Algorithmic Management in the Healthcare Sector: Evidence from case studies in Italy and France

JRC Working Papers Series on
Labour, Education and Technology
2025/05

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LABOUR EDUCATION TECHNOLOGY

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JRC142306

Seville: European Commission, 2025

How to cite this report: Bisaschi, L., Calderoni, P., Garces, I., Lechardoy, L. and Nardoni, S., *Algorithmic Management in the Healthcare Sector: Evidence from case studies in Italy and France*, European Commission, Seville, 2025, JRC142306.

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Abstract

This study report investigates how the technological transformation occurring in four Italian hospitals and two French hospitals affects their organisational processes and structure. The results show that the Italian establishments developed a higher degree of digitalisation rather than pure automation processes, hence entailing reorganisation of work processes more than human substitution. Indeed, the use of the technological tools and software described in the present study implied relevant changes in the work organisation, both in terms of methods and digital instruments used. However, no fear of substitution by the machine or perception of threat to the jobs of the medical staff and other workforce have been reported in any of the hospitals. Rather, it has emerged in more than one occasion how such technologies are more complementary and supportive to the medical staff's decisions. In France, the findings reveal that the use of the algorithmic tools has reduced patient waiting times at the emergency room, increased work coordination, communication between medical services, and decreased stress for hospital staff. The paper concludes that the adoption of algorithmic management tools has increased the quality of life at work and highlights the potential for these tools to transform the health sector.

Keywords: Algorithmic Management, Healthcare, Working Conditions, Job Quality

Joint Research Centre reference number: JRC142306

Executive summary

The report presents a selection of case studies of algorithmic management technologies (AMT) in the healthcare sector in Italy and France.

The first case study in Italy investigates the implementation of a digital tool in a university hospital (***Italian Healthcare 1***), which assists the medical and administrative staff in efficiently managing the drug-related big flow of data within the hospital. For the sake of the comparative perspective of the report, the second study is based on evidence from three Italian hospitals (***Italian Healthcare 1***, ***Italian Healthcare 2***, ***Italian Healthcare 3***), as retrieved from the report "Case studies of automation in services", published by the Joint Research Centre of the European Commission in November 2022. Thus, this report consists of a comparative analysis between the evidence collected from the interviews carried out at *Italian Healthcare 1* and the main findings contained in the "Case studies of automation in services" report. In this sense, the information hereby reported about *Italian Healthcare 1*, *Italian Healthcare 2*, *Italian Healthcare 3* are not as exhaustive as those concerning *Italian Healthcare 1*. The use of the AMTs and software described in the present study implies relevant changes in the work organisation, both in terms of methods and digital instruments used. At *Italian Healthcare 1*, in particular, the introduction of the digital technology for drug-related data management resulted in less burdens and hurdles at work. Now, the personnel are indeed less engaged in low value-added activities and, overall, the workload has diminished. Many manual tasks related to data collection and management has been replaced by the use of the technology. The digital solution has taken away administrative time from doctors and nurses, hence contributing to the creation of a new profession for data management. Thus, the time saved by medical staff can be reinvested in strictly medical activities. On the other hand, the deployment of telestroke, remote monitoring devices, and televisits, as explained in the "Case studies of automation in services" report, has deeply affected the content of tasks for the medical staff involved. Such technologies replaced – and in some cases added – some already medical activities with new ones. In this sense, all the staff affected by the technologies has made increased use of digital technologies and needed to follow specific protocols and procedures to ensure their correct functioning, although their workloads have not increased. In particular, nurses employing the telestroke technology and remote monitoring devices has undergone remarkable upskilling in terms of digital competences, new complex tasks to be carried out and expanded medical knowledge. Doctors have increased their autonomy and have more time to make diagnoses.

In France, the report studies two hospitals - ***French Healthcare 1*** and ***French Healthcare 2*** -, which use different AMTs to coordinate and organise their daily work. The two case studies present the findings concerning the dimensions of the research project, including how the AMT is embedded in the work processes of the hospitals. The case studies highlight how these technologies impacts workers' relations and delivery of services, the different occupational levels, and how the use of AMTs affects job quality, including working conditions and industrial relations. The case studies are conducted through qualitative, in-depth, semi-structured interviews, complemented with desk research. A total of fifteen interviews were conducted online, covering all relevant profiles: doctors, nurses, HR managers, general managers, bed-management workers, technology specialists, and providers. Prior to the adoption of these technologies, both hospitals were facing increasing challenges in managing the flow of patients to their emergency departments, which had experienced a soar in the number of patients in recent years. Likewise, both hospitals were uncomputerized and lacked technological resources to overcome heightened activity. As a result, *French Healthcare 1* and *French Healthcare 2* adopted two different technologies to help predict the activity at the emergency room (ER), detect whether a patient has an immediate emergency need or not, and identify which specialist a patient must see. Both AMTs help emergency workers triage incoming ER patients in advance, whilst improving the working conditions of staff by decreasing stress with an increased organisation and management during periods of tensions at the ER.

The role of technology specialists and data managers is expected to acquire greater relevance inside Italian hospitals as quickly as similar technologies are implemented. However, no fear of substitution by AMTs or perception of threat to the jobs of the medical staff and other workforce have been reported in any of the cases. Rather, it has emerged in more than one occasion how such technologies are more complementary and supportive to the medical staff's decisions. As a matter of fact, this appears especially evident in the healthcare sector, where – despite the increasing deployment and significance of technology – the human component remains intrinsic to the daily activities of doctors and nurses. In this sense, operators do not believe technologies like those considered under this study could fully replace their jobs, as it might instead happen in other sectors where unskilled workforce is largely employed.

In France, the staff interviewed in both hospitals believed that if doctors and nurses used AMTs to analyse patient flows with parameters that interest them, they could save time and optimise the management of serious patients and those who are less urgent. The workers interviewed agreed that there was a need to save time, improve efficiency and reduce the workload of other key workers - medical and paramedical. With the help of the two predictive technologies, the staff interviewed agreed that the algorithms helped predict the activity at the ER, the number of free beds, and detect which patient has the highest emergency need and must be admitted first.

Main findings

This study highlights the positive impact of AMTs on work organisation, job quality, and workflows in the healthcare sector. In Italy, the technological transformation occurring in the establishments considered by the present study has mainly resulted in digitalisation rather than pure automation processes, hence entailing reorganisation of work processes more than human substitution. In particular, no direct human substitution has been witnessed. In France, by adopting the technologies, the hospital has increased the job profiles of 'bed management' and increased patient experience by decreasing their time spent in the ER. The report suggests that the adoption of these technologies have increased the quality of life at work for healthcare professionals, decreased patient morbidity, and increased management efficiency. The use of both AMTs has transformed the content and distribution of workers' tasks by enabling them to focus on their medical role and to disregard administrative duties. However, the study also highlights the need to ensure that the use of AMT is not detrimental to the working conditions and job quality of healthcare professionals, and that its adoption is in line with ethical principles and respects workers' rights.

1 Introduction

The rapid advancement of the digital revolution and the growing connectivity in the workplace are reshaping the world of work. Digital tools and algorithmic management practices are now being adopted in traditional workplaces as mechanisms for work coordination. The digitalisation of work, along with digital monitoring and algorithmic management - defined as the use of computer-programmed processes to coordinate labour within an organisation – creates new business opportunities, enhances efficiency, and optimises workflows. However, this shift also raises concerns about working conditions, the potential decline in job quality, and the increased risk of worker surveillance[1].

Over the past few decades, the use of algorithms across industries has quickly spread throughout the world. Especially impacting the most industrialised countries, algorithms have transformed our societies, how companies and markets operate, and how humans interact with machines: from academia to business practices, and from operations to human management. Algorithmic management refers to the use of AI and other algorithmic techniques to manage and supervise workers and business processes. Essentially, it involves automating certain managerial tasks that would normally be carried out by human managers. In practice, algorithmic management technologies (AMT) can take many different forms. For example, they can involve using machine learning (ML) algorithms to analyse employee performance data and make decisions about promotions, bonuses, and other forms of compensation. They can also involve using chatbots or other automated tools to communicate with employees and answer their questions or using predictive analytics to forecast future business needs and adjust staffing levels accordingly.

Digital labour platforms have been pioneers in adopting surveillance technologies and algorithmic management practices[2,3]. This has been facilitated both by their inherently digital operating environment and by the informal nature of their working relationships, which has often allowed them to bypass many of the restrictions typically found in traditional workplaces. However, algorithmic management and digital surveillance are now increasingly permeating conventional work settings as well, prompting broader concerns about their impact on labour processes, the organisation of work, and the balance of power in the workplace[4]. For example, there are concerns about algorithmic bias, where algorithms may inadvertently discriminate against certain groups of workers or perpetuate existing inequalities. There are also concerns about worker privacy and autonomy, as well as potential legal liability if algorithmic decisions lead to negative outcomes for workers. Therefore, it is important for organisations to carefully consider the implications of algorithmic management and ensure that they have robust policies and procedures in place to address these issues.

The case studies presented in this report were conducted at the end of 2022 in the frame of a broader research study commissioned by the Joint Research Centre (JRC) to Open Evidence, investigating the impact of algorithmic management tools on work organisation. The research study was part of a broader project carried out jointly by the JRC and the International Labour Organisation (ILO) focusing on country-sector analyses in the logistics and healthcare sectors in

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[1] Rani, U., Pesole, A. and Gonzalez Vazquez, I., Algorithmic Management practices in regular workplaces: case studies in logistics and healthcare, Publications Office of the European Union, Luxembourg, 2024, doi:10.2760/712475, JRC136063.

[2] Pesole, A., Urzì Brancati, M.C., Fernandez Macias, E., Biagi, F. and Gonzalez Vazquez, I. 2018. Platform Workers in Europe Evidence from the COLLEEM Survey, EUR 29275 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-87996-8, doi:10.2760/742789, JRC112157.

[3] ILO. 2021. World Employment and Social Outlook 2021: The Role of Digital Labour Platforms in Transforming the World of Work. International Labour Organization.

[4] Baiocco, S., Fernández-Macías, E., Rani, U. and Pesole, A., 2022. The Algorithmic Management of work and its implications in different contexts, Seville: European Commission, JRC129749.

two European countries (France and Italy) and two non-EU countries (India and South Africa) allowing for a comparative analysis across countries with different levels of development[5].

The aim of the overall project was to assess applications of algorithms in the workplace and examine their impacts on the coordination of work and working conditions, together with the role of social dialogue in the adoption and implementation of these technologies. The logistics sector was chosen as an example of a highly digitalised sector in which the use of digital monitoring and algorithmic management technologies has been widely documented in the literature. In contrast, in the healthcare sector the use of algorithmic management as part of digital health platforms is more recent and less well documented. This report focuses on the healthcare sector in Italy and France.

1.1 The Italian healthcare system

Although the Italian healthcare system is known for its universal coverage and high-quality care, healthcare establishments in the country are experiencing challenging times in terms of adequate public health professionals, resources, and efficient organisation. In 2019, around 684,000 healthcare professionals were employed in the Italian healthcare system[6], with a budget for public health in relation to the national GDP relatively small (around 9.5% in comparison to the EU average of 10.9%, in 2020)[7]. Nurses represent 59.3% of the total workforce, doctors, and dentists 23.1% while 17.6% are represented by other profiles such as managers, technical personnel, rehabilitation staff and other staff with surveillance functions. Women are two-thirds of the total (68%), mainly nurses[8]. Moreover, in 2020, 76% of total health spending in Italy was financed through governments schemes, while households' out-of-pocket payments accounted for 21% of all health spending[9].

Also, shortages of some specialties are already becoming visible, resulting in longer waiting times for patients – especially consequently to the COVID-19 pandemic. Therefore, human resources continue to play a key role in Italian hospitals at the moment. The lack of targeted policy actions, combined with the economic situation in Europe, is having an impact on pay levels, attrition rates and the attractiveness of working in the sector[10]. The phenomenon of *medici a gettone* (i.e., recent medicine graduates, retired doctors or free medical professionals who leave the national healthcare system (*Sistema Sanitario Nazionale*, hereafter SSN) becoming employees of cooperatives which send them to public establishments where, as employees, would be paid half or would not have permanent contracts) has widely spread in the country in recent years, and is just the latest anomaly affecting the well-being of the Italian healthcare system[11].

Workers are framed within the "Healthcare Personnel" national collective bargaining agreement. Trade unions play a major role in the company bargaining of the sector. Indeed, both confederal unions (CGIL, CISL and UIL) and the specific trade unions (SMI, SNAMI, Nursind, etc.) actively play important roles during the drafting of collective agreements and when company regulations and the distribution of economic funds need to be established. Also, together with company managers,

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[5] Rani, U., Pesole, A. and Gonzalez Vazquez, I., Algorithmic Management practices in regular workplaces: case studies in logistics and healthcare, Publications Office of the European Union, Luxembourg, 2024, doi:10.2760/712475, JRC136063.
[6] Ministero della Sanità, Il personale del sistema sanitario italiano, 2019, available at: https://www.salute.gov.it/portale/documentazione/p6_2_2_1.jsp?lingua=italiano&id=3164.
[7] OECD/European Union, Health at a Glance: Europe 2022: State of Health in the EU Cycle, OECD Publishing, Paris, 2022, https://doi.org/10.1787/507433b0-en.
[8] Ministero della Sanità, Il personale del sistema sanitario italiano, 2019, available at: https://www.salute.gov.it/portale/documentazione/p6_2_2_1.jsp?lingua=italiano&id=3164.
[9] OECD/European Union, Health at a Glance: Europe 2022: State of Health in the EU Cycle, OECD Publishing, Paris, 2022, https://doi.org/10.1787/507433b0-en.
[10] WHO, Health and care workforce in Europe: time to act, WHO Regional Office for Europe, Copenhagen, 2022.
[11] ANAP (Associazione Nazionale Anziani e Pensionati) website. Available at: https://www.anap.it/notizia/medici-a-gettone-e-cooperative.

they agree on important regulations including working hours, part-time contracts and salary progressions.

Thus, it is now evident that exploiting data and new technologies has become essential to guarantee an effective and efficient healthcare system. The deployment of technologies, algorithms and digital tools aimed at reducing times, saving costs and making the work of doctors and nurses more efficient is expected to grow further in the coming years.

However, it should be stressed that the deployment of digital tools and software or remote monitoring devices appears more diffused than sheer algorithms, AI tools and robots. As a matter of fact, although automation usually implies the full replacement of different work activities, for the purpose of this study it should be intended as the replacement of data analysis, monitoring and diagnosis activities previously performed by humans.

1.2 The French healthcare system

According to data from the French National Institute of Statistics and Economic Studies (INSEE), the healthcare industry in France accounts for 12.3% of the GDP, with 67,000 establishments (including all healthcare and social assistance), and 2.8 million jobs, making it one of the largest employers in the country[12]. Moreover, in 2020, the French government spent more than 200 billion euros in healthcare, which represented around 9% of the country's GDP, and an additional 26 billion euros coming from private co-financing was poured into the sector[13].

In 2020, 85% of total health spending in France was financed through governments and compulsory insurance, while households' out-of-pocket payments accounted for only 9% of all health spending.[14] The French healthcare system is known for its universal coverage and high-quality care. Primary care is provided by general practitioners and specialists, who are reimbursed by a mix of public and private insurance funds. Hospital care is also covered by these funds, with patients being admitted to public or private hospitals depending on their choice.

The system is mostly managed by the government and financed through a combination of taxes, social security contributions, and patient co-payments. The *tarification à l'activité* (T2A) system[15] is used to finance hospitals, with each procedure or activity being assigned a specific cost. Under T2A, hospitals are paid based on the specific services and procedures they provide to patients, rather than receiving a fixed budget. Each procedure is assigned a specific price, which considers the resources needed to perform it. This system aims to encourage hospitals to be more efficient and cost-effective by providing incentives for them to perform procedures more quickly and with fewer resources, whilst ensuring that patients receive the care they need. However, some critics argue that T2A can lead to a focus on profitability rather than patient outcomes and can lead to underfunding of hospitals that treat more complex cases. Finally, social dialogue and workers' representation are integral parts of the French healthcare system, as they give healthcare workers a platform to voice their concerns and negotiate with employers and government agencies. This helps to promote collaboration and cooperation, leading to better outcomes for patients and a more efficient healthcare system. However, unionisation in the French healthcare sector varies depending on the occupation and establishment. For example, nurses and paramedical staff in large public hospitals have relatively high levels of unionisation, with the main union being the *Syndicat*

[12] Ministère de la Santé et de la Prévention, Les dépenses de santé en 2021 – édition 2022, 2022, available at: https://drees.solidarites-sante.gouv.fr/publications-documents-de-reference-communique-de-presse/panoramas-de-la-drees/CNS2022.
[13] INSEE, 2021, available at: https://www.insee.fr/fr/statistiques/5432497?sommaire=5435421.
[14] OECD/European Union, Health at a Glance: Europe 2022: State of Health in the EU Cycle, OECD Publishing, Paris, 2022, https://doi.org/10.1787/507433b0-en.
[15] French Health Ministry (2022), Financement des établissements de santé, available at https://sante.gouv.fr/professionnels/gerer-un-etablissement-de-sante-medico-social/financement/financement-des-etablissements-de-sante-10795/article/financement-des-etablissements-de-sante.

National des Professionnels Infirmiers (SNPI), whereas other occupations such as administrative staff have lower levels of unionisation.

Overall, social partners such as unions and employer organizations have played a significant role in the adoption and use of algorithmic management tools in the sector. For instance, unions have been involved in negotiations with management to ensure that the use of new tools does not negatively impact workers' rights or working conditions. Social partners are actively engaged in discussions around the use of AMT and are working to ensure that workers' rights and interests are protected as these tools become more prevalent in the industry.

In recent years, emergency departments across French hospitals have experienced heightened tensions due to continuous surges in patient flows to the ER[16]. This has caused serious backlogs in emergency wards and added important strains to medical and paramedical staff. This increase has been attributed to a variety of factors, including an aging population with more chronic health conditions, a shortage of primary care physicians, and a lack of access to after-hours care. The increase in demand for emergency services has put pressure on French hospitals, leading to longer wait times and overcrowding in some ERs. This has prompted the government to act, such as implementing new policies to encourage more patients to seek care from primary care physicians and other healthcare providers outside of hospital settings. Efforts are also being made to improve the efficiency of emergency services and reduce wait times, such as implementing triage systems to prioritize patients based on the urgency of their medical needs and expanding the use of telemedicine to provide remote consultations and follow-up care.

For example, in one of the establishments covered in the study (*French Healthcare 2*, see section 3) one interviewee noted that between 2008 and 2019, the number of patients admitted each day at the emergency room rose from 119 to 195 (+ 64%), creating huge pressures on staff at the expense of patient care. The hospital's infrastructure, dating several decades, was unable to cope with the sudden upsurge in patients. At the other establishment analysed in France (*French Healthcare 1*) all interviewees agreed that emergency services in France have lived through dramatic changes in the past 30 years. The staff argued that a major increase in the flow of patients to the Emergency Room have not been followed by similar investments in infrastructure, technology, or resources to deal with such increase. One doctor explained that since the 1990s, there has been 30-40% more activity in the ER and that services have become obsolete as a result. The same interviewee argued that the increase in patients is linked to changes in the behaviour of people who demand more specialised tools and the reduction of general practitioners at the local level.

> *Emergencies are a complex and difficult system to manage and are constantly evolving with the needs of our society. Emergencies in the 1990s were not the same as today. Emergencies today are both real emergencies and 'perceived emergencies', hence the increasing flow.*
>
> ***French Healthcare 1*, General manager**

For this reason, both hospitals devoted extensive internal and external resources in R&D in the search for solutions that would ease the tensions at the ER and reduce the staff's added stress. Prior to the introduction of the technologies studied below, both hospitals were not computerised and lacked technologies that could assist the staff in efficiently organising and coordinating their work. Many non-medical tasks that could easily be automated such as counting the number of free beds available, running inventory checks on patients, or deciding on hospitalisation between emergency and specialist doctors, were instead done by hand or through phone calls by doctors and nurses. This inefficiency was causing a massive loss of medical time at the expense of patient care,

[16] Vie Publique (2022), *Crises des urgences médicales: un malaise persistant*, available at https://www.service-public.fr/particuliers/actualites/A15931.

and a demoralising situation for doctors and nurses which instead of doing their medical jobs were forced to waste time with routine, mechanical tasks.

The demands to tackle these problems grew over time, with a 'crisis in the emergencies' declared in 2019 throughout France when hundreds of emergency departments went on strike to demand greater resources: more beds, more staff, and higher wages[17]. By September 2019, over 250 emergency departments were on strike in France and by May 2022 120 remained on partial strike[18]. Consequently, the origin of both projects arises from the multiplication in the number of emergency patients between 2008 and today (in 2022 an average of 200 adults/130 children are admitted per day) in unchanged premises. Moreover, it comes from the need to anticipate patient flows to optimise the mobilisation of medical and nursing staff.

However, there are several potential obstacles to further deployment of algorithmic management tools in the French healthcare sector. Firstly, there are concerns about the potential impact on patient privacy and confidentiality. As algorithmic tools collect and analyze large amounts of data, there is a risk that sensitive patient information could be compromised or misused. Secondly, there are concerns about the potential for AMT to exacerbate existing inequalities and biases in the healthcare system. For example, if the algorithm is based on historical data that reflects systemic discrimination against certain groups, then the tool may perpetuate these biases and inequalities. Thirdly, there are concerns about the potential for algorithmic tools to lead to a de-skilling of healthcare professionals, as the decision-making process is increasingly automated. This could lead to a loss of professional autonomy and a reduction in the quality of care provided to patients. Lastly, there are also concerns about the potential cost and complexity of implementing algorithmic management tools in the healthcare sector, as well as the need for ongoing maintenance and training.

2 Methodology

Each case study considered in the project was conceived to include a number of qualitative, in-depth, semi-structured interviews and field visits in an establishment using algorithmic management for the coordination of work processes, to be complemented by desk research as appropriate[19]. Specifically, the case studies involved interviews with individuals in different functions and roles in each establishment including managers at different levels, union and worker representatives, technology specialists, and workers affected by the technology. A semi-structured interview guide was designed and organised around a set of core themes and questions intended to investigate the impact of algorithms and digital solutions on work organisation and working conditions. All interviews were recorded and later transcribed. A content analysis of each interview was carried out: interviews' transcripts were individually studied and developed from generalised contents towards robust analyses progressively crystalising on the key dimensions covered. The main topics covered in the interviews include: (i) impacts on business model and the delivery of services; (ii) impacts on organisation and coordination of work processes; (iii) impacts on occupations, tasks and skills; (iv) impacts on work intensification; (v) impacts on autonomy; (vi) impacts on social interaction; (vii) impacts on monitoring and surveillance; and (viii) impacts on industrial relations.

The participation and involvement of different stakeholders in the research allows to provide a balanced understanding of the implementation of the digital solution, the level of algorithmisation of the technology in place, and its impacts in the workplace. In addition to the qualitative interviews,

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[17] Franceinfo (2019), *Grève aux urgences: neuf chiffres pour comprendre une crise sociale sans precedent*, available at https://www.francetvinfo.fr/sante/hopital/cinq-chiffres-pour-comprendre-la-crise-dans-les-services-d-urgences_3475921.html.

[18] Le Monde (2022), *Crise aux urgences: des fermetures, des grèves et le regret du «temps perdu»,* available at https://www.lemonde.fr/societe/article/2022/06/27/crise-aux-urgences-des-fermetures-des-greves-et-une-reponse-du-gouvernement-jugee-trop-tardive_6132135_3224.html.

[19] Rani, U., Pesole, A. and Gonzalez Vazquez, I., Algorithmic Management practices in regular workplaces: case studies in logistics and healthcare, Publications Office of the European Union, Luxembourg, 2024, doi:10.2760/712475, JRC136063.

the case studies are supplemented with information and documentation provided by the establishments' management and other working papers.

In **Italy**, the case study at *Italian Healthcare 1* draws primarily from qualitative interviews conducted with a range of key stakeholders in the establishment. The research team had a first preliminary meeting with the doctor in charge of the deployment of the new technology in November 2022, who immediately confirmed their participation in the study. Evidence from *Italian Healthcare 1* has been collected by the study team through 12 interviews with the hospital's personnel, which were conducted online (about 1-hour video-call with pre-identified workers) between December 2022 and January 2023 with the presence of the research team and the interviewees following a pre-established questionnaire sent in advance, and covered all relevant profiles: doctors, department directors, pharmacists, administrative employees, and IT specialists (see appendix for more details).

In view of the difficulties to find an additional establishment in the healthcare sector in Italy, the JRC coordination team and the researchers agreed to draw additional evidence from the report "Case studies of automation in services"[20], published by the Joint Research Centre of the European Commission in November 2022. This concerns the three additional establishments covered in this report (*Italian Healthcare 2*, *Italian Healthcare 3* and *Italian Healthcare 4*). Thus, this report consists of a comparative analysis between the evidence collected from the interviews carried out at *Italian Healthcare 1* and the main findings contained in the "Case studies of automation in services" report. In this sense, the information hereby reported about the *Italian Healthcare 2*, *Italian Healthcare 3* and *Italian Healthcare 4* hospitals are not as exhaustive as those concerning *Italian Healthcare 1*.

In **France**, the research team contacted the CEO of the technology provider for the AMT used at *French Healthcare 1* in June 2022, and the first preliminary meeting was held in October 2022. At that meeting, the company agreed to participate in the project alongside staff members of the establishment. Interviews were carried out between November and December 2022, and were conducted online via MS Teams with a pre-established questionnaire sent in advance. For *French Healthcare 2*, the research team had a first preliminary meeting with the establishment in June 2022, during which the hospital confirmed its participation. Interviews were conducted between August and October 2022 via MS Teams with a pre-established questionnaire sent in advance. For both cases, a total of fifteen interviews were conducted online (about 1-hour videocall with pre-identified workers)[21] and covered all relevant profiles: doctors, nurses, HR managers, general managers, bed-management workers, technology specialists and providers (see appendix for more details).

3 Profiles of the case studies

The technologies considered in the case studies span a wide range of categories. The tools deployed by *Italian Healthcare 1*, *French Healthcare 1*, and *French Healthcare 2* mainly concern hospital information systems with predictive data analytics elements. In contrast, the evidence from the report "Case Studies of Automation in Services"[22] primarily pertains to telemedicine tools. Hospital information systems with predictive analytics optimise hospital workflows, resource allocation, and patient care by analysing data and forecasting needs. In contrast, telemedicine tools enable remote consultations, diagnostics, and monitoring, improving accessibility and reducing in-person visits. While both support healthcare coordination, hospital information systems enhance internal operations, whereas telemedicine focuses on remote patient-provider interactions.

[20] Cirillo, V., Rinaldini, M., Virgillito, M.E., Divella, M., Manicardi, C., Massimo, F.S., Cetrulo, A., Costantini, E., Moro, A. and Staccioli, J., Case studies of automation in services, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-58953-2, doi:10.2760/347087, JRC129691.
[21] Including some interviews with key informants and stakeholders.
[22] Cirillo, V., Rinaldini, M., Virgillito, M.E., Divella, M., Manicardi, C., Massimo, F.S., Cetrulo, A., Costantini, E., Moro, A. and Staccioli, J., Case studies of automation in services, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-58953-2, doi:10.2760/347087, JRC129691.

Thus, although the tools described below are not strictly algorithmic management (e.g., involving automation of managerial control and decision-making), they are nonetheless used for the coordination and allocation of work. In this case, they are relevant insofar as to influence work organisation, job quality and worker relations.

3.1 Description of the establishments

3.1.1 Italian Healthcare 1

Italian Healthcare 1 is one of the largest hospitals in central Italy in terms of employment and number of hospital wards.[23] In 2022, it had a total capacity of 1,139 beds and around 52,000 hospitalisations (with significant percentages of extra-regional hospitalisations), employing 4,898 workers under the Italian national healthcare system and 244 university doctors. *Italian Healthcare 1* is a public hospital unit, part of the SSN and of ESTAR, a regional support body established in 2014 for the exercise of technical and administrative functions of health bodies in the Tuscany region.

Italian Healthcare 1 devoted extensive internal and external resources to R&D in the search for solutions that would ease the management of big data. Efficient processes were found necessary to integrate the available drug-related data and transform them into organised, useful, clear, reliable and immediate information. Indeed, the hospital lacked a technology that could assist the staff in efficiently managing the flow of drugs. Many non-medical tasks, such as data entry, data collection and data analysis, were done manually by doctors and nurses, at the expense of patient care.

3.1.2 Italian Healthcare 2

Italian Healthcare 2 is a public hospital unit part of AUSL, the Emilia-Romagna regional health agency. It is the most important hospital of the province in terms of number of hospital wards and employees.

3.1.3 Italian Healthcare 3

Italian Healthcare 3 is part of ASUR, the Marche regional health authority. The hospital is at the forefront of technological innovation and, in 2022, it has been recognised as one of the best public hospitals in Italy by the National Agency for Healthcare Services.

3.1.4 Italian Healthcare 4

Italian Healthcare 4 is a highly specialised polyclinic hospital, a clinical and scientific research centre, and a university teaching centre. *Italian Healthcare 4 is* also one of the most renowned hospitals in northern Italy and it is a reference point for research on cancer and immunodegenerative diseases at the international level. In 2022, it had 25 wards for a total of 759 beds, with approximately 3,400 staff and 45,000 hospitalisations per year.

3.1.5 French Healthcare 1

French Healthcare 1 is a leading university hospital in France and one of two university hospitals in the region. In 2022 it had a total capacity of 1,701 beds, with approximately 6,500 staff, including nearly 800 doctors. Being a university hospital, it ensures the triple mission of care, teaching, and research. The hospital actively collaborates with other health establishments to promote medical excellence, facilitate patient care, and propose new innovative care structures.

[23] The hospital is highly specialised in testing points and clinics, transplants (liver, kidney, pancreas, marrow) and robotic surgery. It collaborates with other health establishments to promote medical research, improve the quality of patient care and advance innovative care treatment. Moreover, the hospital is integrated with the university of the city, as it also functions as a health research centre and it hosts medical students.

3.1.6 French Healthcare 2

French Healthcare 2 is a similarly leading general hospital in France. It has a capacity of 1,850 beds, more than half of which are in Surgery, Medicine, and Obstetrics. The hospital has an agreement with the polytechnic university of the city for joint work in favour of health research. An innovative and expanding establishment, the hospital is at the forefront of technological advancements experienced in recent years throughout French hospitals.

3.2 Description of the technologies

3.2.1 The digital technology for drug-related data management used at *Italian Healthcare 1*

The **digital technology for drug-related data management** was adopted by *Italian Healthcare 1* in 2019 on the initiative of the Hospital Pharmacy Director. Indeed, the Hospital Pharmacy is the most affected department by the introduction of this technology. The project has been developed in the form of a public-private sponsorship, together with the participation of several pharmaceutical industries and the Department of Engineering of a university. The outbreak of COVID-19 did not particularly affect the deployment of the technology. As a matter of fact, the pandemic, by exerting strong pressures on the overall health system, further highlighted the need to identify and exploit every margin of efficiency within the hospital.

The drug-related data management technology was conceived to automate the optimization of drug policies management by developing an integrated, open and replicable system. Indeed, drug-related data are transversally collected and processed by different departments, as drugs go across different processes of the hospital. For example, they are used by clinical departments when conducting trials, by the administrative department when stipulating contracts with pharmaceutical companies, and mostly by the Hospital Pharmacy, as it receives drug deliveries, manages economic resources, maintains contact with the other actors involved (the hospital's Health Directorate, ESTAR, etc.) and dispenses the drug directly or supplies it to the departments where it is dispensed.

The problem found by the Hospital Pharmacy department was that it was difficult to reconcile all the information linked to drugs going across the different processes. Information was consequently disaggregated, giving only a partial view of the whole process. Moreover, because of the enormous advancements of drug research, pharmaceutical spending is increasing year by year. Thus, in order to be financially sustainable, it became fundamental for the hospital to have a dynamic, automated and updated tool reflecting the use of drugs within the establishment.

The main objective of the technology, which is now fully deployed, is to streamline the flow of data related to the reassignment of credit notes deriving from negotiated agreements for innovative and non-innovative drugs or high-cost drugs used in multiple therapeutic areas, by:

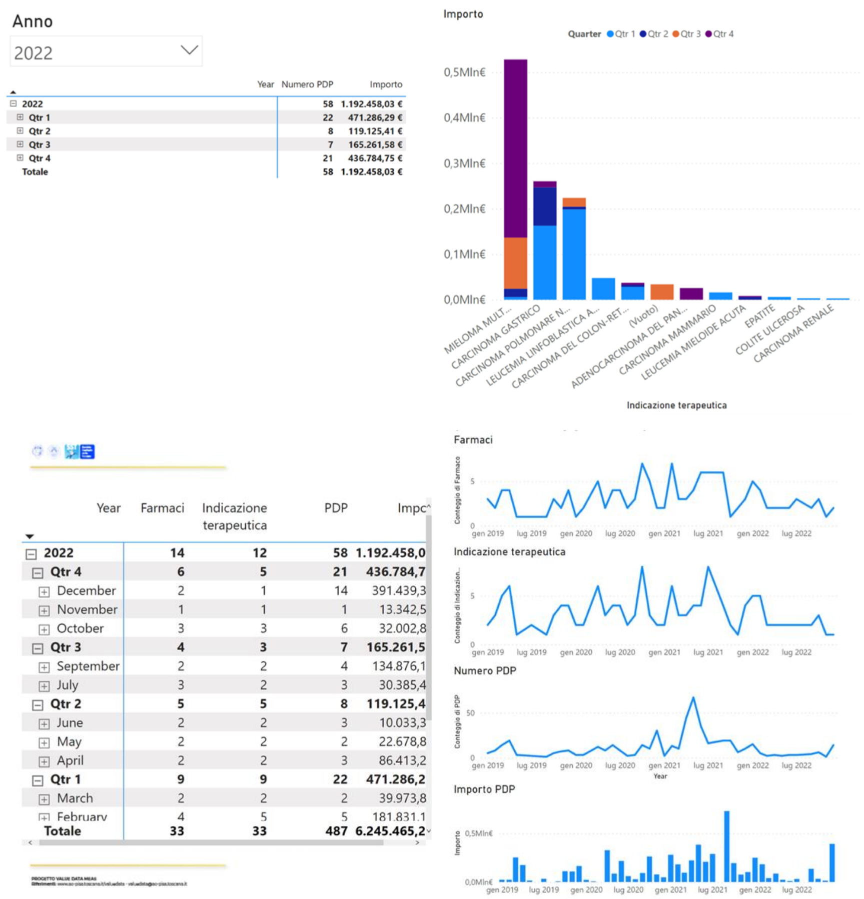
— providing all actors involved in the process (i.e., SSN, ESTAR, the hospital, other health facilities in the region) tools that allow timely actions in the recovery of credit notes;

— creating an organisational path to elaborate all the data available;

— integrating real world evidence data with the obtained credit notes data in order to identify the real value of drugs.

The software implemented automatically calculates how much of the credit notes should be reassigned to the hospital and creates easily accessible dashboards which are used for economic analysis.

Figure 1: An example of dashboard



<u>Source</u>: *Material provided by the hospital*

3.2.2 Telestroke used at *Italian Healthcare 2*

Italian Healthcare 2 in recent years has adopted several services of telemedicine, such as televisits, systems of remote reporting and systems of remote monitoring of implantable devices. The technology of **telestroke**, in particular, was adopted in 2019 and is now fully integrated. In the context of this technology, in case of a presumed cerebral stroke, the emergency doctor or the nurse in any hospital of the province calls the neurologist at *Italian Healthcare 2*, activates the telestroke tool for teleconsultation and carries out the televisit led by the neurologist.[24]

3.2.3 Remote monitoring of heart devices used at *Italian Healthcare 2*

Similarly, the **remote monitoring of heart devices** has been implemented at *Italian Healthcare 2* in 2014, but it was only with the spread of the COVID-19 pandemic that its full potential was finally released. Thanks to the use of the technology, patients are included in a "virtual clinic" and can undergo a remote checkup on a yearly basis. The report of the automatic visit is uploaded on the digital platform for document sharing used by the establishment and then added to the electronic health record of the patient.[25]

[24] Cirillo, V., Rinaldini, M., Virgillito, M.E., Divella, M., Manicardi, C., Massimo, F.S., Cetrulo, A., Costantini, E., Moro, A. and Staccioli, J., Case studies of automation in services, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-58953-2, doi:10.2760/347087, JRC129691.

[25] Ibid.

3.2.4 Remote monitoring of cardiovascular conditions used at used at *Italian Healthcare 3*

The technology for remote monitoring of cardiovascular conditions has been adopted at *Italian Healthcare 3* in 2015 after a pilot phase in other establishments of the region and is now fully operational. The devices allow the remote monitoring of cardiovascular conditions and the defibrillation onboard of advanced emergency vehicles. The device has required the installation of a station, consisting of a desktop computer associated to the monitor/defibrillator.[26]

3.2.5 Televisits

Televisits have been introduced at *Italian Healthcare 3* in May 2020, independently of the pandemic situation, and are now fully integrated in the Hematology and Oncology units. Patients at *Italian Healthcare 3* can book the televisits through the hospital platform or by calling the switchboard. To undergo the televisit, patients log into the platform, where they are also can upload any personal document to share with doctors. Doctors, instead, stand in a teleconsultation station, composed of a computer and a webcam. Once the visit is over, the doctor uploads the report on the platform, so that the patient can consult and download it. Patients' data are then stored automatically on the platform for three months and deleted after that.[27]

3.2.6 The technology to predict the activity at the ER used at *French Healthcare 1*

The technology was introduced in *French Healthcare 1* in 2014 and is now fully functional. The technology supports the organisation of patient flow at the hospital through artificial intelligence that is trained with data from the computerised medical records. Its goal is to monitor patient flows in the ER and predict the need for hospital beds and resources (staff, equipment, etc.) to improve bed management. The targeted users are emergency physicians and nurses as well as bed management workers.

The technology predicts patient progress from the moment they enter the ER, throughout their care, until they are discharged or hospitalised. Since 2014, over 200 000 people have passed through the ER at *French Healthcare 1*, meaning a quick and efficient management of patient flow is needed to decide on each course of action: hospitalise the patient or not, in which service, for how long and what medical resources to use.

The Data Protection Officer (DPO) interviewed, explained that the project started with the recognition of an overcrowding problem at the ER and a need to decrease a patient's time waiting to be admitted. It was once the decision to hospitalise a patient was made, that he/she was losing the most time (the time it took to find a free space). The DPO noted that the tool was born from recognising that it was possible to check earlier whether a patient was going to be hospitalised. The project demonstrated that technology experts could put in place a useful, reproducible, and automated tool.

Therefore, the technology's objective is to predict hospitalisation and reduce a patient's time spent at the ER. By speeding up this process, the tool increases efficiency and time-management at the emergency department whilst improving the overall organisation of the hospital. One doctor pointed out that the work of sorting and organising patients at the ER has progressively become more difficult and time consuming.

> *Doctors must think carefully about how to sort and organise patients in an efficient way so that each person is allocated to the right bed. Thus, the goal of*

[26] Cirillo, V., Rinaldini, M., Virgillito, M.E., Divella, M., Manicardi, C., Massimo, F.S., Cetrulo, A., Costantini, E., Moro, A. and Staccioli, J., Case studies of automation in services, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-58953-2, doi:10.2760/347087, JRC129691.
[27] Ibid.

the technology is the same as before: to detect and differentiate between urgent and non-urgent patients to triage them more quickly. It is therefore necessary to be able to identify the serious patients and manage them.

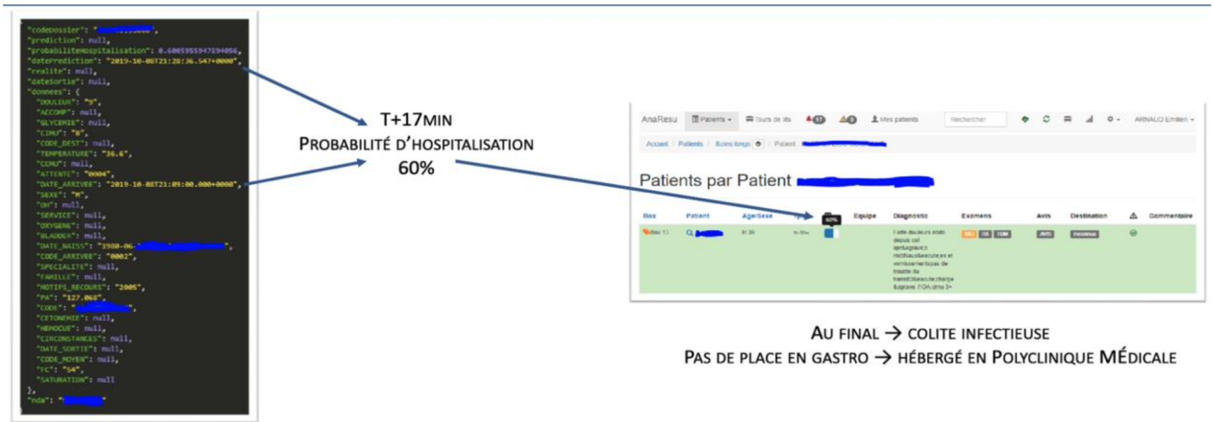
***French Healthcare 1*, Doctor**

With the use of the technology, patient information is collected by the receptionist nurse in the same way, asking the same questions and using the same software and interface. This information is stored within the hospital and the decision on what to do with the patient is taken. Then, the algorithm calculates a probability of hospitalisation from the information inputted, which can be the same or different as the initial doctor's decision. The software programme then displays in real time the number of patients at the ER and the severity of each patient to help decide who to hospitalise and in which speciality immediately.

In concrete terms, the programme offers a global vision in real time of the flow of patients and gives the needs by speciality and by department. It provides a summary of the hospital's situation at any given moment. This avoids having to go round all patients if doctors want to do an inventory check, which is a costly step in terms of medical time to the detriment of patient care.

The information from the technology is displayed on a portable dashboard easily available to emergency workers on request. Emergency physicians have the choice to check, or not, the information at their disposable at any time. On the left-hand side of Figure 2, we notice the algorithm in play. On the right-hand side, the dashboard is displayed with information separated by patient with box location, name, sex, and age, waiting time, probability of hospitalisation and diagnostic. Figure 2 illustrates the first step of the technology by identifying the patient and summering his/her diagnostic alongside with their waiting time and hospitalisation probability.

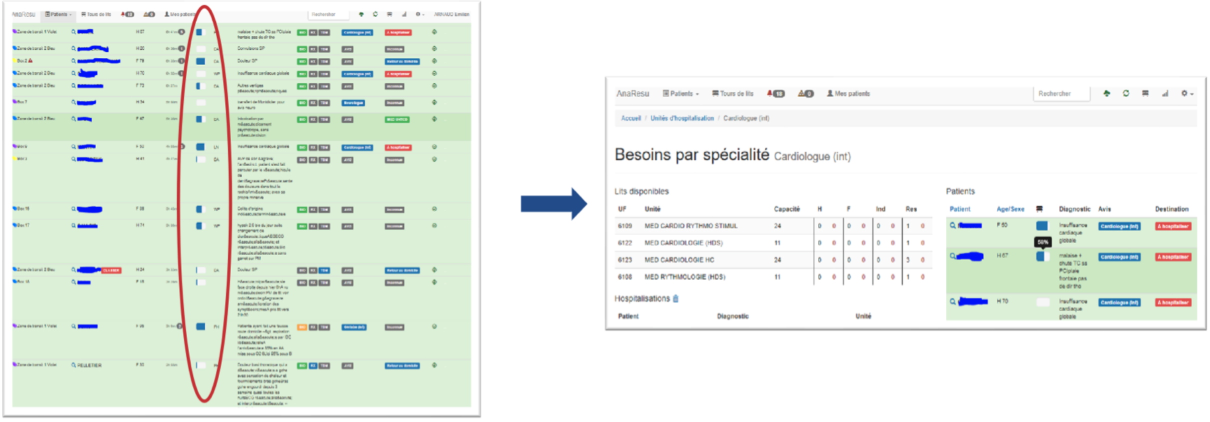
Figure 2: Demo of algorithm and dashboard



Source: Material provided by the hospital

On the left-hand side of Figure 3, we can see the technology's dashboard with an overview of all patients and relevant information, including waiting time and probability of hospitalisation. On the right-hand side of Figure 3, we can see the dashboard of the needs by speciality – in this case cardiology. With this information, emergency workers can identify in real-time the available spaces and free beds in each speciality and decide where to send each patient that needs hospitalisation from the ER.

Figure 3: Dashboard with overview of hospitalization probability and specialty needs



Source: Material provided by the hospital

3.2.7 The technology to predict the activity at the ER used at *French Healthcare 2*

The algorithmic technology was introduced in *French Healthcare 2* in 2019 and includes different tools, some of which are finalised and others in testing phase. The first tool introduced is similar to the technology implemented at *French Healthcare 1*, in which the technology predicts emergency room flows at the hospital and helps anticipate peak activity. Other tools concern organisational support with a goal to predict patient arrivals in the Emergency Department, ensure patient profiling, monitor the progress of patient care during their stay at the ER, and optimise staff and bed management. The targeted users are medical/paramedical staff in emergency departments and destination departments outside of the ER. The overarching objective is to improve the quality of work for the hospital staff and to improve the services given to patients.

The data used is taken from territorial information (time, traffic, etc.) and from the hospital's warehouse (history of patient data, etc.), and is hosted within *French Healthcare 2*. The reliability of the tool's predictions is 90% on average, which reduces the number of "hospital under stress" periods. The key success factors of the tool are a management change with directorate of information systems staff (data management), a management change with medical/paramedical staff, and a transparency and sharing of the results of predictions provided by the AI. Overall, the nature of the tool is multivarious:

— Predict the flow of patients at the emergency department in real-time over the following 24h and the next 5 days, including the number of hospitalisations per day, the number of patients, and the 'tension' periods;

— Profiling of patients by pathology (neuro, cardio, digestive, etc.);

— Monitoring of patient care during their stay in the emergency department;

— Predict the management of hospital beds downstream of the emergency department with real-time data sharing via a smartphone application.

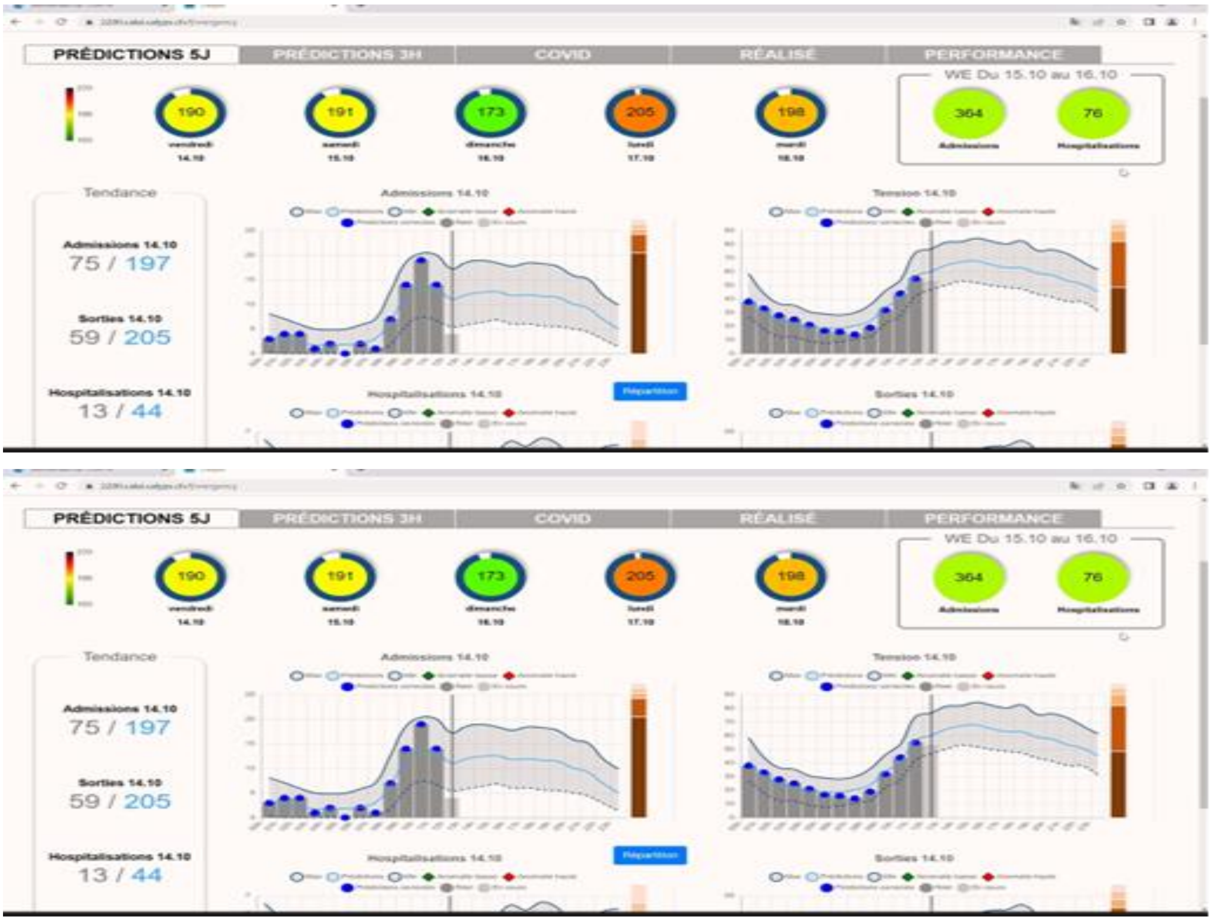
In this sense the tool provides information to adapt human resources (especially paramedical, but also medical) with the prediction of the flow of patients at the ER. Likewise, the tool communicates the next steps to be taken and estimates waiting time to avoid multiple calls from relatives and a staff's interruptions of priority tasks. Finally, the tool improves bed management to better plan the number of beds necessary at any given moment, as well as to anticipate the periods of heightened tension (when there are too many patients in the ER).

The algorithmic management tool is presented as a purely managerial tool that also helps to increase communication in the ER by providing figures and data in real-time that can be used to decide to increase or reduce the number of staff requested or the number of beds to make available. The staff interviewed explained that the tool is used and shared among the ER medical and paramedical staff and that it helps with management and especially with HR management.

> *In the past, if one person was on leave, we would replace him/her immediately. Now, we can see if they are really needed or not. The tool also helps to reevaluate the needs during a single day and potentially grant some recuperation to staff if it's going to be less busy.*
>
> ***French Healthcare 2*, General manager**

The tool's dashboard can be seen in Figure 4 with the predictions of the flow of patients to the ER. The top circles indicate the total number of patients predicted at the ER on that day, with the probability in blue, and the different colours illustrating whether the flow will cause 'tensions' or not. The two circles on the right indicate the predictions over the weekend. On the left-hand side of Figure 4, the grey numbers indicate the current, real flow of patients to the ER, the number of discharges, the number of patients over 75 years, the number of 'tensions' causing patients and the number of hospitalisations for that day and time. The blue numbers indicate the total predicted number of the same information for that entire day. The graphs in the middle with bar charts and line bars indicate the same above information broken down per hour and with the minimum, maximum and mean predictions for the day, as well as the actual real observation recorded.

Figure 4: Demo of the technology dashboard



<u>Source</u>: Material provided by the hospital

In the '*réalisé*' tab on top of the dashboard, the hospital can compare the past, present, and future predictions of the algorithm with reality, which is usually above 96% correct.

Staff interviewed in both hospitals believed that if doctors and nurses used algorithms to analyse patient flows with parameters that interest them, they could save time and optimise the management of serious patients and those who are less urgent. This would then respond to the recent needs of the French healthcare system and the guidelines outlined in the *tarification à l'activité* policy mentioned above, encouraging hospitals to improve efficiency and cost-effectiveness by incentivizing faster procedures with fewer resources (and fewer number of hospital beds), while still ensuring that patients receive necessary care.

4 Business model and work organisation

4.1 Business model and the delivery of services

At ***Italian Healthcare 1***, the implementation of the drug-related data management technology has significantly improved the productivity of doctors and nurses by enhancing efficiency, reducing costs, and increasing patient satisfaction. In large hospitals like the one considered here, the lack of digital tools for non-medical tasks often forces medical staff to spend excessive time on repetitive administrative processes, leading to inefficiencies, errors, and resource misallocation. By systematising and automating data management, the hospital has optimised workflows, minimised human error, and freed medical staff from manual tasks. In the Hospital Pharmacy department, user-friendly dashboards powered by the technology allow doctors and nurses to analyse and adjust data efficiently, eliminating the need for manual data collection. As a result, healthcare staff can dedicate more time to essential activities, such as patient care and direct interactions.

Likewise, the reduction of hospitalisations, patients' flow for routine visits and emergency department visits is pivotal for a more efficient patients' management.[28] Overcrowding in hospitals and unessential hospitalisations entail indeed major costs and the employment of human resources. In this sense, the introduction of technologies like the remote monitoring of heart devices at ***Italian Healthcare 2*** and of televisits at ***Italian Healthcare 4*** has been fundamental. During the pandemic, in particular, patients were able to continue being visited in spite of the whole healthcare system's block.[29]

> *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.*
>
> ***Italian Healthcare 2*, Cardiologist**[30]

Similarly, at ***Italian Healthcare 4*** televisits helped to replace in-presence follow-up visits after a surgery and routine checkups, hence decreasing the costs of carrying out on-site activities and improving the quality of post-operations follow-ups.[31] Moreover, just like at the ***Italian Healthcare 2***, televisits reduced the flow of external people within the establishment during the COVID-19 outbreak, as explained by the Cardiologist:

> *The use of the televisit system increased with the peaks of the pandemic since people could not move. However, the technology was meant to be a natural accomplishment of our document sharing platform which was conceptualised and implemented out of the pandemic perspective.*
>
> ***Italian Healthcare 2,* Cardiologist**[32]

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[28] Cirillo, V., Rinaldini, M., Virgillito, M.E., Divella, M., Manicardi, C., Massimo, F.S., Cetrulo, A., Costantini, E., Moro, A. and Staccioli, J., Case studies of automation in services, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-58953-2, doi:10.2760/347087, JRC129691.
[29] Ibid.
[30] Ibid.
[31] Ibid.
[32] Ibid.

At ***Italian Healthcare 1***, as emerged from the interviews, the time-saving aspect was one of the core values of the project. For both streams, the introduction of the technology resulted in a change of procedures that allows employees to better manage big data related to drugs.

> *The introduction of the technology led to an improvement not only of the activities related to patients' care, but also of the tasks concerning the budget planning, which constitutes a big portion of the work I do. Through the dashboards developed by the technology, I can see how many patients participate to trials and the costs that the hospital saves by conducting these trials with innovative drugs.*
>
> ***Italian Healthcare 1,* Pharmacist 2**

The interviewee added that the workflow is now much smoother, and that the technology is of great help to retrieve the information, enabling them to avoid repetitive data collection and data entry activities. Also, it is now much easier to do dynamic analysis and immediate comparisons between different drug treatments, which are fundamental activities for pharmacists in order to follow the best therapies for their patients.

The Hospital Pharmacy Director reported that, thanks to the technology implemented, pharmacists can save up to 3 hours and a half per day.

Likewise, the most relevant drivers behind the adoption of the telestroke technology at ***Italian Healthcare 2*** concern some aspects related to productivity, i.e., time-saving, the reduction of diagnostic errors and the cost of unnecessary transfers to the hub. Indeed, in emergency situations such as strokes or heart attacks, where every minute is critical, prompt diagnosis and intervention can significantly impact patient outcomes, reducing the risk of severe complications or mortality. By enabling remote assessment and decision-making, this technology not only optimizes workflow efficiency but also enhances physicians' effectiveness in delivering timely, life-saving care.[33] On this matter, some of the interviewees argued:

> *The technology is of great help for managing emergencies remotely. It enables us to assess whether the patient can be treated on the spot in the peripheral hospital or needs to be transferred.*
>
> ***Italian Healthcare 2,* IT Specialist of Neurophysiopatology unit[34]**

> *Our rationale about technology adoption is about time-saving rather than labour-saving. Technology is therefore not seen in the perspective of reducing the number of people who work there.*
>
> ***Italian Healthcare 2,* Managers of the emergency service[35]**

Moreover, at ***Italian Healthcare 1*** the use of the technology resulted in major cost savings. By assigning a monetary value to the drugs dispensed, pharmacists can get a full overview of how much of that value can be recovered by the hospital. Given that the resources mainly consist in human resources, if these are spent for added value activities, the hospital can have important benefits in terms of money saved, as less personnel will be needed to carry out administrative tasks.

[33] Cirillo, V., Rinaldini, M., Virgillito, M.E., Divella, M., Manicardi, C., Massimo, F.S., Cetrulo, A., Costantini, E., Moro, A. and Staccioli, J., Case studies of automation in services, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-58953-2, doi:10.2760/347087, JRC129691.

[34] Ibid.

[35] Ibid.

4.2 Organisation and coordination of work processes

At ***Italian Healthcare 1***, thanks to the drug-related data management technology, there has been a redefinition of roles and responsibilities within the hospital. Yet, more than the creation of new roles and responsibilities, functions have been refitted according to each employee's competencies and expertise. According to the Hospital Pharmacy Director, both streams of the project allow pharmacists to carry out the task they were originally supposed to, namely the drug administration to patients. Indeed, before the introduction of the technology, they were engaged in conducting administrative tasks not directly related to the core of their occupation.

> *With the development of the technology, pharmacists will be able to regain their competence on the activities linked to drug administration to patients, pharmacovigilance and counselling. Until now, clinical trials specialists conducted these tasks, even if they should only be competent on activities directly related to clinical trials.*
>
> ***Italian Healthcare 1,* Hospital Pharmacy Director**

Given the transversal nature of the drug management within the hospital, the technology has affected the work of several figures in different departments. As a matter of fact, while at the beginning the only figures directly involved in the project were pharmacists, the advantages of its development soon affected also other profiles both inside and outside the hospital. Indeed, different figures within the hospital carry out drugs-related activities. For example, doctors and nurses of various departments administer drugs to patients on a daily basis or use innovative drugs when conducting clinical trials; the ESTAR administrative staff signs contracts with pharmaceutical companies to buy drugs; data managers follow and analyse the drugs-related flows to assist the hospital's managers to take budgetary decisions and so on.

Both at ***Italian Healthcare 2*** and ***Italian Healthcare 3*** emergency doctors and nurses have been deeply affected in terms of task content.[36] The adoption of the telestroke and of the technology for remote monitoring of cardiovascular conditions respectively resulted in a significant upskilling of the medical staff not only as far as digital competences are concerned, but also in terms of expanded knowledge, and increased interaction with colleagues, technology providers and technology specialists.[37] In particular, the nursing staff started performing more tasks of different nature autonomously, without the presence of doctors directly supervising them, hence experiencing an increase of physical, intellectual and social tasks (e.g., information processing, monitoring, problem solving, increased interaction with other medical staff, training activities, etc.).[38] On the other hand, doctors did not perceive any form of intensification. Rather, emergency doctors can now save more time previously dedicated to useless transfers and employ that to make more accurate diagnoses.[39]

Likewise, at ***Italian Healthcare 2*** and ***Italian Healthcare 4***, following the introduction of remote monitoring of implantable cardiac devices and televisits, a significant increase of physical, intellectual and social tasks affected tech specialists and administrative units, with a consequent upskilling trend especially in the field of digital competences.[40]

The implementation of the **technologies to predict the activity at the ER** has had major impacts on both **French hospital's work organisation**. Overall, responses across case studies were positive but differed on the visible, or 'tangible' effects of their technologies on daily work. For

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[36] Cirillo, V., Rinaldini, M., Virgillito, M.E., Divella, M., Manicardi, C., Massimo, F.S., Cetrulo, A., Costantini, E., Moro, A. and Staccioli, J., Case studies of automation in services, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-58953-2, doi:10.2760/347087, JRC129691

[37] Ibid.

[38] Ibid.

[39] Ibid.

[40] Ibid.

example, some paramedical workers interviewed at ***French Healthcare 1*** agreed that the technology is 'silent', meaning that it is not seen or interacted with directly but instead works in the background. For this reason, although the tool has impacted the hospital's overall organisation, some interviewees explained that it had not visibly impacted their workflow since the usual steps to triage and organise patients remained the same. This contrasts with the ***French Healthcare 2*** case study, where all interviewees agreed that the technology had positively impacted and changed their workflow.

In the first case, a nurse interviewed at ***French Healthcare 1*** was not aware of the existence of the technology itself but knew about the dashboard and interface that she uses daily to encode patients' information ('*ResUrgences*') – where the data feeds into the tool.

> *The tool has not changed the organisation of work at my level. At the paramedical level, we fill out our file as before. The nurses have no contact with the algorithm and no specific instructions on how to complete the records. There was no need for paramedics to adapt.*
>
> ***French Healthcare 1*, Emergency nurse**

On the other hand, for the architect of the technology, this has a direct effect on doctor's workflow by increasing their time spent with each patient. He also believed the hospital administration has been impacted, which now has a better understanding of the number of patients and free beds available at any given moment. Finally, the architect alleged that the bed management unit is especially impacted, as their work has become swifter by the increase in organisation of the bed search. The technology has decreased the staff's time doing non-medical tasks, which is not their job, and increased the time spent with patients. For the head of the emergency services at *French Healthcare 1* , the technology is finer with a more subtle impact.

> *The fact that the algorithm helps us anticipate allows to relieve the workload. Normally a patient must wait in the ER up to 6 hours to be sent to the right department. If we can anticipate this with the algorithm, we can bring forward steps that reduce the patient's wait, so it doesn't impact the diagnosis or the referral decision, but it does impact on the time.*
>
> ***French Healthcare 1*, General manager**

Similarly, the HR Manager at ***French Healthcare 2*** believed the impact of the technology on work organisation is evident. She explained that knowing the daily flows of patients to the ER allows for a better allocation of human resources on the medical and paramedical side. The activity and flow curve over 24 hours is precise, sharing the patients permanently in the ER and the number of entries per hour. This enables the hospital to adapt human resources and profiles in line with these flows, she explained (how many are in surgery, how many in medicine etc.).

> *We have been able to adapt our resources to activity peaks. We can now adapt the administrative resources for entering patients' data on arrival. Depending on the flow of patients, we can ask second-line staff to come in as reinforcements for two hours at a time, for example, which creates organisational agility. Instead of being in crisis management all the time, we can look for solutions earlier for capacity.*
>
> ***French Healthcare 2*, HR manager**

Nurses who used to enter patient information by hand on a computer, are now scanning a QR code on the patient's wristband and stretcher. These additional elements, integrated into the bed management project, ensure that staff can focus on their core responsibilities and dedicate more time to patient care instead of administrative tasks, explained the technology specialist at *French Healthcare 2*.

Furthermore, most interviewees at ***French Healthcare 1*** agreed that the work coordination improved thanks to the predictive technology. On a similar note, the architect of the technology said that the aim was to integrate it into the work coordination processes as discreetly and unobtrusively as possible. In this sense, the reception nurses enter the same data on the patient with or without the tool. The benefit comes with the bed management unit talking more fluidly and directly with management, as to remove the need to constantly ask for manual patient counts from different departments.

In terms of HR management at ***French Healthcare 2***, the tool can plan a number of things for doctors by taking into account the expected workload, organisational constraints, and the wishes (schedules etc.) of the carer. For a head of department, the automation of the planning is a time saving of 1 hour per week.

4.3 Occupations, tasks and skills

At ***Italian Healthcare 1***, the introduction of the technology did not come along with a change in the nature of tasks, but only with a new organisational process and information flow across teams. Therefore, at *Italian Healthcare 1* no major changes in the composition of the workforce occurred, nor any form of outsourcing. Indeed, the development of the technology has been mainly carried out by internal staff, including general managers, doctors and data managers. The use of external profiles has been limited to ICT and communication experts, which have been enrolled ad hoc for the development of specific tasks.

However, some elements regarding the emergence of new profiles within the Hospital Pharmacy department have been highlighted by the interviewees. According to an interviewee, the figure of data manager is not well-recognised within Italian hospitals. However, there is increasing attention about this role in the healthcare sector. Following the implementation of projects like the one considered here, their role is becoming more institutionalised. For example, at the Hospital Pharmacy department, now there are 4 data managers, thanks to the introduction of the technology, who are responsible for managing drug records, monitor data accuracy and analysing drug-related data to support decision-making. Moreover, some interviewees stated that, thanks to the saving resulted from to the implementation of the new technology, there might be space for new hires of medical staff in the near future.

Likewise, the adoption of the new technologies at ***Italian Healthcare 3*** and ***Italian Healthcare 4*** did not generally need the hire of new employees in the relative departments.[41] Instead, at ***Italian Healthcare 2***, the introduction of remote monitoring devices has been accompanied by the need to hire new personnel for the correct functioning of the technology. For this purpose, a new technical unit within the electrophysiology division has been created ex-novo for the remote monitoring of implanted heart devices.[42]

Also, according to some interviewees at ***Italian Healthcare 1***, the use of the technology, given the revised administrative processes related to drug management and the resulting savings in monetary terms, allows to allocate more efficiently the resources where needed.

> *The chance of gaining full knowledge in real time by all the actors involved in the process results in the possibility to allocate resources more efficiently, recruit more people and increase the level of care and other clinical aspects.*
>
> ***Italian Healthcare 1,* IT Specialist 2**

The deployment of the technology has not changed the distribution of tasks per se at *Italian Healthcare 1*. However, relieving the workload of staff, the software allows doctors and nurses to

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[41] Cirillo, V., Rinaldini, M., Virgillito, M.E., Divella, M., Manicardi, C., Massimo, F.S., Cetrulo, A., Costantini, E., Moro, A. and Staccioli, J., Case studies of automation in services, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-58953-2, doi:10.2760/347087, JRC129691.
[42] Ibid.

concentrate their time on patients' care. Moreover, the way in which they collect and consult data has improved in terms of time and efficiency. In this sense, the interviewees agreed that the new methods in which they carry out activities are more stimulating than before, adding value to their tasks and making the overall process smoother. Also, trivial and demotivating activities (e.g., data entry activities) have been replaced with more stimulating ones (e.g., data analysis and discussing results with colleagues).

> *The workload has remained similar, but for the same work I would say that the quality has increased. Indeed, data entry about drugs, trials and reporting are not new activities, as they have always been made. Nevertheless, although the system still requires someone to carry out these tasks, these have now been greatly simplified: the interface is more dynamic, it is easily updatable and makes us save a lot of time. Now we work on the same platform and it is no longer necessary for everyone to carry out their activities separately and aggregate them in a second phase.*
>
> ***Italian Healthcare 1,* Oncology department Director**

In light of a decreased workload and smoother activities, a pharmacist stated that now tasks can be carried out more accurately.

At ***Italian Healthcare 3***, the adoption of the new technology resulted in a significant upskilling of the medical staff, and of nurses in particular.[43] Now, these can indeed carry out additional medical procedures and interact directly with cardiologists, thus resulting in higher interaction with the medical staff. Also at the ***Italian Healthcare 2***, following the implementation of the telestroke technology and the consequent improvement in correct diagnosis, the nursing staff underwent a relevant upskilling, carrying out more complex tasks than before, and thus becoming more autonomous from doctors and medical staff. Moreover, in both establishments, given that the accuracy of diagnoses rely on the harmonisation of medical language between non-specialists and specialist doctors, nurses and emergency doctors have undergone a further on-the-job upskilling in order to endure effective communication of patients' symptoms with cardiologists and neurologists.[44]

However, such upskilling of nurses in the field of medical knowledge has been to a certain degree criticised by some of the medical staff, while others perceive it as the only solution to the personnel shortages in emergency departments - and the reduction of emergency doctors in particular - Italian healthcare establishments are currently experiencing.[45]

Similarly, at ***Italian Healthcare 2***, the introduction of remote monitoring of implantable cardiac devices has resulted in a significant enrichment in digital skills for the IT Specialist of the Electrophysiology Unit. Given the continuous updates concerning the functioning and applicability of the technology, the IT Specialist is now in charge of more tasks as well as of the overview of more patients. However, the remote monitoring technology did not impact on the workload of cardiologists.[46]

At ***Italian Healthcare 4***, following the introduction of televisits, the administrative staff and operators for the customer service started playing a significant role for the correct functioning of the system itself, having to carry out several new tasks and activities (e.g., scheduling of visits, preparing documents, uploading reports, etc.). Moreover, the introduction of televisits fostered the digital competences of all actors involved. Although doctors' time schedule has not been impacted

[43] Cirillo, V., Rinaldini, M., Virgillito, M.E., Divella, M., Manicardi, C., Massimo, F.S., Cetrulo, A., Costantini, E., Moro, A. and Staccioli, J., Case studies of automation in services, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-58953-2, doi:10.2760/347087, JRC129691.
[44] Ibid.
[45] Ibid.
[46] Ibid.

by the technology, the way in which they get ready televisits has changed, devoting more time to prepare the relevant documents.[47]

At ***Italian Healthcare 1***, with the introduction of the technology, the employees interacting with it had to undergo extra training sessions to understand its functioning. According to the Hospital Pharmacy Director, even if a two-hour training was needed to understand how to use the digital tool, this is based on a very well-known and accessible software. The rest of the interviewees agreed that the technology is very intuitive.

The IT Specialist consulted during the study affirmed that training sessions were customised according to the different needs of the employees using the technology.

> *After the two-hour training sessions, I provided tailor-made support to the hospital's employees, so that they would be able to keep using the technology autonomously when carrying out their daily activities.*
>
> ***Italian Healthcare 1,* IT Specialist 2**

Similarly, at the ***Italian Healthcare 2***, neurologists and nurses involved in the adoption of the telestroke technology had to undergo a very intensive training job.[48]

> *The involvement in the diagnostic and therapeutic process of stroke has spread knowledge. Now, also the medical and nursing staff has a precise idea of what to do in a patient with stroke.*
>
> ***Italian Healthcare 2,* Neurologist[49]**

Instead, for other figures involved in the process, the adoption of the technology has not required further training or the acquisition of specific digital skills.

> *I am the only technician responsible for this. There has been no training for me in this respect, I just follow the protocol to keep trace of eventual problems. [...] It does not require any specific mental effort.*
>
> ***Italian Healthcare 2*, IT Specialist of the Neurophysiopathology Unit[50]**

Also at ***Italian Healthcare 3*** emergency doctors had to acquire new skills for the deployment of the technology for the remote monitoring of cardiovascular conditions.[51] A doctor interviewed reported he had paid for a private course on the proper understanding of cardiovascular conditions and defibrillation. However, he also noted that experience might have been sufficient after some months of on-the-job training.[52]

In **France**, depending on the worker interviewed across both establishments, the technologies had more or less of an impact on the nature of their tasks. For the head of the emergency department at ***French Healthcare 1***, the medical and paramedical teams have the same tasks as before adopting the predictive technology. Nonetheless, the doctor believed that the algorithm has reduced the staff's mental workload. Instead of completing tasks at the last moment, work can be anticipated which allows for better organisation and faster turnaround - for the patients this means less waiting time.

[47] Cirillo, V., Rinaldini, M., Virgillito, M.E., Divella, M., Manicardi, C., Massimo, F.S., Cetrulo, A., Costantini, E., Moro, A. and Staccioli, J., Case studies of automation in services, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-58953-2, doi:10.2760/347087, JRC129691.
[48] Ibid.
[49] Ibid.
[50] Ibid.
[51] Ibid.
[52] Ibid.

> *If we know that a patient will be hospitalised at 98%, we no longer must discuss whether to admit him or not. The system between doctors, workers and the machine are now synchronised.*
>
> ***French Healthcare 1*, Doctor**

For ***French Healthcare 1***'s director of innovation, the use of the technology has not required any additional skills or training from the staff, nor new job profiles. Another worker assured that no additional skills were required to use the tool. This statement was confirmed by a nurse who reaffirmed that no additional skills were necessary by her to 'utilise' the tool, since she does not engage with the algorithm directly.

Likewise, for the head of the emergency services at ***French Healthcare 2***, no particular knowledge of AI or algorithms is required for the average user of the new technology. For the technology specialist interviewed, the tool is easy to use. For the bed management tool, the bed managers explained that a minimum training will be needed to use the tools properly and teams will need to be accompanied, as in any change process, to provide support, mutual assistance, and debriefing.

Finally, when asked whether the algorithm had caused any redundancies or layoffs, the architect of the technology implemented at ***French Healthcare 1*** explained that such phenomenon was more cyclical than linked to the technology. He explained that management units keep increasing whilst having fewer carers across France, so beds are closing. The tool only accelerates this transformation and makes the needs more reliable, but it is not a definitive answer, he explained. The doctor stated that *French Healthcare 1* has not had any hiring, layoffs, or reassignments because of the tool, since the objective is not to replace human decision making with the machine but to keep the human medical guaranteed.

At ***French Healthcare 2***, in terms of new job profiles, one doctor explained that since adopting the new technology, the hospital has created a new bed management unit. However, this is not necessarily linked to the technology because it was a request by the French Health Ministry to have an effective bed management solution. For the HR manager at the hospital, there is no attempt to cut costs or staff.

5 Working conditions

5.1 Work intensification

Overall, according to ***Italian Healthcare 1*** interviewees, the deployment of the technology did not result in increased workload, level of stress or pressure for employees. Rather, pharmacists have now more time for the administration of the drug, improving their direct relationship with patients. In this sense, they argue the technology can also be considered as a psychological support, as patients can now feel more well-treated and the hospital personnel has more time to carry out activities, feeling less pressure and reducing their mental workload.

However, one of the IT specialists interviewed raised an interesting point concerning the peer pressure the technology might make feel to the medical staff.

> *Medical staff do not feel more under pressure because of the deployment of the technology. However, I believe that now users are more aware of the importance colleagues attribute to their jobs. All the actors involved in the process can indeed view how their colleague has inserted some data. In this sense, workers might now feel under scrutiny of their peers, but I would say it is a positive aspect as it enhances collaboration and more precision in carrying out the activities.*
>
> ***Italian Healthcare 1*, IT Specialist 1**

Also at ***Italian Healthcare 3*** the staff of the emergency vehicles feel the remote consultation with cardiologists while using the technology acts as an important psychological support during their activities.[53] In this sense, the interaction with a specialised colleague helps them to see things more clearly and makes them feel more reassured.[54]

The decreased workload reported at ***Italian Healthcare 1*** is in contrast with the results of the "Automation in services" report, where the evidence points quite clearly towards increased workloads, particularly for nursing staff.[55] As a matter of fact, nurses employing the telestroke technology and remote monitoring devices, in particular, has seen their workload increasing, as they are now in charge of new complex tasks and have expanded their medical knowledge accordingly. This difference might be in any case explained by the different nature of the technology adopted at *Italian Healthcare 1*, which – unlike the telestroke and the remote monitoring devices technologies – did not change the practical tasks carried out by the medical staff but only the way in which they go through processes.

Although it might be true that in some cases the workload has increased following the adoption of the new technologies, it should however be said that such expansion is related to an extension in terms of tasks and functions of certain medical figures. Thus, this disruptive effect of increased workload might be easily contained by hiring new personnel and training new medical staff within the establishments. In this sense, the increased workload is not so much due to the adoption of the technologies per se, but mostly to an intrinsic problem of the Italian national healthcare system, whereby hospitals permanently face lack of medical personnel. Although the upskilling of nurses mentioned before is a relevant trend that goes in this direction, it won't probably be sufficient to compensate to such scarcity.[56]

Working hours have not changed in any of the hospitals following the adoption of the technologies. One interviewee at *Italian Healthcare 1*, in particular, has argued that the staff's working hours are now better used.

> *The working time has undergone a "restructuring". It has not been shortened, because the workload is always quite heavy. However, I have more time to carry out higher value activities. I do not finish work earlier than before, but the time I am saving thanks to the technology can be dedicated to other activities.*
>
> ***Italian Healthcare 1*, Pharmacist 3**

A doctor interviewed in ***French Healthcare 1*** specified that the introduction of the predictive technology has led to a reduced workload for health professionals and improved service quality. The tool had indirectly reduced workload by freeing up time for carers. However, the doctor explained that the technology has not impacted on the quality of care directly. For another doctor and head of the EMS, the tool improves flow management and the quality of work. She believed that the algorithm allows emergency physicians to reduce the level of stress because they have a tool for predicting hospitalisation. The tool, and other technologies, contributes to reducing the level of stress in flow management when doctors have 60 patients to manage at any given moment. She clarified that the ER used to be a stressful and messy place, but now, with modern advances like this, doctors are helped in management and timing.

At ***French Healthcare 2***, for the technology specialist, it was difficult to answer whether using the new technology decreased job-related stress. The tool makes proposals but does not make decisions. He explained that decision-making is not automated, and it is always the staff who decide.

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[53] Cirillo, V., Rinaldini, M., Virgillito, M.E., Divella, M., Manicardi, C., Massimo, F.S., Cetrulo, A., Costantini, E., Moro, A. and Staccioli, J., Case studies of automation in services, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-58953-2, doi:10.2760/347087, JRC129691.

[54] Ibid.

[55] Ibid.

[56] Evidence collected from the interview with Prof. Marialuisa Divella (University of Bari) and Prof. Eleonora Costantini (University of Modena and Reggio Emilia), co-authors of the report "Case studies of automation in services".

5.2 Autonomy

In **Italy**, the development of the technologies did not have any major impacts on the personnel's autonomy, nor on the decision-making process, which remains exclusively human-made. Indeed, all the interviewees consulted during the study generally believed that in the healthcare sector it would be difficult to witness to a full replacement of human work by machines.

The Oncology department Director of ***Italian Healthcare 1*** pointed out that, even if a lot of the data collection work has been taken over by the technology, there is still a human component. In this sense, the introduction of the technology is seen as a key support to their daily activities, and not a threat to their job.

> *The human component will always be essential in our sector. For example, the evaluation of the health of a patient may rely on some objective aspects, but the majority of the elements that we asses can be measured only through a direct doctor-patient relationship.*
>
> ***Italian Healthcare 1,*** **Oncology department Director**

One pharmacist and the Hospital Pharmacy Director further added:

> *Even in our sector, the role of technology is increasingly important and algorithms helping us to take decisions will be key in the future. However, technology and the human component are complementary.*
>
> ***Italian Healthcare 1,*** **Pharmacist 1**

> *Decisions about patients' treatment remain in the hands of doctors and nurses. The technology enables us to make fewer errors and supports us in making evidence-based decisions. But our final goal is the patient's care, who remains a person "flesh and spirit", with his/her own "value". Thus, I believe that only thanks to the relationship between caregiver and patient it is possible to understand the proper "value" of the medical act.*
>
> ***Italian Healthcare 1,*** **Hospital Pharmacy Director**

Also, an IT specialist underlined that the human component may lead to errors, as the technology cannot make mistakes intrinsically, but only consequently to errors made by the human worker. However, in the case of the technology, the workers consulted agreed that errors are easily noticeable and correctable.

> *When the technology was still not in place, misalignments and discrepancies in the data were not easy to identify and, consequently, they were also difficult to correct. Thanks to the new technology, the corrective actions are easier and allow the employees to save time.*
>
> ***Italian Healthcare 1,*** **IT Specialist 2**

One interviewee consulted further added that workers of the healthcare sector are usually very specialised, with respect to other sectors where unskilled workforce is largely employed and can be easily replaced by machines. In addition to that, it has been argued that, while such sectors are usually aimed at the delivery of a product or a good, in the healthcare sector the final outcome consists in the delivery of a service, hence making the substitution of the human element by machines even more challenging and unlikely in the near future.

At *Italian Healthcare 1*, following the development of the technology, the personnel interviewed also highlighted that autonomy has changed in a twofold direction. On the one hand, their activities are more interrelated, hence decreasing their level of autonomy. On the other hand, the increased collaboration makes sure that there is no need to contact other persons to retrieve and collect the data they need.

My autonomy has increased in the sense that I do not depend anymore on my colleagues to ask what I need to know, as all the information can be easily found. On the other hand, now I feel part of a team who works together and cooperates with a common goal. So, in this regard, my autonomy has in some way decreased.

***Italian Healthcare 1,* Pharmacist 1**

Similarly, the introduction of the remote monitoring of cardiovascular conditions at ***Italian Healthcare 3*** did not replace the first base diagnosis of the medical staff. Indeed, the diagnosis provided by the device is only intended as a support for the one made by the emergency doctor or by the nurse. By way of example, an emergency doctor argued:

I try not to look at the diagnosis done by the machine, I give myself an evaluation first but it is usually very correspondent. 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.

***Italian Healthcare 3,* Emergency Doctor**[57]

At the ***Italian Healthcare 2***, following the adoption of the telestroke technology, nurses have become more autonomous from doctors and medical staff. However, nurses are allowed to perform the visit only in presence of the emergency doctor. Indeed, the possibility to give nurses a greater autonomy by launching and managing the tool is still a sensitive topic.[58]

Nurses can take charge of the patient, start the telecommunication with the neurologist and ask for the intervention of the emergency doctor. [However,] in the case of telestroke it is not so much the physical execution of some maneuvers to come to a decision, it is that there are therapies that can have a series of complications and therefore the monitoring of the patient in my opinion must be entrusted to the emergency doctor in this case.

***Italian Healthcare 2,* Neurologist**[59]

Also at ***Italian Healthcare 4***, doctors still have wide margins of discretion towards the decision to carry out the visits remotely or in presence.[60]

At ***French Healthcare 2***, the flow prediction tool gives information but does not change the autonomy of the caregivers nor what they do. In the bed management solution currently being tested, the hospital has a specialised software where they can indicate the need for a bed and the system signals the room and calls a stretcher team. This also avoids numerous calls and interruptions of tasks.

It will have no impact on the decision, which is medical. The diagnosis will be made by the doctor, the referral will be decided between the emergency team and the specialty, and once there is an agreement the tool is an aid to finding a bed and stretcher.

***French Healthcare 2*, General manager**

At ***French Healthcare 1***, when asked whether the new tool affects worker autonomy, one doctor interviewed answered that they are not there yet. He explained that the tool was solely concerned with helping doctors in their daily work and not in replacing them by machines. Furthermore, the

[57] Cirillo, V., Rinaldini, M., Virgillito, M.E., Divella, M., Manicardi, C., Massimo, F.S., Cetrulo, A., Costantini, E., Moro, A. and Staccioli, J., Case studies of automation in services, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-58953-2, doi:10.2760/347087, JRC129691.
[58] Ibid.
[59] Ibid.
[60] Ibid.

doctor clarified that the tool does not give any obligations but offers a suggestion and a decision-support that does not affect doctor's medical autonomy or decision-making. Similarly, the head of the EMS at ***French Healthcare 1*** said that the tool has not taken over from the human, as it will always be the human who decides.

> *The tool facilitates the staff's work. It helps them in daily work and improves the quality of life by allowing them to work with more serenity. We aim to avoid irritation between a speciality department and the ER and avoid delays. Thanks to the anticipation, the tool is supposed to generate less misunderstanding, stress, and disorganisation… We can anticipate and make things run more smoothly.*
>
> ***French Healthcare 1*, HR manager**

5.3 Social interaction

Interviewees at ***Italian Healthcare 1*** agreed that the deployment of the technology emphasised the teamwork and social interaction between colleagues of different departments of the hospital.

> *Without any doubt, teamwork has improved. Before, we were more focused on checking manually the data and each profile had their own tasks and activities. Now, all of us are linked to each other by a "circularisation" of the data. This means that we all need to gain full knowledge, not only of our own job, but also of any other colleagues' one. In this sense, collaboration and cooperation have significantly improved.*
>
> ***Italian Healthcare 1,* Pharmacist 1**

One of the IT specialists further added:

> *Before the implementation of the technology, some departments were not even communicating with each other despite their common goals and similar working methods. Now, with the digital tool, different departments and entities involved in the process communicate and collaborate with each other.*
>
> ***Italian Healthcare 1,* IT Specialist 1**

At ***Italian Healthcare 2***, the deployment of the telestroke technology implies a strong relationship of trust between the neurologist – not present during the visit – and the emergency doctor carrying out the visit. In this sense, the capacity to work in a team became even more pivotal after the introduction of telestroke, as now neurologists need to trust their colleagues.[61] Although at the beginning some doctors were afraid that this could become a buck-passing, interviewees seem to agree that the new technology in the end has fostered the teamwork.

> *In the dynamics of traditional first aid the neurologist arrives and the emergency doctor can leave. Instead, now it is a team evaluation because one is the arm of the other. […] Following the adoption, emergency doctors have become more part of the process and neurologists learnt to trust colleagues and guide them to make all the relevant assessments for a correct diagnosis.*
>
> ***Italian Healthcare 2,* IT Specialist[62]**

[61] Cirillo, V., Rinaldini, M., Virgillito, M.E., Divella, M., Manicardi, C., Massimo, F.S., Cetrulo, A., Costantini, E., Moro, A. and Staccioli, J., Case studies of automation in services, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-58953-2, doi:10.2760/347087, JRC129691.

[62] Cirillo, V., Rinaldini, M., Virgillito, M.E., Divella, M., Manicardi, C., Massimo, F.S., Cetrulo, A., Costantini, E., Moro, A. and Staccioli, J., Case studies of automation in services, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-58953-2, doi:10.2760/347087, JRC129691.

The deployment of implanted devices with remote monitoring system increased the collaboration between the electrophysiology division and cardiologists at the hospital as well.[63]

Likewise, at the ***Italian Healthcare 3*** the technology for remote monitoring of cardiovascular conditions has positively influenced the level of collaboration among colleagues of different levels. Like at *Italian Healthcare 2*, indeed, the collaboration between cardiologists and emergency doctors has increased, as the latter are continuously supported by the former while using the technology.[64] All interviewees believed that competition among colleagues did not increase, given that each of them has its own assigned activities and tasks.

5.4 Monitoring and surveillance

No specific impacts concerning the monitoring and surveillance of workers have been reported in any of the cases object of the study. At ***Italian Healthcare 1***, according to the different interviewees consulted during the study, the introduction of the technology did not result in a change in how their activities are monitored by their superiors. However, the Hematology department Director claimed that the use of this technology will help measuring performances, how resources are used and the pharmaceutical expense in the future. At the ***Italian Healthcare 3***, the fact that the device can store the timing of actions (which can also be made available upon request) is not regarded as a threat of further control by the medical staff.[65] As a matter of fact, legal complaints are quite the normality in emergency units, so that the possibility to verify the compliance with medical protocols has never been opposed by the staff.

> *Checks aimed at verifying the compliance to 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. 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.*
>
> ***Italian Healthcare 3,* Emergency doctor**[66]

The predictive system deployed at ***French Healthcare 2*** is designed to streamline workflows and enhance efficiency rather than for monitoring and evaluation purposes. The collected data is used solely to facilitate real-time coordination, reduce errors, and optimize patient flow within the hospital, without being employed for staff surveillance or performance assessment.

Similarly, one interviewee at ***French Healthcare 1*** said that the technology does not evaluate the worker, their performance or efficiency, nor will it be misused for that. He explained that in the future the hospital could use the tool to check the ‘correctness’ of the decision and the appropriateness of hospitalisations, but for that they needed to ‘stabilise’ the technology first. However, the head of the emergency unit believed in the future the tool could be used to evaluate doctors, although he remained cautious about this possibility.

> *When we are sure that it works well, it could become a tool for evaluating doctors, to compare the machine's decision with that proposed by the doctor. And maybe later, it could also be used to decide what medical procedure to use. It will be a tool that will reinforce performance or allow us to understand why we have a different result. It could become a training and evaluation tool. However, we are not there yet.*
>
> ***French Healthcare 1*, General manager**

[63] Ibid.
[64] Ibid.
[65] Ibid.
[66] Ibid.

The doctor explained that the current algorithm was simply a “modern information channel”, and that it was too early to say what the future of assessment will be - “we have no room for error”, he said. Another worker emphasised that doctors cannot experiment with algorithms but must always make sure that technology is correct, safe, and ready to be used.

In terms of monitoring performance, the head of the emergency services at ***French Healthcare 2*** stated that the tool’s computer data can trace who is logged in to a patient and can find out how many patients a doctor has seen and how much time is spent per patient. However, he explained that this is not a useful measure because in the ER, seeing one patient does not mean you have worked less than someone who has seen 20. Ultimately, the doctor noted that as long as he is working, he will oppose the use of the tool to measure performance. For the technology specialist, the tool does not allow to say that one caregiver is more efficient than another but how the services welcome patients. It gives some indicators that management look at, such as the occupancy rate of a ward, the average length of stay, the number of stays outside the right wards.

6 Industrial relations

The deployment of the new technologies did not result in any major changes in communication strategy between the management and workers in any of the cases considered. Similarly, no major changes concerning the hospital’s relations with key industrial partners, providers and suppliers, as well as clients and other relevant stakeholders have been reported following the adoption of the technologies.

At ***Italian Healthcare 1***, however, an important element of novelty consisted in the employment of a public-private sponsorship for the development and application of the digital technology. As argued by the Hospital Pharmacy Director, this instrument is indeed quite uncommon in Italian healthcare establishments, hence resulting in some legal and operational challenges for its implementation. However, interviewees believed that the relations between the hospital and pharmaceutical companies have improved in the end, as these are now highly interested in conducting studies and clinical trials at the hospital.

The medical staff interviewed at the hospital also believes that the deployment of the technology will be beneficial to all other operational units of the hospital, other establishments in the Tuscany region and ESTAR. Interviewees indeed hope that further cooperation and dynamic tools like the technology will be ensured at regional level in order to better manage healthcare activities and the reallocation of human and financial resources, as successfully experimented at the hospital.

> *Digital tools like those implemented in the context of the technology are highly beneficial to monitor any hospital’s productivity. They are a big advantage not only for us directly, but also for the administrative offices above us and the regional healthcare system as a whole.*
>
> ***Italian Healthcare 1,* Hematology department Director**

As far as unions are concerned, these have not been consulted in any of the hospitals object of the study. As a matter of fact, the medical staff involved has only been informed through their managers, collegial meetings or other colleagues about the specific projects before their implementation. In all cases, the introduction of the technologies was planned to fit into the medical staff’s working time.

On the basis of the interviews carried out at ***Italian Healthcare 1, Italian Healthcare 2, Italian Healthcare 3*** and ***Italian Healthcare 4,*** it emerged that the deployment of the new technologies has been widely welcomed by the medical staff, and all the actors involved have participated in a constructive way in the implementation process. No major challenges have been reported regarding the implementation of the technology, if not some organisational requirements (e.g., connectivity issues of some tools, staff shortages for their correct deployment, etc.). At *Italian Healthcare 1*, some interviewees only mentioned some obstacles related to the bureaucratic and administrative aspects of public entities (e.g., purchase orders of software licenses, tender management, external personnel selection process, etc.). However, according to the Economy and Finance department Director, even if the implementation process has been complex, every actor involved has been supportive of the initiative and everyone contributed to its development.

> *Even if we perceive public administration bodies as reluctant to changes and to innovation, every actor involved in the development of the technology understood the real value of this initiative and worked towards its implementation.*
>
> ***Italian Healthcare 1,* Economy and Finance department Director**

The role of industrial relations in the **French healthcare sector** regarding the implementation of algorithmic management tools has been mixed. On one hand, unions and employee representatives have been actively involved in negotiating collective bargaining agreements and representing workers' interests in the introduction of new technologies in the workplace, including AMT. However, there have also been concerns raised by unions and employee representatives about the potential negative impact of these tools on workers' autonomy, workloads, and job security. Some have called for safeguards to be put in place to protect workers' rights and interests in the context of the increasing use of AMT in the sector.

Although, employee representatives were not interviewed in either of the two hospitals, overall, the role of industrial relations in the French healthcare sector regarding AMT has been one of negotiation and advocacy. Interviewees at both hospitals explained that in this specific case, unions were not considered in the development of the technologies considered since there was no contestation or repudiation from the worker's side. Nonetheless, in other cases, unions and employee representatives have played an important role in ensuring that workers' interests are taken into account in the implementation of these tools, while also contributing to broader policy debates and discussions about the impact of technology on the sector as a whole.

A key insight of both case studies are the benefits and added-value of adopting the technologies considered against its hurdles and barriers. One doctor pointed out the mistrust among specialist doctors about the value of algorithms compared to emergency physicians, where algorithms were better accepted.

> *If it's not 100% sure, then what? Nothing is 100% sure, neither man nor machine. For us [emergency doctors] we are talking about the organisation, for them [specialist doctors] this may not be the case. Our aim is precisely to synchronise the system. To help with the organisation of the hospital. The added value is medical. It is a precious help.*
>
> ***French Healthcare 1*, General manager**

The architect of the technology noted that some specialist doctors had been suspicious of the machine's solution and decisions. During the interview, he explained that there is a problem of explicability of the machine, with some specialist doctors wanting to make the diagnosis and decisions entirely themselves rather than with the help of an algorithm. The architect mentioned that specialists complain that algorithms are not 100% correct, something which he criticised is impossible to achieve with or without an algorithm. Finally, the architect said that they are working on this communication drawback to improve 'explainability' to specialists and other workers sceptical of the technology.

For the bed managers at ***French Healthcare 2***, staff were not reluctant to adopt the new technology, but a generalised and minor mistrust was felt at the beginning since the unknown is scary, one of the interviewees said. Another bed manager stated that the solution involves a paradigm shift that is being developed in a crescendo. He explained that relational difficulties still persist after the adoption of the tool between the medical and paramedical teams, or even the establishment's IT department, because they do not speak the same tech-language and do not have the same codes, which can sometimes lengthen delays.

Similarly, during the initial deployment of the technology, the nursing staff questioned the use and need of the technology, whilst others stated that it would not change anything to their work. The biggest fear still in place is that many do not wish to know their daily workload (flow of patients) because it makes them anxious. The HR manager explained that at the beginning some doctors simply did not believe in the benefits of AI and were not convinced by the tool. However, for the HR manager and technology specialist, the majority of doctors today no longer share the same view.

> *At the organisational level, the introduction of an AI-based solution was not easy, and many doctors were afraid that AI would replace them. We had to reassure them and show that Saniia helps them work better and allows them to spend more time on tasks where their human and medical skills are important. At first there was quite a lot of resistance, but then there was a good appetite for the solution among staff.*
>
> ***French Healthcare 2*, Technology specialist**

At ***French Healthcare 1***, another doctor interviewed showcased the overall positive feedback from the emergency department on the use of the technology. The doctor argued that if medical teams do not see the efficiency and impact of the tool, there is no adherence, but since we see the efficiency of the tool (for prediction and decision support), there is adherence from doctors. The software offers some help to physicians that can choose to follow it or not, and it gives an interesting probability which doctors can discuss upstream with the specialists to place patients accordingly.

At the relational level, the head of the emergency services at ***French Healthcare 2*** did not observe major disruptions. However, he explained that at the decision-making level, it allows to have rules that are established and automated that do not depend on one person or one day, instead the procedures are written and fixed. This improves the patient orientation process. For the HR manager, although the tool allows having more agility in management, it is simply a dynamic dashboard that helps but does not force staff to do anything. It puts staff on alert and is a decision-making tool that helps avoid all kinds of crisis situations, she explained. In terms of interaction with management, the HR manager said the bed management solution allows visibility over all the beds in the establishment, which they did not have before.

> *The tool has developed a certain dependence, today we can no longer do without it. We consult it several times a day and it's a reference point in all our meetings and reflections, like an indispensable temperature check before considering certain decisions. It helps and reassures us by allowing to make better decisions on capacity and HR. If we had a week without the tool, everyone would surely miss it. In the end there are no negative interactions with the tool.*
>
> ***French Healthcare 2*, HR manager**

7 Conclusions

The technologies analysed in the study are very different in terms of their nature, drivers behind their adoption and range of profiles affected by their adoption.

The adoption of technological tools and software in the hospitals examined primarily aimed at increasing efficiency, reducing administrative burdens and enhancing patient care. These technologies facilitated better management of information assets and human resources, enabling medical staff to focus on high-value tasks rather than administrative duties. Similarly, digital tools have contributed to streamlining hospital workflows, improving patient management, and reducing the time medical personnel spend on non-medical tasks. These solutions have helped optimise resource allocation and improve the quality of care provided to patients.

Rather than leading to human substitution, the implementation of these technologies has predominantly resulted in process digitalization and reorganisation. The adoption of data management technologies has significantly reduced the workload related to manual administrative tasks, allowing medical staff to reallocate their time to core medical activities. In contrast, tools such as remote monitoring and telemedicine have reshaped the content of tasks, requiring medical personnel to integrate digital tools into their daily routines. These changes have necessitated the upskilling of staff, particularly nurses, who have acquired new competencies in digital processes and patient monitoring, while doctors have benefited from increased autonomy in diagnoses and treatment decisions.

Similarly, algorithmic management tools have improved hospital efficiency by automating administrative and logistical tasks. These technologies have enabled hospital staff to spend more time on patient care by reducing inefficiencies such as searching for available beds or conducting repetitive intake procedures. The optimization of patient flow and predictive management of resources has not only reduced stress on emergency services but also improved overall working conditions. Hospital personnel reported enhanced collaboration across departments, facilitated by the integration of digital solutions into routine operations.

Across all establishments studied, a common trend is the emergence of more collaborative working environments. Medical staff, administrative personnel, and technology specialists increasingly work together to ensure the smooth functioning of digital tools. This shift has led to the creation of new professional roles, such as data managers and technology specialists, who play a crucial role in managing and maintaining these systems. While these technologies have reshaped work dynamics, they have not generated fears of job displacement among medical staff. Instead, they are widely perceived as complementary, enhancing efficiency without replacing the human element essential to patient care.

In conclusion, the adoption of technological tools and software in the hospitals examined has led to increased efficiency, enhanced collaboration, and improved patient care. While their impact varies depending on the specific application, a unifying theme is their role in reducing administrative burdens and optimizing hospital resources. Rather than replacing human workers, these technologies have facilitated the evolution of medical roles, ensuring that healthcare professionals can focus on what matter most – providing high-quality patient care.

The positive impacts observed in these cases suggest that the use of technological tools and AMTs like those considered throughout the study can be effectively integrated into healthcare settings without the negative implications often seen in other sectors[67]. This success is largely attributed to their complementary role in supporting, rather than replacing, human decision-making and expertise. The structured nature of healthcare, where professional judgement and collaboration are essential, mitigates risks associated with job displacement and work intensification. Moreover, clear governance, professional training, and the active involvement of medical staff in the implementation process help prevent issues related to algorithmic opacity and over-reliance on automation, ensuring that these technologies serve as enablers rather than disruptors.

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Appendix

1. Distribution of interviews

Table 1: Distribution of interviews at Italian Healthcare 1

Interviewee	Role/Organisation	Date
Hospital Pharmacy Director	Hospital Pharmacy Director and technology promoter	19/12/2022
Oncology department Director	Oncology department Director	19/12/2022
Pharmacist 1	Clinical oncology galenic Pharmacist	19/12/2022
Haematology department Director	Haematology department Director and University Professor	20/12/2022
Pharmacist 2	Hospital Pharmacist	11/01/2023
Pharmacist 3	Clinical trial Pharmacist	20/12/2022
Director General	Director General	11/01/2023
Economy and Finance department Director	Economy and Finance department Director	12/01/2023
Administration Officer (ESTAR)	Administration Officer at ESTAR	12/01/2023
Clinical Trial Centre Director	Clinical Trial Centre Director	12/01/2023
IT Specialist 1	IT and Communication Specialist	20/12/2022
IT Specialist 2	IT Specialist	19/12/2022

Source: Authors' elaboration

Interviews of staff from *Italian Healthcare 2, Italian Healthcare 3* and *Italian Healthcare 4* have been extracted from the report "Case studies of automation in services". The interviews have been carried out both in person and online between October 2021 and February 2022 by the research team in charge of the report drafting.

A follow-up meeting to further discuss the main findings of the "Case studies of automation in services" report with two of the researchers who drafted it, i.e., Prof. Marialuisa Divella (University of Bari) and Prof. Eleonora Costantini (University of Modena and Reggio Emilia), took place on 06/04/2023.

For *French Healthcare 1*, the research team had a first preliminary meeting in June 2022, during which the establishment confirmed its participation. Interviews were conducted between August and October 2022 via Teams with a pre-established questionnaire sent in advance.

Table 2: Distribution of interviews at French Healthcare 1

Interviewee	Role/Organisation	Date
Technology specialist	Emergency physician, project manager, university researcher and architect of the technology	04/08/2022
General manager	Emergency physician, head of the emergency unit and EMS	13/09/2022
Key worker affected by the technology	Emergency physician and teacher/researcher	15/09/2022
Key worker affected by the technology	Emergency physician and head of EMS	22/09/2022
Key worker affected by the technology	Emergency Nurse	22/09/2022
Technology specialist	Data protection officer (DPO) and emergency physician	29/09/2022
HR manager	Director of Innovation	14/10/2022

Source: Authors' elaboration

For the *French Healthcare 2* case study, the research team contacted the CEO of the technology provider for the algorithmic management tool used in June 2022, but the first preliminary meeting was held only in October 2022. On that occasion, the company agreed to participate in the project alongside staff members of the hospital. Interviews were carried out between November and December 2022, and were conducted online via Teams with a pre-established questionnaire sent in advance.

Table 3: Distribution of interviews at French Healthcare 2

Interviewee	Role/Organisation	Date
General manager	Emergency physician and head of department	07/11/2022
HR manager	Head of HR	07/11/2022
Technology specialist	Director of performance and IT	09/11/2022
Technology specialist	Technology provider	10/11/2022
Key worker affected by the technology	Bed manager	14/11/2022
Key worker affected by the technology	Bed manager	16/11/2022
Key worker affected by the technology	Physician	07/12/2022

Source: Authors' elaboration

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