall, the analysis confirms the complexity in automating presumably low-value-added phases: human labour remains crucial in conducting activities that require the flexibility, adaptability and reconfiguration of physical tasks as in the case of cleaning, but also in the logistic there is a 'self-imposed limitations' on automation, responding to the flexibility requirement that AGV automation cannot ensure. In the health sector automation intended as pure substitution of human activity so far has not been implemented. The technologies in question appear more complementary rather than substitutive, in the sense that they provide

better support for the tasks performed by the medical staff, though never implying their complete substitution or, to some extent, 'automation'. This becomes particularly evident with respect to an initial diagnosis.

Our main second finding concerns internal and external drivers and barriers to technological adoption. Although the three sectors show a high level of heterogeneity and very different degrees of adoption of the three technologies, we can assess that internal (to the firm) drivers play an important role across the three cases. In the logistic sector, for instance, safety (and ergonomics), quality, productivity and reduction of low-value-added operations are crucial factors to evaluate the adoption and integration of AGVs. Similarly, cost-effectiveness may represent an important managerial driver in the cleaning sector: the potential removal of the operator driving the semi-automated cleaning machine during night shifts, paid more than a daily one, would have represented the saving of money. In addition, automated vehicles optimise cleaning routes while ride-on machines do not guarantee such time optimisation. Even in the health sector cutting costs and increasing efficiency (e.g. by reducing the flow of patients going to hospitals for routine visits and, thus, hospital overcrowding) have clearly emerged during interviews. Of course, in the health cases the need to ensure improved health assistance (e.g. by avoiding incorrect diagnoses and reducing time before treatment in case of emergency) plays a crucial role.

Furthermore, in the logistic sector business reconfiguration is an important factor shaping investment decisions. PMI is a case of market innovation: in the framework of a medium-to-long-term strategy, PMI decided to develop no-smoke tobacco products, which implied the design of a new production process, that of HeatSticks, at the new site in Bologna. AGVs are at the centre of this new production process and are integrated into a digitised and partially automatised organisational environment. POSTE is a case of market diversification. As reported by management, POSTE is facing a dramatic decline in postal traffic and the goal is to find new business lines. AGVs are part of the new 'Deliver 2022' strategy, whose goal is POSTE's entry into the market segment of e-commerce deliveries, a strategy which also includes a commercial partnership with AMAZON. Lastly, AMAZON is a case of market expansion since AGV-equipped FCs have been opened by AMAZON over the last years in Europe, in a context of huge sales and operations expansion. From this point of view, 'external' drivers of technological adoption must be linked to monopolistic power of companies in the global markets and their investment strategies in intangible assets (such as those related to these technologies).

On the other side, obstacles to automation are diverse and range from technical unfeasibility intended as all problems associated with the adaptation of AGV systems to the layout of the plants (see the case of POSTE) or high level of rigidity in the organisation of the infrastructure (see the case of PMI), or even inadequacy of technologies available on the market (Dussmann for the cleaning sector). Software obstacles matter since new technologies require a high level of integration: technologies can only be adopted if they are compatible with the other technologies, and this limits the choice of adoption unless the decision is made to reconfigure the entire system. Obviously, technologies' integration matters mostly for technologically dependent companies lacking technical autonomy even if they also innovate when adopting new techniques (Rikap and Lundvall, 2021).

This emerged to be relevant also in the health sector where the problem of software integration among diverse units, such as central healthcare divisions and hospitals (see the case of the telestroke) has been highlighted during the interviews. However, in the health sector there are also organizational elements to discourage or limit the adoption of technologies. In fact, telestroke is not active on night shifts since there is only one neurologist in operation at Santa Maria Nuova Hospital, who would not be able to carry out both routine tasks and the teleconsultation. In the case of health, partial constraints to technology implementation related to competence and human resource availability have also emerged.

Focusing on external obstacles, market instability plays an important role: market variations cannot be completely governed, and planning must always be flexible and reactive enough. AGV automation does not provide the degree of flexibility required. Therefore, at AMAZON for instance, management did not replace all internal logistics operations with AGVs, but maintained a share of them under human governance and execution. In the case of health sector, one of major drawbacks has to do with lack of connectivity on the territory that can slow down the whole process (see the case of Lifepack 15). The possibility of disconnecting the device from the remote monitoring system is also acknowledged as the main limit of the technology (remote monitoring of heart devices at Santa Maria Nuova Hospital).

Spatial and environmental constraints are considered very important in the cleaning sector - see the case of Coopservice, which provides cleaning services in highly unstructured workplaces that require fine, precise,

agile and fast intervention relying on dexterity and fluid mobility, all factors preventing the standardisation of the service.

Lastly, institutional factors are relevant in all sectors. For instance, in the provision of cleaning services, the social regulation adopted by public entities that ensures the maintenance of the entire workforce from one tender to another influences the decision to introduce cleaning robots. Similarly in the health sector, the main real barrier to adoption points at the staff shortages for telestroke and therefore public policies financing recruitment of personnel in healthcare.

Overall, drivers and barriers to technological adoption (with the exception of institutional factors) are mainly linked, as said, to techno-organizational capabilities of the companies and their abilities to govern technological change.

Our third main finding concerns organizational changes, declined mainly in terms of work-organization, job quality and task content. In this respect, technological and organizational changes have been treated as two intimately related processes. Among all case studies, POSTE has been the one where the introduction of AGVs did not require any special reorganisation of the workflow. The latter remained the same due to technical problems with the layout and the low number of AGVs, although workers reported some micro-changes occurring within the workflow. Compared to POSTE, and even compared to PMI, AGVs at AMAZON have had a huge impact on work and on the global organisation of the production process. Work activities characterising the job of pickers and stowers have been reshuffled entirely and new professional figures have been introduced, like that of Amnesty Responder, although representing a tiny fraction of the workforce. Similarly to PMI where the use of AGVs impacts different groups of workers – PMI Supervisor Logistics Automation, LOGISTA operators and SIMIC technical figures -, in the cleaning sector the automation seems to give more autonomy to intermediate figures employed at Coopservice, such as the contract leader, responsible for the overall management of the specific sites, and team leaders, who coordinate and supervise groups of operators.

Indeed, work organizational aspects have been shown to be crucial in the health sector: for all of the technologies under study, some relevant changes have been identified in terms of work organisation, both in terms of methods (e.g. at least a partial increase in repetitiveness and standardisation for nursing staff, while possible increasing autonomy for doctors) and tools (i.e. increased use of digital technologies and need to follow specific protocols and procedures to ensure correct functioning).

Lastly, in terms of job quality, results are diverse. In some cases improvements of working conditions (see the case of POSTE) due to the reduction in human-driven forklifts on the floor and in the pedestrian transit zones have been registered in the logistic sector. With regard to ergonomics and safety, the task relocation and the introduction of AGVs that could have opened the door for new kinds of risks for operators seems, instead, to have led to greater compliance with safety provisions.

With regard to working rhythms, in the logistic sector they do not appear as a direct and immediate consequence of AGV introduction. But of course, AGV introduce a new constraint for workers in terms of the determination of pace of work: either because machinery continues with informatisation and more monitoring; and because machinery has a pace of work that can be independent of the will of workers. The introduction of AGVs has standardised the work activities of manufacturing operators, reducing time spent on low-value-added tasks.

In the case of cleaning robots, task 'densification' was recorded for all companies considered: operators perform more tasks besides the daily maintenance of the machine. Similarly, in the health sector major effects on job quality concern the increased workloads, especially for nursing staff and specialised technicians, and the creation of more collaborative working environments in which nursing and medical staff operate, especially for telestroke and the Lifepak defibrillator, yet the remote monitoring of cardiac devices is also crucially dependent on daily interaction between the cardiologist and the dedicated IT division. Furthermore, in the case of specific technologies of the health sector few possible negative impacts on workers' health and safety have been detected, represented, for instance, by the weight of the Lifepak and the related fatigue that emergency doctors, together with drivers of ambulances and nurses, have to face when reaching patients' houses.

Together of increases in workloads in some cases, we found evidence of task enrichment and relevant upskilling, particularly in the field of digital competences in the health sector. For instance, the latter did not occur in the logistic or cleaning sectors where digital competences to use (and not to govern) technological artefacts are very basic.

Lastly, in this research report we have focused on the degree of involvement of trade unions in the processes of technological design, adoption and implementation following previous evidence and research developed for the automotive sector (Cirillo et al., 2020; Garibaldo and Rinaldini, 2022). All companies share a common factor that is a low level of involvement of trade unions in the decisions concerning technological change. Unions do not intervene in the matter of technological innovation, and this is understood and confirmed by the trade unionists themselves when declaring that they 'manage the outcomes' of automation. The adoption was, in all aspects, a managerial decision: unions have never been involved in the process, not even for safety- or training-related matters, and they were informed only when it was all set for the technology to be operational. Even for the cleaning robots, the involvement of workers and their unions in strategic decisions related to innovation technologies can be considered extremely negligible, and no trend reversal seems to occur in the near future given the lack of debate within trade unionists. The same applies for the health sector where unions have not been involved and other medical staff, such as the nurses in the hub and the emergency doctors in the spoke, were informed about the aim of the project in collegial meetings before the start of the experiment.

All these elements suggest that when approaching the problem of the reorganization of the world of work because of the introduction of new automation technologies in the service sector there are patterns of both continuity and discontinuity with findings in the manufacturing sector.

In terms of continuity, the managerial decision to adopt these new artefacts is extremely oriented to motives of productivity efficiency and cost saving. In addition, monitoring and control of the work process are indeed the most of effective gains that those technologies allow to gather, together with reduction of human intervention (in the case of AGVs). Therefore, the most relevant driver of adoption remains the reduction of low-added-value phases and related low-added-value human functions/operators, in line with the just-in-time approach quite widespread in the manufacturing sector.

From the labour perspective, continuity with the manufacturing is represented by the intensification of working rhythms, densification of tasks and saturation of time. These patterns are well known in the manufacturing sector (Cirillo et al., 2021) and quite neatly apply, although with differences (see the case of POSTE), to the service sector.

In terms of discontinuity, the obstacles to adopt still prevail when compared to the drivers, in particular technical and institutional obstacles are such that widespread adoption of automation and monitoring technologies in services are still not the preferred choice. We do observe an even more cautious and function-specific/disease-specific pattern of adoption than in the manufacturing.

In addition, the role of human agency, workers involvement, high-performance work practices are almost non-existent in the service sector, *per sè*, and even more so when linked to technological adoption. Indeed, human agency and worker representation, in particular the role of trade unions, are almost disregarded and not considered by the firms when deciding to introduce a new technology (see for example the case of the "horizontal" human resource model of AMAZON, or the lack of recognition of increasing workloads for nursing and organizational staff, or the lack of interest even from trade unions themselves toward cleaning workers).

Finally, if different hierarchical functions, from managers to operators in a manufacturing firm, are distinctively affected in terms of the autonomy in doing the job by technologies, this is even more so comparing doctors versus nurses/managers of the cooperative vs cleaning workers: technology exerts different capacity to reconfigure the working activity depending on the power and knowledge embedded by the occupation under consideration and the service sector is per sè more unequally structured in terms of division of labour when compared to the manufacturing. Therefore, inter-firm inequalities tend to be deeper.

All in all, although the task-based approach is useful in assessing the reconfiguration of the working activities, occupations and their hierarchical roles inside the organization in which operate remain a crucial aspect in affecting the unfolding of technologies upon the world of work. This is so because technologies tend to accelerate pre-determined roles and functions deriving from the ex-ante technical division of labour and knowledge inside organization, they are not the *cause* but rather the *mediating factor* amplifying existing conditions (as the role of hierarchies), practices (as the space of negotiation), and patterns (as the pace of working rhythms). In that, this implies that technologies can be administrated and governed with very differentiated end scopes.

Future analyses should more explicitly entail the role of hierarchies as potential co-founding factor behind the human-machine relationship, together with the role of the techno-organizational capabilities of the firm under analysis. In addition, more effort is needed to uncover the entire supply chain, including subcontractors of the final service delivered (from truck drivers to caregivers). Research should be devoted to understand ongoing

processes affecting the lowest segments of the occupational hierarchies in the service sector, nowadays populating the largest fraction of labour markets even in advanced countries, combining the gender and the race dimensions as other crucial determinants of the effects of technologies upon the world of work.

References

Allen, W. B., 'The logistics revolution and transportation', *The ANNALS of the American Academy of Political and Social Scien*ce, Vol. 553, No 1, 1997, pp. 106–116.

Alvesson, M., Karreman, D., *Qualitative research and theory development: mystery as method*, Sage Publications, 2011.

Autor, D. H., Levy, F., Murnane, R. J. 'The skill content of recent technological change: An empirical exploration', *The Quarterly Journal of Economics*, Vol. 118, No 5, 2003, 1279-1333.

Bonacich, E., Wilson, J. B., *Getting the goods. Ports, labor, and the logistics revolution*, Cornell University Press, Ithaca (NY), 2011.

Bottalico, A., *Automation processes in the port industry and union strategies: the case of Antwerp*, New Global Studies, 2022.

Briken, K., Chillas, S. and Krzywdzinski, M., *The new digital workplace: how new technologies revolutionise work*, Macmillan International Higher Education, 2017.

Brynjolfsson, E., McAfee, A*., The second machine age: work, progress, and prosperity in a time of brilliant technologies*, W. W. Norton & Co., 2014.

Calvino, F., Virgillito, M.E., *'The innovation employment nexus: a critical survey of theory and empirics'*, *Journal of Economic Surveys*, Vol. 32, No 1, 2018, pp. 83–117.

Cetrulo, A., Guarascio, D. and Virgillito, M. E., 'Anatomy of the Italian occupational structure: concentrated power and distributed knowledge', *Industrial and Corporate Change*, Vol. 29, No 6, 2020, pp. 1345-1379.

Cirillo, V., Evangelista, R., Guarascio, D. and Sostero, M., 'Digitalization, routineness and employment: an exploration on Italian task-based data', *Research Policy*, Vol. 50, No 7, 2021, 104079.

Cirillo, V., Fanti, L. and Tubiana, M., 'Tecnologie I4.0 e profili di innovazione delle imprese italiane', *Economia & Lavoro*, Vol. 55, No 1, 2021, pp. 99-120.

Cirillo V., Mina A. and Ricci A., 'Digital technologies, labor market flows and investment in training. Evidence from Italian employer-employee data', *Inapp Working Paper* No 79, Roma, Inapp, 2022.

Cirillo, V., Rinaldini, M., Staccioli, J. and Virgillito, M. E., 'Trade unions' responses to Industry 4.0 amid corporatism and resistance', *LEM Working Paper Series* No 21, Scuola Superiore Sant'Anna, Laboratory of Economics and Management (LEM), Pisa, 2020.

Cirillo, V., Rinaldini, M., Staccioli, J. and Virgillito, M. E., 'Technology vs. workers: the case of Italy's Industry 4.0 factories', *Structural Change and Economic Dynamics*, Vol. 56, 2021, pp. 166-183, 2021.

Delfanti, A., 'Machinic dispossession and augmented despotism: digital work in an Amazon warehouse', New Media & Society, Vol. 23, No 1, 2021, pp. 39-55.

Dosi, G., Nelson, R., *Technical change and industrial dynamics as evolutionary processes in Handbook of the Economics of Innovation*, edited by Bronwyn H. Hall and Nathan Rosenberg Vol. 1, North Holland, 2010.

Dosi, G., Virgillito, M. E., 'Whither the evolution of the contemporary social fabric? New technologies and old socio-economic trends', *International Labour Review*, Vol. 158, No 4, 2019, pp. 593-625.

Dosi, G., Marengo, L. and Virgillito, M. E., 'Hierarchies, knowledge, and power inside organizations', *Strategy Science*, Vol. 6, No 4, 2021a, pp. 371-384.

Dosi, G., Piva, M., Virgillito, M. E. and Vivarelli, M., *'Embodied and disembodied technological change: the sectoral patterns of job-creation and job-destruction'*, *Research Policy*, Vol. 50, No 4, 2021b, 104199.

Eisenhardt, K. M., 'Building theories from case study research', *Academy of Management Review*, Vol. 14, No 4, 1989, pp. 532-550.

Equality and Human Rights Commission, *The invisible workforce: employment practices in the cleaning sector,* findings report, 2014, https://www.equalityhumanrights.com/sites/default/files/the_invisible_workforce_full_report_08-08-14.pdf.

Fernández-Macías, E., Automation, digitalisation and platforms: implications for work and employment, Publications Office of the European Union, Luxembourg, 2018, https://hdl.handle.net/1813/87388.

Fernández-Macías, E., Bisello, M., 'A comprehensive taxonomy of tasks for assessing the impact of new technologies on work', *Social Indicators Research*, Vol. 159, No 2, 2022, pp. 821-841.

Fernández-Macías, E., Bisello, M., Peruffo, E. and Rinaldi, R., 'Routinization of work processes, de-routinization of job structures', *Socio-Economic Review*, 2022, https://doi.org/10.1093/ser/mwac044.

Fernández-Macías, E., Hurley, J., 'Routine-biased technical change and job polarization in Europe', *Socio-Economic Review*, Vol. 15, No 3, 2017, pp. 563-585.

Ford, M., *The Rise of the robots. Technology and the threat of mass unemployment*, Basic Books, 2015.

Garibaldo, F., Rinaldini, M., *Il lavoro operaio digitalizzato: inchiesta nell'industria metalmeccanica bolognese*, Il Mulino, Bologna, 2022.

Grande, R., Vallejo-Peña, A. and Urzi Brancati, C., 'The impact of IoT and 3D printing on job quality and work organisation: a snapshot from Spain', JRC Working Papers Series on Labour, Education and Technology No 10, Seville, European Commission, 2021.

Grimshaw, D., Cartwright, J., Keizer, A., Rubery, J. with Hadjivassiliou, K. and Rickard, C., *Coming clean: contractual and procurement practices.* Research Report 96. Manchester, Equality and Human Rights Commission, 2014, www.equalityhumanrights.com/publications/our-research/research-reports.

Gutelius, B., Theodore, N., *The future of warehouse work: technological change in the U.S. logistics industry*, UC Berkeley Labor Center, 2019.

Massimo, F., 'Burocrazie algoritmiche. Limiti e astuzie della razionalizzazione digitale in due stabilimenti Amazon', *Etnografia e ricerca qualitativa*, No 1, 2020a, pp.53-78.

Massimo, F., A *struggle for bodies and souls: Amazon management and union strategies in France and Italy* in *The cost of free shipping: Amazon in the global economy* edited by J. Alimahomed-Wilson and E. Reese, Pluto Press, 2020b.

Mondolo, J., *The composite link between technological change and employment: a survey of the literature*, Journal of Economic Surveys, 2021

Montobbio, F., Staccioli, J., Virgillito, M. E., and Vivarelli, M., 'Robots and the origin of their labour-saving impact', *Technological Forecasting and Social Change*, Vol. 174, 2022, 121122.

Moro, A., Rinaldini, M., Staccioli, J. and Virgillito, M. E., 'Control in the era of surveillance capitalism: an empirical investigation of Italian Industry 4.0 factories', *Journal of Industrial and Business Economics*, Vol. 46, No 3, 2019, pp. 347-360.

Moro, A., & Virgillito, M. E., 'Towards Factory 4.0? Convergence and divergence of lean models in Italian automotive plants', *International Journal of Automotive Technology and Management*, 22(2), 2022, pp. 245-271.

Jürgens, U., & Krzywdzinski, M., *New worlds of work: varieties of work in car factories in the BRIC countries*, Oxford University Press, 2016.

Litwin, A., *Technological change in health care delivery: its drivers and consequences for work & workers*, Berkeley, UC Berkeley Labor Center, 2020.

Lloyd, C., & Payne, J., 'Rethinking country effects: robotics, AI and work futures in Norway and the UK', *New Technology, Work and Employment*, Vol. 34, No 3, 2019, pp. 208-225.

Randstad Research, Le nove sfide per il futuro del lavoro nella logistica, 2020, https://research.randstad.it/rapporti/rapporto_completo_logistica.pdf

Rikap, C., & Lundvall, B. Å., *The digital innovation race*, Springer Books, 2021.

Sostero, M., *Automation and robots in services: review of data and taxonomy*, *JRC Working Papers Series on Labour, Education and Technology*, No 14, 2020, European Commission, Joint Research Centre (JRC), Seville.

Staccioli, J., Virgillito, M. E., 'Back to the past: the historical roots of labor-saving automation', *Eurasian Business Review*, Vol. 11, No 1, 2021a, pp. 27-57.

Staccioli, J., Virgillito, M. E., *The present, past, and future of labor-saving technologies* in *Handbook of labor, human resources and population economics*, Cham: Springer International Publishing, 2021b.

Smith, C. and M. Vidal, *The lean labour process: global diffusion, societal effects, contradictory implementation,* in International Handbook of Lean Organization, ed. by Thomas Janoski and Darina Lepadatu, Cambridge University Press, 2019

U.S. Bureau of Labour Statistics, *Occupational outlook handbook*, 2022, https://www.bls.gov/ooh/home.htm

Wood, A. J., 'Algorithmic management consequences for work organisation and working conditions', JRC Working Papers Series on Labour, Education and Technology No 7, Seville, European Commission, 2021.

List of figures

List of tables

Annexes

Annex 1. Content model for analyses of interviews

First-level code	Second-level codes	Third-level codes
Economic processes	Transformation of the business model because of automation	Investment in physical capital
		Investment in digitalisation
		Investment in building, infrastructure, trucks
		Investment in specific types of automation
	Relations with supply chain	Providers and their location
		Product assistance and customisation
		Financing – access to external funds
Drivers of adoption	Managerial drivers	Increasing productivity
		Reducing costs and lead times
		Reducing errors
		Performance tracking
		Gaining market share
	Automation and labour demand	Expel labour force
		New hiring
		Change workforce composition
	Worker drivers	Trade unions fostering adoption
Barriers to adoption	External obstacles	Absence of market opportunities
		Cost of investments
		Process not automatable (manual dexterity too complex)
	Internal obstacles	Absence of internal capabilities in using automated machines
		Reorganisation of the production process
		Trade unions or workers' resistance
Work organisation	Human-machine relationship	Pace and working rhythms (internal working time)
		Autonomy in setting procedures and regulating the process
		Communication systems
		Monitoring systems
	Knowledge diffusion and decision-making processes altered by automation	Decentralised decision-making
		Centralised decision-making
		Team work
		Job rotation practices
	Hierarchies fostered by automation	Existence of team leaders
		Relationships with superiors
	Forms of control induced by automation	Bureaucratic control
		Physical control
		Social control
Job quality	Job satisfaction	Increase in wages
		Career improvements
		Vertical mobility paths
		Horizontal mobility paths
	Ergonomics	Increasing ergonomics
		Reducing ergonomics
	Cognitive and manual dexterity	Performing physical and mentally stressful activities
		Fatigue
		Moving heavy objects
	Work-life balance	Shifts and roster- schemes
	Relationship with colleagues	Competitive environment
		Collaborative environment

Annex 2. Automated guided vehicles (AGVs) - Company profiles

Basic information about the establishment	Site	Centro di Meccanizzazione Postale di Bologna (1995)
	Participation in value chains and/or outsourcing activities	Registered and non-registered mail, public administration and legal mail, e-commerce parcel delivery
	Type of business entity (stand-alone or part of a corporation/organisation)	Part of a corporation (Poste Italiane Group)
	Geographic location of the establishment under investigation	Bologna (Italy)
	Company ownership (public, private)	Poste Italiane (mainly state-owned, private corporate governance) + SDA (courier/express subsidiary, owned by Poste)
	Size of establishment (number of employees)	695 (including 34 short-term contracts and 1 agency worker) + 25 NEXIVE (Poste subsidiary)
	Economic activity sector	National Universal Postal Service + B2C e-commerce delivery
	Type(s) of goods/services provided	Mail, e-commerce delivery
	End user(s)	B2C, C2C
	Type(s) of technology	8 AGVs (provided by INDEVA) [+ 1 AGS with 9 robots (provided by SOLYSTIC)]
	Form of employee representation within the establishment (for example, trade union, workers' council, etc.)	Union-appointed workers' representatives (RSA)
Information on adopted technology	Year when technology was introduced	2019
	Reason for technology adoption	1 - Process efficiency 2 - Cost saving 3 – Increasing quality and standardisation 4 – Increasing safety 4 - Expansion of service portfolio
	Application areas (for example, production, service or product delivery, interaction with customers)	8 AGVs. Used for automatic handling of objects and towing of trolleys (6-wheel trolleys, Pally & Lid and Rol containers). They have path-reading boards on which three sensors are mounted that detect the presence of a band positioned on the floor. Charging stations are placed along the route, consisting of 2 copper contacts on a plastic base, on which each AGV (also equipped with 2 copper contacts) lingers to keep itself constantly charged. AGVs are not informatically integrated into the rest of the machinery and tools operating within the plant, but only at Poste's central offices at the headquarters. AGS. Using robots that sort any type of tracked objects with a cart on board. They take the objects from an operator and sort them into trolleys in a defined area. The use of robots that handle the classic yellow boxes both for loading the product at the mail-sorting plant entrances and for handling empty boxes.
	Main purpose/use of the technology	Substitution of forklifts, managing handling, reduction of human activities in handling, improving quality in synchronisation of activities, avoiding accidents

Basic information about the establishment	Site	Philip Morris Manufacturing & Technology Bologna (2016)
	Participation in value chains and/or outsourcing activities	One of the two Italian-based affiliates – Philip Morris International. Philip Morris Manufacturing & Technology Bologna, the first plant of its kind worldwide, is the centre which establishes the manufacturing processes for hi-tech filters and heat-not-burn tobacco products. As a research centre, it deals with the conversion strategy (smoke-free tobacco products) for the other 38 PMI manufacturing affiliates in 28 countries. The production established at the plant satisfies international demand from more than 64 countries where IQOS is currently marketed.
	Type of business entity (stand-alone or part of a corporation/organisation)	Part of Philip Morris International Corporation
	Geographic location of the establishment under investigation	Bologna, Emilia-Romagna (Italy)
	Company ownership (public, private)	Private (public company)
	Size of establishment (number of employees)	1 719 PMMTB (including 79 short-term contracts and 57 agency workers) + 35 PMI-ML (including 4 short-term contracts and 2 agency workers) + 28

		outsourced technical maintenance workers (SIMIC Automation) + 269 outsourced logistics workers (LOGISTA).
	Sector of economic activity	Tobacco and smoke-free tobacco products.
	Type(s) of goods/services provided	Sticks for the electronic device IQOS
	End user(s)	B2C
	Type(s) of technology	34 AGVs (provided by Oceaneering International, Inc.). Governance is multi-layered and AGV software is integrated into the other manufacturing and IT software.
	Form of employee representation within the establishment (for example, trade union, workers' council, etc.)	Union-appointed workers' representatives (RSA)
Information on adopted technology	Year when technology was introduced	2016 (Greenfield)
	Reason for technology adoption	1 – Process efficiency 2 – Cost saving 3 – Increasing quality and standardisation 4 – Increasing safety 4 – Expansion of service portfolio
	Application areas (for example, production, service or product delivery, interaction with customers)	Internal logistics. AGVs transport raw materials and semi-finished products through the manufacturing chain. AGVs carry out their functions within the departments and transit corridors where there are numerous workers. The proximity of robots to humans is frequent and intense. AGVs are integrated into the whole production process through external customised software.
	Main purpose/use of the technology	Substitution of forklifts, managing handling, reduction of human activities in handling, improving quality in synchronisation of activities, avoiding accidents.

Basic information about the establishment	Site	Amazon FCO1 Fulfillment Center (2017)
	Participation in value chains and/or outsourcing activities	Fulfillment Centers (FCs) are part of the Amazon Logistics network for the storage, shipment and delivery of e-commerce sales. In FCs, products are received and stored. Orders on the website arrive in real time, items are picked, packed and shipped to sorting centres, from which they are directed to delivery stations for last-mile delivery. FCs store and process items owned and sold by Amazon as well as items sold by third-party sellers and shipped by Amazon (Fulfillment by Amazon, FBA).
	Type of business entity (stand-alone or part of a corporation/organisation)	Owned by Amazon Italia Logistica S.r.l., part of Amazon.com, Inc.
	Geographic location of the establishment under investigation	Passo Corese, Latium (Italy)
	Company ownership (public, private)	Private (public company)
	Size of establishment (number of employees)	1 500 (Estimation. Precise number to be confirmed by management)
	Sector of economic activity	E-Commerce and Logistics
	Type(s) of goods/services provided	Storage, sorting and shipment
	End user(s)	B2C
	Type(s) of technology	AGV (provided by Amazon Robotics, ex-KIVA system, an Amazon subsidiary acquired in 2012) AGC (provided by unknown company. Awaiting information) Governance is granted by Amazon Robotics and AWS servers
	Form of employee representation within the establishment (for example, trade union, workers' council, etc.)	Union-appointed workers' representatives (RSA)
Information on adopted technology	Year when technology was introduced	2017 (Greenfield)
	Reason for technology adoption	1 – Process efficiency 2 – Cost saving 3 – Increasing quality and standardisation 4 – Increasing safety 4 – Expansion of service portfolio
	Application areas (for example, production, service or product	Internal Logistics. AGVs transport mobile shelves called PODs, where items are stowed and picked. AGVs operate in a closed area and software drives them,

	delivery, interaction with customers)	via a QR code on the ground, to the stow and pick stations. AGVs are equipped with an artificial intelligence camera. The maintenance service is in-house. AGCs are a similar kind of robot, guided by a magnetic line on the floor, which transport items from the inbound conveyor department to the stow station.
	Main purpose/use of the technology	AGV – substitution of walking-pick, reducing non-added-value activities, partial replacement of human activities in handling, improving quality in synchronisation of activities, increasing ergonomics, increasing productivity, increasing monitoring and informatisation. AGC – reducing non-added-value activities, partial replacement of forklifts, partial replacement of human activities in handling, improving quality in synchronisation of activities, increasing ergonomics, increasing productivity, increasing monitoring and informatisation.

Fieldwork information

PMMTB

Following negotiations with the management, we were invited to the plant for a visit. Once we arrived on-site, in the morning, we were welcomed by PMI's External Relations Officer. He introduced us to our guide, the Head of the PMI Logistics Automation Team, and we immediately started the tour. During the tour we were joined by the PMI Factory Services Manager. The visit lasted around 90 minutes, during which informants presented us with the functioning of the technology and its location within the global workflow on-site. We visited Primary and Secondary areas and the docks where AGVs are loaded with raw material. We also visited the control room where the AGVs are monitored. The tour lasted around 60 minutes. After the visit we carried out semi-structured interviews with: an IT specialist, team leader of the Logistics Automation team, IT manager, operations manager, central operations manager (based in Bologna), central HR manager (video call). Each interview followed a specific matrix and was recorded (lasting between 45 minutes and 76 minutes). Most interviews were conducted in the presence of the external relations officer. Interviewees were chosen internally by the company's offices who tried to comply as best they could with our profile requirements. The visit was followed by several follow-up email exchanges to gather further data and fill possible information gaps spotted during initial data processing.

POSTE

Following negotiations with management, we were invited to visit the plant located on the outskirts of Bologna. At the beginning of the visit, we had a briefing with two senior operations managers from Poste headquarter in Rome, a Poste Lean production specialist (also based in Rome) and an IT specialist, based at the Bologna site. These key informants provided a general introduction to the technology and its process of adoption. The brief lasted around 50 minutes. The briefing was followed by a visit to the site with the above-mentioned informants. The visit lasted around 90 minutes, during which informants presented the functioning of the operation and its location within the site's global workflow. After the visit we carried out the semi-structured interviews with workers, union representatives, an IT specialist, HR manager. The interviews each followed each a specific matrix, were conducted separately and were recorded (lasting between 43 minutes and 72 minutes). Interviewees were chosen internally by the company's offices who tried to comply as best as they could with our profile requirements. The visit was followed by several follow-up email exchanges in order to gather further data and fill possible information gaps spotted during initial data processing.

AMAZON

Following negotiations with AMAZON management, we were allowed to visit the plant located about 50 km from Rome. Before the visit we were welcomed by the site's external relations officer. This officer introduced us to two operations managers, a manager for the AGV area (called RPS OPS Manager) and the manager for the entire 'outbound' area (called Senior OPS Manager Outbound). The two, together with the external relations officer and the press officer, guided us through the site. We started at the receiving area, then we went upstairs to the first of three floors, where they showed us the role of AGVs in stowing operations. Less time was dedicated to the picking operation – which is the reverse but still presents some differences. Our guides also showed us another AGV (AGS) fulfilling operations in pallet transportation and replenishment for the pick and stow workstations. Then we went back downstairs to the ground floor where we promptly went across to the packing area. There the tour was concluded. The visit lasted around 60 minutes.

After the visit we carried out semi-structured interviews with 4 workers (3 stowers and 1 Amnesty Responder), 1 IT specialist from the European-level Advanced Technology division (video call), a senior HR manager (also covering the site in Colleferro, near Rome), 1 safety manager (based on-site but covering all Italian, French and Spanish sites). Interviews with the IT specialist and HR manager were conducted collectively at the presence of the external relations and press officers. The remaining interviews were conducted separately. The interview with the safety manager was conducted in the presence of the press officer, while interviews with workers were conducted in the presence of the external relations officer. The duration of interviews spans from 25 minutes to 60 minutes. Interviewees were chosen internally by the company's offices who tried to comply as best they could with our profile requirements.
The visit was followed by several follow-up email exchanges in order to gather further data and fill possible information gaps spotted during initial data processing.

Annex 3. Professional cleaning robots - Company profiles

	Establishment template	Screening questions
Basic information about the establishment	Name of the company/establishment	Nestlé Vera- Via Valsugana (contact person: Michele Perin, Factory Supply Chain Manager NW Italy)
	Name of corporation if applicable	Sanpellegrino – Nestlé
	Participation in value chains and/or outsourcing activities	4 plants in Italy
	Type of business entity (stand-alone or part of a corporation/organisation)	Part of a corporation (SANPELLEGRINO S.p.A.)
	Year of establishment	2005
	Geographic location of the establishment under investigation	San Giorgio in Bosco (Padova)
	Company ownership (public, private)	Private
	Size of establishment (number of employees)	200-230 employees
	Sector of economic activity	Food and beverage
	Type(s) of goods/services provided	Sanpellegrino soft drinks and Sanbitter non-alcoholic aperitifs are bottled
	End user(s)	Restaurants, shopping centres, supermarkets
	Type(s) of technology (professional cleaning robots, AVGs, remote monitoring devices) in focus	Professional cleaning robots (RA660 Navi Cleanfix)
	Form of employee representation within the establishment (for example, trade union, workers' council, etc.)	Trade union
Information on adopted technology	Year when technology was introduced	The first test of the scrubber dryer cleaning robot was carried out in 2017, while they have been testing another sweeper-type cleaning robot since 2021.
	Reason for technology adoption	(i) The need for constant cleanliness around the clock and in small spaces such as production areas; (ii) machines that reduce safety risks and do not interfere with employees; (iii) the pursuing of Factory 4.0 and Smart Factory models requiring a fully automated environment.
	Application areas (for example, production, service or product delivery, interaction with customers)	Production lines and automated end-of-line area
	Extent of technology integration	The technology is not directly embedded in the work processes; it is dedicated to cleaning small areas along production lines. The deployment of the technology has gone beyond the pilot phase.
	Main purpose/use of the technology	Fast and around-the-clock cleaning without interruptions
	Maturity level in the uptake of technologies	They have used the RA660 Navi Cleanfix robot since 2017. The experimental phase lasted 7-8 months in 2017.

	Establishment template	Screening questions
Basic information about the establishment	Name of the company/establishment	Dussmann Service S.r.l. Contact person: Renato Santinon (DPCI – Director of Planning Control Innovation Unit)
	Name of corporation if applicable	Dussmann Group
	Participation in value chains and/or outsourcing activities	9 locations
	Type of business entity (stand-alone or part of a corporation/organisation)	Dussmann Service is a division of the Dussmann Group and, as such, is part of an international service network for public institutions and private companies.
	Year of establishment	1969
	Geographic location of the establishment under investigation	Headquarters: Capriate S. Gervasio, Lombardy, Italy Airport (Milan Malpensa) Hospital (Azienda Ospedaliero Universitaria Pisana)
	Company ownership (public, private)	Private entity

	Size of establishment (number of employees)	Establishment size: Not available Company size: 17 700 (overall) – Italian division: Capriate S. Gervasio/Bari/Cesena/Marghera/Napoli/Olbia/Prato/Roma/Vercelli
	Sector of economic activity	Facilities Management
	Type(s) of goods/services provided	Cleaning, catering, hard and soft maintenance, security, surgical kit sterilisation, logistics, pest control, auxiliary services, space management
	Known end user(s)	1- Airport (Milan Malpensa) 2- Hospital (Azienda Ospedaliero Universitaria Pisana)
	Type(s) of technology (professional cleaning robots, AVGs, remote monitoring devices) in focus	Professional cleaning robots
	Form of employee representation within the establishment (for example, trade union, workers' council, etc.)	Trade unions
Information on adopted technology	Year when technology was introduced	Professional cleaning robots have not be used so far (Dussmann has tried existing robots and they have been evaluated as insufficiently productive and very expensive; therefore, in the past Dussmann decided to avoid their application). However, Dussmann is developing its own robot, which will be introduced in April 2021 (tested in March at Milan Malpensa Airport and at the Cisanello University Hospital).
	Reason for technology adoption	Improve productivity, overcome limits of existing machines
	Application areas (for example, production, service or product delivery, interaction with customers)	Hospitals, airports (large and empty spaces)
	Extent of technology integration	The deployment of the technology is in the pilot phase. Two patents have been developed and registered. The machines will be sold on the market as soon as the pilot phase is over.
	Main purpose/use of the technology	Cleaning large spaces, eliminating low-added-value types of activities
	Maturity level in the uptake of technologies	The adoption of professional cleaning robots will open up new market opportunities, expanding the set of services to be sold to final clients. The availability of cleaning robots on the menu has a reputational effect for the company.

	Establishment template	Screening questions
Basic information about the establishment	Name of the company/establishment	Coopservice (Reggio Emilia) Contact person: Luca Baracchi (Head of Technical Sales and Innovation Manager Coopservice)
	Name of corporation if applicable	The Coopservice Group is formed of subsidiary and affiliated companies operating in several business areas that are adjacent and/or complementary to the service lines supplied directly by Coopservice.
	Participation in value chains and/or outsourcing activities	Several locations around the world, participation in outsourcing activities
	Type of business entity (stand-alone or part of a corporation/organisation)	Corporation
	Year of establishment	1991: Coopservice was created through the merger of two major service companies, Coopsicurezza (founded in 1976) and Cierrepi (founded in 1972)
	Geographic location of the establishment under investigation	Reggio Emilia, Emilia-Romagna (Italy)
	Company ownership (public, private)	Private entity (cooperative society)
	Size of establishment (number of employees)	16 149 employees (overall)
	Sector of economic activity	Cleaning and facilities management
	Type(s) of goods/services provided	Healthcare cleaning, professional cleaning, logistics and waste management, security services, energy and facilities management
	End user(s)	Coopservice mainly provides services to public entities (60% of the total revenue)
	Type(s) of technology (professional cleaning robots, AVGs, remote monitoring devices) in focus	Professional cleaning robots
	Form of employee representation within the	Trade unions

	establishment (for example, trade union, workers' council, etc.)	
Information on adopted technology	Year when technology was introduced	Professional cleaning robots and sanitisation robots (Diversey) have been used by Coopservice in the past (hospitals, airports, agri-food warehouse); the use has been limited to the testing phase.
	Reason for technology adoption	Cleaning robots are no longer in use
	Application areas (for example, production, service or product delivery, interaction with customers)	1- Hospitals – common large spaces, halls (not suitable for the application of cleaning robots and AGVs due to large numbers of people within the structure) 2- Airports – overnights (the presence of people hinders a full application of the machine) 3- Agri-food warehouse (inefficiency of cleaning, the machine not able to clean below shelving)
	Extent of technology integration	The technology is embedded in the business and work processes of Coopservice; however, the deployment of the technology has not gone beyond the pilot phase.
	Main purpose/use of the technology	Ageing workforce; potentially useful help in cleaning activities
	Maturity level in the uptake of technologies	Due to the low-level performance of the technology (below 1 000 m2 per hour, which is the standard reference), Coopservice no longer uses cleaning robots.

Fieldwork information

Dussmann service S.r.l.

In terms of the construction of the case study and the visit to the site, the research group started by approaching the management of the company. Following negotiations, we were invited to the cleaning site (Milan Malpensa Airport) for a visit. Once we arrived at the site, we were welcomed by the site manager (head of the cleaning service for the external area of Milan Malpensa Airport). He guided us to the specific area of the airport (Terminal 1) where a cleaning robot was used and we started the visit: first, he showed us the cleaning robot parked in the garage and explained the technical characteristics; second, he activated the robot and showed us how it works. The visit lasted around 80 minutes and it was an opportunity to collect detailed information and data about the functioning of the technology of interest.
After the visit, we settled in several rooms reserved for the Dussmann staff and we carried out semi-structured interviews with employees and managers. Interviewees were chosen internally by the company's offices who tried to comply as best they could with our profile requirements. In-person interviews were conducted with the site manager (head of the cleaning service for the external area of Milan Malpensa Airport), one team leader cleaning operator and two cleaning operators. During the same interview session, we remotely (by video call) interviewed the IT specialist in the technical department. Over the following days we made arrangements to remotely interview two other managers: the Head of the Planning and Control Department and the innovation Manager for Warrant Innovation Lab S.r.l.
The interviews followed specific matrices – one for managerial levels, one for operators – and were recorded and fully transcribed. The visit was followed by several follow-up email exchanges in order to gather further data and fill possible information gaps spotted during initial data processing.

Nestlé Vera

Although repeated attempts were made to reach an agreement to visit the establishment, the research group was not able to visit the site due to COVID restrictions. The company provided the availability to interview only one selected person remotely, the supervisor of logistics automation for the San Giorgio plant in Bosco. The interview, following a specific matrix, was recorded and fully transcribed.

Coopservice

Coopservice tried to implement cleaning robots at their sites in previous years but the gains in terms of productivity and reputation were considered negligible, leading to the withdrawal of the adoption. Therefore, it was not possible to visit any cleaning site, as no cleaning robot was deployed by Coopservice at the time the research was carried out. Nevertheless, after negotiating with the management, we were invited to the headquarters of Coopservice in order to carry out semi-structured interviews with managers and technicians. Interviewees were chosen internally by the company's offices who tried to comply as best they could with our profile requirements. The research team arrived at Coopservice on the morning of the appointed day. In the

morning we interviewed one Chief Innovation Officer, one Chief Operating Officer, two IT specialists, one HR manager, one coordinator of employee training and development within the HR department. The following day we interviewed another IT specialist online. Through other contact channels we then made an appointment with a union representative for FILT CGIL and we carried out the last semi-structured interview (online) the following week. The interviews followed were conducted separately, were recorded and fully transcribed.

Annex 4. Health monitoring devices- Company profiles

	Establishment template	Screening questions
Basic information about the establishment	Name of the company/establishment	ASL – Distretto sanitario, Santa Maria Nuova Hospital - Reggio Emilia Contact person: Marco Foracchia
	Name of corporation if applicable	ASL – Reggio Emilia. In Italy, the ASLs are part of the national health service (since 1993, they depend on the regions); ASLs are public companies provided with organisational, managerial, technical, administrative autonomy as well as entrepreneurial autonomy. In 2017, Santa Maria Nuova Hospital turned from '*Azienda ospedaliera*' to '*Presidio ospedaliero*'. The hospital unit has autonomy at management level and separate accounting, but within the ASLs budget. The ASLs manage both hospitals and territorial health system (general doctors, home-health services, etc.). The territorial health system integrates its services with social services (the latter financed by the municipalities and often carried out by private cooperatives that have won the tenders).
	Participation in value chains and/or outsourcing activities	n/a
	Type of business entity (stand-alone or part of a corporation/organisation)	n/a
	Year of establishment	n/a
	Geographic location of the establishment under investigation	Reggio Emilia (RE) - Italy
	Company ownership (public, private)	Public
	Size of establishment (number of employees)	n/a
	Sector of economic activity	Health system
	Type(s) of goods/services provided	Health and care services
	End user(s)	Patients
	Type(s) of technology (professional cleaning robots, AVGs, remote monitoring devices) in focus	Remote monitoring devices (many kinds)
	Form of employee representation within the establishment (for example, trade union, workers' council, etc.)	Trade unions
Information on adopted technology	Year when technology was introduced	n/a
	Reason for technology adoption	Cost reduction (from a long-term perspective) and increase in service quality
	Application areas (for example, production, service or product delivery, interaction with customers)	Many departments and areas, health services and home services, in particular
	Extent of technology integration	High
	Main purpose/use of the technology	Three types of remote diagnostic monitoring identified that involve the replacement of (human) labour input with (digitally enabled) machine input for some types of tasks. a) In-hospital bedside monitoring (e.g. in the intensive care unit). The hospital staff (doctors and nurses) monitor bedridden patients from a 'control room'. The diagnostic data transmitted by bedside devices are reported in real time on various monitors. The collection of diagnostic data is automated and many physical/personal visits by doctors and nurses (and related tasks) are eliminated (obviously not completely). b) Home monitoring of electrophysiology devices (pacemakers, implantable defibrillators, etc.). Implantable cardiac devices provide a significant amount of diagnostic data that indicate patients' status daily. This remote control allows the monitoring of patients remotely, by eliminating some tasks of caregivers, doctors and nurses (for example, the reduction in the number of visits to the hospital or outpatient clinic) and by introducing others (control and interpretation of the collection of transmitted data). c) Telestroke (televisit and telemonitoring of stroke patients from Reggio HUB to peripheral hospitals). The telestroke is a device available for first aid in cases of suspected cerebral stroke. Telestroke allows for the framing of the problem and definition of the appropriate level of intervention. The hospital staff and the patient

		(accompanied by caregivers) are connected via video. CT brain scan images are sent from peripheral hospitals to the central hub where the hospital staff carry out an assessment and decide upon whether the patient needs to be transferred to a specialised unit.
	Maturity level in the uptake of technologies	High

	Establishment template	Screening questions
Basic information about the establishment	Name of the company/establishment	Sistema di Emergenza Sanitaria Territoriale (118) / Emergency Medical Service Contact person: Roberto Pretini
	Name of corporation if applicable	Agenzia Regionale Sanitaria – Regione Marche
	Participation in value chains and/or outsourcing activities	1 regional centre and 4 territorial units
	Type of business entity (stand-alone or part of a corporation/organisation)	Under regional public health authorities
	Year of establishment	1998
	Geographic location of the establishment under investigation	Ancona (AN), Italy – (reference contact: Dr Antonio Pierucci)
	Company ownership (public, private)	Public
	Size of establishment (number of employees)	
	Sector of economic activity	Emergency health services
	Type(s) of goods/services provided	Coordination and prompt medical interventions in the reference area, activating hospital responses 24 hours a day
	End user(s)	Emergency vehicles' onboard medical team (doctors and nurses)
	Type(s) of technology (professional cleaning robots, AVGs, remote monitoring devices) in focus	Advanced emergency vehicles provided with remote monitoring devices (PHYSIO CONTROL – LIFEPAK 15)
	Form of employee representation within the establishment (for example, trade union, workers' council, etc.)	Trade unions
Information on adopted technology	Year when technology was introduced	2015
	Reason for technology adoption	Providing advanced and timely support in case of serious or particularly complex situations related to heart diseases. The devices allow timely and somewhat 'automatic' diagnosis in remote, that is, well before patients arrive at the hospital and regardless of the presence of a doctor onboard. Despite this, the presence of a doctor remains essential to ensure prompt (physical) intervention in case of emergency, which means that the substitution of nurses for doctors is not quite advisable and foreseeable.
	Application areas (for example, production, service or product delivery, interaction with customers)	Emergency medical services
	Extent of technology integration	Fully integrated
	Main purpose/use of the technology	Advanced monitoring system of various parameters relevant to patients' cardiovascular conditions, which allows for automatic data sharing (via the web) to hospital medical teams, facilitating a diagnosis and, therefore, reducing the time before treatment, especially in cases of emergency when patients require an immediate rapid transfer to the operating theatre.
	Maturity level in the uptake of technologies	High readiness

Fieldwork information

Santa Maria Nuova Hospital

We conducted an initial semi-structured interview with the head of the 'Complex Structure ICT and Telematics Service' of the health agency (known as ASL) in Reggio Emilia. The interview provided a general description of the context in terms of tech adoption. We selected two different cases, highly effective for the purpose of the research: telestroke and remote monitoring.
The head of the IT division at Santa Maria Nuova Hospital played a pivotal function in scheduling the following field activities, organising a full day of interviews at the hospital in Reggio Emilia and one video interview with the head of the neurology unit. During a training day in Pisa, the research group paid specific attention to adapting the interview guidelines to the healthcare sector.
With respect to the telestroke, the head of the neurology unit (video call) and the IT specialist from neurophysiopathology (the maintainer of the digital device) were interviewed. After the interview with the head of the neurology unit (the doctor who promoted and coordinated the process of telestroke adoption at the hospital), we decided to also involve the peripheral hospitals of Guastalla and Castelnuovo Monti, in order to better understand the entire organisational transformation process. Therefore, adopting a snowball process, we interviewed the emergency doctor responsible for telestroke at Guastalla (where the tech has been successfully adopted) and the manager of the emergency department at Castelnuovo Monti and Scandiano (where the tech has not been adopted).
With respect to remote monitoring, we interviewed the medical director of the electrophysiology unit and the IT specialist for cardiovascular physiopathology involved in the technology of interest.
Lastly, we interviewed both the head of the IT division and the IT specialist in the clinical engineering department (the clinical engineer responsible for their implementation).

ASUR Marche

After successfully negotiating with the ASUR board of directors, our proposed fieldwork agenda was approved and we were invited to visit the emergency division of Riuniti Torrette hospital and to carry out the interviews in person on 1 October 2021. Once there, we had an initial meeting with the medical director of the emergency division – who in this case also represents the IT specialist responsible for the technology adoption – who provided a general introduction to the technology of interest, explaining (and practically showing us) its functioning and overall integration in the work processes of the emergency division. Moreover, we had the chance to visualise the technology onboard the advanced emergency vehicles in use. This first meeting lasted around 1.5 hours and was fully recorded and transcribed. Then, we carried out 7 semi-structured interviews of the following profiles: 1 IT specialist, 1 HR manager and 5 workers (i.e. 2 emergency doctors and 2 nurses working onboard on the ambulances, plus another doctor, in the role of medical director of the cardiac intensive care unit, who is responsible for receiving the information transmitted by the technology in question). With the exception of the IT specialist, already identified through our key informants, all other interviewees were chosen internally by the board of directors, with the aim of complying as best it could with our specific requirements. Each interview followed a specific matrix (cf. Annex) and was conducted separately. All of the answers have been recorded and fully transcribed.

Humanitas Research Hospital

After lengthy negotiations with the hospital management, the fieldwork was carried out on 4 February 2022. Unfortunately, in this case we were not allowed to visit the hospital, nor to carry out the fieldwork activities in person, mainly because of time limits and due to issues related to privacy and industrial confidentiality. Despite this, we got the opportunity to carry out a deep and extended interview remotely (via online platform), in particular, with the IT specialist responsible for the adoption and integration of the technology under study. The medical director of the hospital information systems was also present during the interview, integrating further information, especially regarding the integration of the technology into the hospital work flows and activities and the related changes in the work organisation of all hospital personnel. For the interview, we followed a specific matrix, fully recording and transcribing the content.

GETTING IN TOUCH WITH THE EU

In person

All over the European Union there are hundreds of Europe Direct centres. You can find the address of the centre nearest you online (european-union.europa.eu/contact-eu/meet-us_en).

On the phone or in writing

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

— by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),

— at the following standard number: +32 22999696,

— via the following form: european-union.europa.eu/contact-eu/write-us_en.

FINDING INFORMATION ABOUT THE EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website (european-union.europa.eu).

EU publications

You can view or order EU publications at op.europa.eu/en/publications. Multiple copies of free publications can be obtained by contacting Europe Direct or your local documentation centre (european-union.europa.eu/contact-eu/meet-us_en).

EU law and related documents

For access to legal information from the EU, including all EU law since 1951 in all the official language versions, go to EUR-Lex (eur-lex.europa.eu).

Open data from the EU

The portal data.europa.eu provides access to open datasets from the EU institutions, bodies and agencies. These can be downloaded and reused for free, for both commercial and non-commercial purposes. The portal also provides access to a wealth of datasets from European countries.

The European Commission's science and knowledge service

Joint Research Centre

JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

EU Science Hub
joint-research-centre.ec.europa.eu


@EU_ScienceHub


EU Science Hub - Joint Research Centre


EU Science, Research and Innovation


EU Science Hub


EU Science

Publications Office
of the European Union