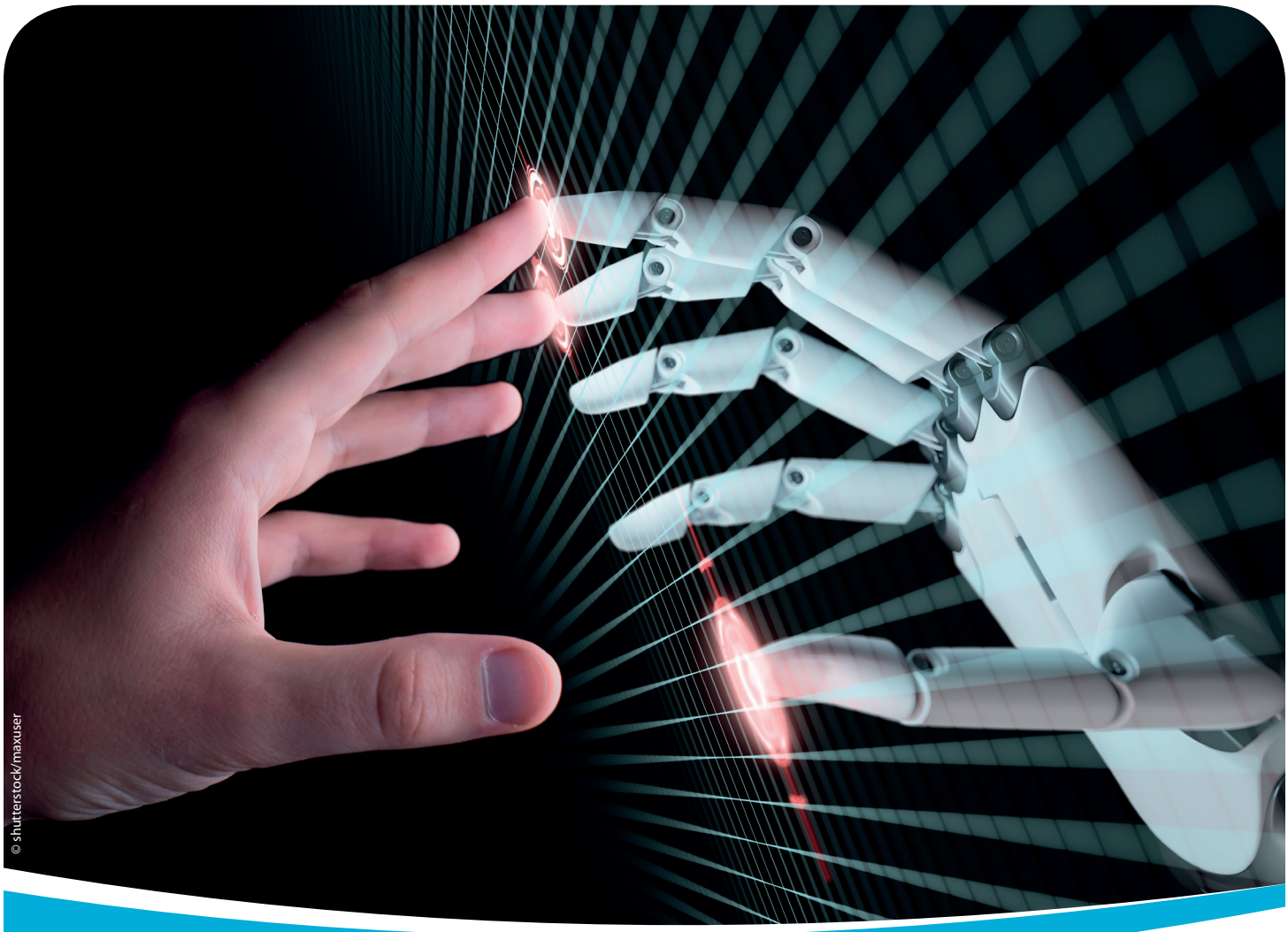

How the Digital Transformation can put humans at the centre of robotics and automation

Collaboration between humans and machines for better quality products and services

STUDY

European Economic and Social Committee

How the Digital Transformation can put humans at the centre of robotics and automation – collaboration between humans and machines for better quality products and services

Study

General information

STUDY FOR	*The European Economic and Social Committee (EESC)*
REQUESTING SERVICE	*The Employers' Group*
STUDY MANAGING SERVICE	*Foresight, Studies and Policy Assessment Unit*
DATE	*April 2021 (corrected version)*
MAIN CONTRACTOR	*Ab.Acus s.r.l.* *Wise Angle Consulting S.L.*
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IDENTIFIERS

		ISBN	doi
STUDY			
print	*QE-01-20-716-EN-C*	*978-92-830-5132-9*	*10.2864/858419*
PDF	*QE-01-20-716-EN-N*	*978-92-830-5131-2*	*10.2864/733324*

Foreword

Digital Transformation (DT) represents a huge opportunity in a variety of sectors of the economy and the society. Enabling technologies are becoming cheaper and increasingly accessible. Their availability and their easy and wide spreading are modifying working processes and roles. Governments and institutions are also pushing the phenomenon by means of multiple funding and incentive sources. It is the turn of the organizations to redesign their processes in a more sustainable and human-centric way.

Indeed, the unavoidable technological transformation needs to be driven by a rethinking of the human role within the entire value chain.

Customers, more and more accustomed to the penetration of new technologies in interpersonal communication and daily life, are the main drivers of the transformation, demanding for innovative services and products. Relationships between manufacturers, service providers and users are rapidly evolving driving an important part of the DT adoption.

While answering the new clients' needs, asking for fast reaction and high personalization, services and industries have also to revise their internal organization and embrace new paradigms in the relations between humans as well as between humans and machines. Thus, an effective involvement of workers, as well as customers, in the rethinking of businesses and processes is a central condition to put in place a successful and sustainable DT.

To several extents, the current COVID-19 pandemic has demonstrated to be an additional driver to DT adoption. The containment measures imposed by many governments to implement physical distancing and reduce the spread of the virus are heavily transforming interpersonal relationships in the workplaces and require new working modalities: while most of technologies are mature and ready for adoption, the imperative need to adapt to the new "normality" dictated by the global emergency is likely to speed up their adoption fostering novel work practices and processes.

This work is the final result of a research analysis tendered by the European Economic and Social Committee, aimed at identifying main trends in the DT adoption process and pointing out a bundle of good practices in different sectors to support a set of recommendations, all of them keeping the human in the loop, to foster and facilitate a wider implementation.

The study describes the main results from literature and web search together with inputs and contributions from the field, collected by means of a devoted questionnaire, interviews and focus groups addressing relevant stakeholders in the area in Europe and beyond.

Abstract

Digital Transformation (DT) is changing the economy, remodelling the business activities, transforming the world of work and, more in general, affecting common daily activities such as communicating, shopping, researching. Despite the remarkable effort of the EU in encouraging the use of advanced technologies, EU businesses are not currently taking full advantage of them or of the innovative business models offered by the collaborative economy. To avoid missing out the growth of the DT potential, policy makers and business leaders must be prepared for it and devote more effort to build future societies permeated by a sustainable and inclusive DT.

The present study demonstrates that to achieve this goal organizations must embrace DT putting people at its centre, which also implies that the application of these technologies should not only be consistent with legal and regulatory prescriptions, but also be coherent to ethical principles and ensure that their implementations avoid unintended harm.

Champions of a positive DT implementation, able not only to replace humans in certain tasks but to empower them, have been searched and investigated. Despite the diversity of needs and objectives, all the successful cases shared clarity of objectives, codesign practices, wide and tailored communication to the workers, as well as extensive involvement of the management.

Finally, from the results of the field investigations, the study identifies a set of operational recommendations for both DT adopters and policy makers.

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List of abbreviations

Table 1. Terminology abbreviations

Terminology	*Abbreviation*
Artificial Intelligence	**AI**
Artificial Intelligence for Europe	**AI4EU**
Coordination and Support Action	**CSA**
Cyber-Physical systems	**CPS**
Cyber-Physical-Social System	**CPSS**
Digital Innovation Hub	**DIH**
Digital Transformation	**DT**
European Innovation Council	**EIC**
European Union	**EU**
Factories of the Future	**FoF**
Fast Track to Innovation	**FTI**
Horizon 2020 Research and Innovation Framework Programme	**H2020**
High Performance Computing	**HPC**
Human Resources	**HR**
ICT Innovation for Manufacturing SMEs	**I4MS**
Industrial Internet of Things	**IIoT**
Information and Communication Technology	**ICT**
Information Technology	**IT**
Innovation Action	**IA**
Internet of Things	**IoT**
Organization for Economic Co-operation and Development	**OECD**
Public-Private Partnership	**PPP**
Research & Development	**R&D**
Research and Innovation Action	**RIA**
Small Medium Enterprise	**SME**
Smart Logistic for Manufacturing SMEs	**L4MS**
Southern Europe, Middle East and Africa	**SEMEA**
Partnership for Robotics in Europe	**SPARC**
Technology Readiness Level	**TRL**

Executive Summary

Introduction

Digital Transformation (DT) is changing the economy, remodelling the business activities, transforming the world of work and, more in general, affecting common daily activities such as communicating, shopping, researching. It will be difficult to think of activities that will not benefit of Artificial Intelligence (AI), Robotics, Internet of Things (IoT), Automation, etc. in the near future.

If accompanied by a responsible use, the increase of robots, spreading in offices, hospitals, industrial environments, clearly show how they can benefit society as a whole and how priorities to stimulate robotics should be now taken into account to define their evolution and to best exploit them for increasing growth, jobs and innovation in Europe. Companies need to reach this goal by introducing automation into their operations in a way that complements the contribution of their human workers since, as to date, interpersonal and human skills remain something that technology cannot replicate.

Despite the remarkable effort of the EU in encouraging the use of advanced technologies, European businesses are not currently taking full advantage of them or of the innovative business models offered by the collaborative economy they are helping emerge. There are also large disparities between adoption rates in large companies and SMEs.

To avoid missing out the growth of the DT potential, policy makers and business leaders must be prepared for it and put more effort towards a future permeated by enabling technologies. This needs to be done with the idea that DT is not only an enhancer of our current way to produce and deliver goods and services but a powerful change maker that can transform the way we create, communicate and generate growth and wellbeing.

The present study demonstrates that to achieve this goal organizations must embrace DT putting people at its centre, which also implies that the application of these technologies should not only be consistent with legal and regulatory prescriptions, but also be coherent to ethical principles and ensure that their implementations avoid unintended harm. The study's results emphasize that DT adoption should be built with the aim to enhancing people's abilities and not replace them.

Study methodology

The present study departs from a widespread literature review and web search of ongoing and recently completed R&D activities both in Europe and overseas as well as relevant policy initiatives supporting and fostering R&D efforts and large-scale deployments. Then, the study develops through two additional conceptual steps. The first one is a field analysis of the current status of DT implementation and it is run by means of online questionnaires distributed to a broad stakeholders dataset identified through the desk search. Finally, the last step of the study consists of the deep investigation of the selected cases of the adoption of DT, with the final aim of highlighting good practices and fostering DT benefits while mitigating risks and concerns for the society as a whole.

Main study results

DT opportunities

The panorama of the literature about the adoption of DT in Europe as well as worldwide is still flowing with ongoing debate on definitions and key components. Most of the current research is still focused on

the potential benefits of the new technologies and methods or on the new professional and working roles to be created. The specific role of "human" is still scarcely addressed.

There is a large consensus about the opportunities that DT offers. The core advantages of embracing DT are represented by the opportunity "to transform data into action" and take a comprehensive approach to systems integration. DT enables operations, finance, digital security, technology, and supply chain to collaborate and respond to the real-time needs of the production and service ecosystems.

In general, experts agree that when organizations go through a successful DT implementation, risk is minimized, collaboration increases, and better decisions are made more quickly, thus efficiencies naturally occur. When information is shared across entire "systems of systems", miscommunication is reduced and a wealth of valuable knowledge is generated with correlated increases in quality and productivity.

DT supporting technologies

Along with manufacturing, aerospace and automotive industry are leading the way to DT. Since major investments in the manufacturing and aerospace industry go into industrial machinery and fleets of vehicles, maintenance is of critical importance in order to enable greater utilization and longer lifetime and thus maximizing the return on investment. However, existing maintenance processes are far from efficient. As a result, companies are turning to digital technologies, such as the IoT and predictive analytics, to unlock the streams of data coming from the industrial machinery and vehicles and turn this data into value. Energy and utilities are considered the leading adopters of AI and automation, with a rich set of use cases where the business value of DT has been unraveled obtaining less energy and resources' consumption without sacrificing productivity or comfort. Fashion and retail brands are also leveraging AI-driven technologies to bring the online and in-store experience closer together. Logistic is witnessing an unprecedented rise of robots in warehousing driven by the volume growth stimulated by e-commerce. Piece-picking robots and automatic guided vehicles, which can intelligently sense the environment around them to assist workers with tasks such as picking, packing, and sorting, are seeing first major deployments in logistics. Financial services is a sector where traditionally data - including market data, risk data, client data and performance data - has been highly siloed, decision making processes are made slower by internal politics and employee engagement has been generally low. International banks are increasingly making use of AI-based solutions and investing in financial analytics start-ups, that enable institutions to mine a wealth of big data and instantly answer millions of complex financial questions by automating previously human-intensive research. The use of AI in the pharmaceutic and biotechnology industry has redefined how scientists develop new drugs, tackle disease, find suitable candidates for a clinical trial, increase adherence and more. In the healthcare sector, technology finds widespread adoption to increase patient safety and quality of care. Robots can efficiently disinfect hospitals using UV light and have proved to be helpful in slowing coronavirus spread. AI is also deployed in human resource management across sectors.

Governments across Europe are encouraging manufacturing industry companies to invest in DT in an attempt to raise the economy to a more sustainable level. Several countries across the world have also developed formal AI frameworks to help spur economic and technological growth. In a view to bolster and support national efforts, a variety of programmes and instruments are put in place by the European Union.

Nevertheless, despite the significant potential impacts stated previously, Europe is still at an early stage in achieving the true potential of DT. As for the economic impacts and the benefits on business performance, many organizations are reporting they are still in testing mode, and more than half of the executives are still either experimenting or testing on a limited basis around their organizations. Our analysis highlights that the desired outcomes are not just about achieving greater productivity. Enterprises across sectors see the potential to redirect the human effort saved through automation towards innovation.

DT drivers and barriers

The shift towards a human-centred manufacturing system, in which humans concentrate on life-long skill improvement and continuously create high-value-added work, calls for a new paradigm incorporating human aspects in the design of production and service provision models. In general, there is increasing awareness that DT is driven by changes in the broader business and societal ecosystem which technologies serve as enabling factors.

When asked about the main drivers pushing forward DT, the stakeholders consulted through the online questionnaire highlight the "continuous rise of users' expectations", a generalized acceleration of the "pace of business" as well as emerging "innovative business models", as key enabling factors. A determinant role is also played by the demands for innovation posed by the current environmental sustainability, demographic and climate change challenges as well as the global public health threats such as the current COVID-19 pandemic.

The main barriers hindering DT were found in "Cultural and behavioral resistances". The second-chosen barriers are the "Lack of change-oriented mindset" and the inadequacy of "organizational resources". Cultural resistance is intended as having a key influence on both the staff and the managerial side. A still persistent "fear of change" makes DT processes being initiated predominantly by either organizations that are going through crisis and thus need to undertake deep renovation initiatives to overcome those, or very wealthy and innovative ones which are positioning themselves as pioneers in the DT landscape. Lastly, the need for huge infrastructure investments and the insufficient economic resources are perceived as barriers as well.

The main perceived advantage of DT application is given by the possibility of getting improved quality of work. An increase in quality and productivity is key to increase competitiveness, versatility and capacity to adapt to changing demands and needs. Also, quite large preference is given to the advantage related to the decreasing of the numbers of errors that automation brings forward.

The main perceived risk related to DT application is given by the difficult application to the new working practices and the need of high specialization which is confirmed by the large agreement about the need of acquiring new competences for achieving successful DT.

In all the transformation cases, an important role is played by codesign. Involvement of stakeholders and workers since the early phases of the transformation process demonstrates to be a key factor in successful experiences, as well as an adequate training. Overall, most of the responders are happy with their experience in DT that they saw as an unavoidable and necessary process, given the advancement of technologies. However, technologies are just a mean for DT, the key point is the new design of underlying business and industrial processes.

Lessons from the field

As a last step, champions of positive DT experiences have been searched and investigated. In the industrial area, the cases come from different sectors like the manufacturing of components of white goods and the manufacturing of tools for metal crafting, the automotive, the steel industry, the agri-food area and the software (analytics) development. Also, the addressed organizational functions are different: production, maintenance, workers safety, human resources, training, administration. On the services side, healthcare is widely represented through different departments and functions. In all the analyzed cases, the humans were empowered in their working functions. The adoption often required a devoted training and some adjustments of the working practice, but nobody lose their job.

Despite the diversity of needs and objectives, all the successful cases shared clarity of objectives, codesign practices, wide and tailored communication to the workers and extensive involvement of the management.

These aspects are addressed in three key operational steps of the adoption process: **initiation**, **design and development**, **communication**.

Referring to **initiation**, the idea may come from a person in the organization as well as from an external consultant. Sometimes, it is also the case of externally funded initiatives, such as international research projects, when researchers from various disciplines propose the adoption of a new technology in a manufacturing or service environment.

Wherever the idea comes from, it is mandatory that the **development** is "market driven" instead of "technology driven", where "market driven" refers to a DT implementation that is led by a concrete need of the customer, in the case of products/services, or of the workers and/or the organization in the case of internal processes.

The respective role of "technology" and "human/organizational" need is a key point in a successful DT adoption. Often, in innovation, we face "technology driven" interventions. When innovation is purely technology driven, there may be concrete risks of unsuccess. The technology per se may be very appealing, but its success into the organizational environment requires to answer a need. This means that the technology has to be able to adapt to the application and not vice versa.

Once the objective of the DT is clearly identified, it is needed to **design** it, not only in term of technological solution, but also of working flow. In most of cases, the DT, both when aiming to a better product/service for the customer or to an optimized work organization within the company, requires revising an existing working flow or to design a new one.

Users have to be placed at the center of the design. Participatory design (codesign) is the best means to develop processes and products that may be appreciated by the end users.

Process innovation is the cornerstone of a successful DT: the analysis of the whole chain, the interrelation between production phases, departments and functions may shed light on a variety of inefficient processes and rooms for improvements which technologies can help address. Such analysis must be carried in the most collaborative way possible with human aspects always in mind. On the contrary, the way an existing process is modified may cause resistance in the users when the change is not justified.

Users need understanding the reasons behind the design of a process, even before understanding its technological implementation.

Even in well prepared codesign workshops, only representatives of workers are participating. However, the DT adoption is likely to affect a much broader group.

For this reason, a well-planned **communication** campaign may make the difference in a successful adoption.

Communication needs to start with the DT implementation because workers need to know that the process is started, and which are the objectives.

Engagement of the workers is a key element in any organization and, when a change is coming, it becomes still more crucial.

Communication has to raise expectations and participation; end users have to be very well prepared to the tool and ready to test it. Sometimes, even the marketing department is involved in this phase to enhance as much as possible internal communication. In other cases, the workers are trained to the new way of working even before the adoption of the DT.

The role of managers demonstrated to be pivotal in several cases. A committed manager can represent a positive example in a process that requires high change management capacities and thought leadership. Workers' resistances are more easily overcome when all the organizational layers are involved.

As a conclusive remark, it is worthwhile to make some considerations on how the COVID-19 pandemic impacted on DT and vice versa. During the lockdown, the remote or smart working became suddenly mandatory to keep several activities alive.

All kinds of organizations had to change rapidly and to adapt, being forced to modify the way they contact potential clients, interact with them, and in many cases the processes through which they produce, sell, and even deliver their goods and services.

The lockdown leveraged on the DT, did not bring technological innovation *per se*, but in several cases acted as a trigger to overcome the resistance to change, that, at the end, is what make the success or unsuccess of DT.

1. Introduction

1.1 Context

Digital Transformation (DT) is changing the economy, remodelling the business activities, transforming the world of work and, more in general, affecting widely spread activities such as communicating, shopping and travelling. It will be difficult to think of activities that will not benefit of Artificial Intelligence (AI), Robotics, Internet of Things (IoT), Automation, etc. in the near future.

At the top positions of all rankings gathering the most influential technologies, robotics brings undoubted advantages driving operational efficiency and freeing up humans for higher level tasks. However, the use of robotics is now expanding beyond repetitive tasks to more analytics-based activities powered by complementary technologies. If accompanied by a responsible use, the increase of robots spreading in offices, hospitals, industrial environments clearly show how they can benefit society as a whole and how priorities to stimulate robotics should be now taken into account to define their evolution and to best exploit them for increasing growth, jobs and innovation in Europe. Companies need to reach this goal by introducing automation into their operations in a way that complements the contribution of their human workers since, as to date, interpersonal and human skills remain something that technology cannot replicate [1].

Governments have been sharing the view that the technologies under the umbrella of DT configure as facilitators, which some analysts have compared to the combustion engine or electricity [2]. Acknowledging this, several funding programmes, actions and initiatives have been promoted lately by the European Union (EU) to prepare companies, labour markets, and societies for the world of the future. Among these initiatives, a remarkable role is played by the public-private-partnership (PPP) on robotics called SPARC launched in 2013 and representing the largest civilian-funded robotics innovation programme in the world with € 700 M in funding from the European Commission (EC) for 2014 – 2020, and triple that amount from European industry and the AI4EU platform, which is led by the French company Thales and mobilizes the entire European AI ecosystem [3]. AI4EU contributes to create a European AI-on-demand platform to reduce barriers to innovation, to boost technology transfer and promote the growth of start-ups and SMEs in all sectors. The platform acting as a broker enables the sharing of services, expertise, algorithms, software frameworks, development tools, components, data, computing resources, prototyping functions and access to funding.

In addition, the Digital Europe Programme, that will be shortly launched, has the aim of shaping Europe's DT to the benefit of citizens and businesses. Its goal is to improve Europe's competitiveness in the global digital economy and increase its technological autonomy [4].

A further initiative launched to boost the spread and share of knowledge in the field of AI is the European AI Alliance platform, a forum engaged in a broad and open discussion of all aspects of AI development and its impacts. The forum is steered by and High-Level Expert Group on Artificial Intelligence (AI HLEG). The AI HLEG also elaborates recommendations on future-related policy development and on ethical, legal and societal issues related to AI, including socio-economic challenges. The first delivery they have made is the Ethics Guidelines on AI where they put forward a human-centric approach on AI and set the key criteria to be met for a Trustworthy AI [5].

On another hand, a Digital Scoreboard, that extrapolates data from the Digital Economy and Society Index (DESI), has been set to measure the performance of Europe and the Member States in a wide

range of areas, from connectivity and digital skills to the digitisation of businesses and public services. At the moment Finland has the lead of the ranking. What EU wants to ensure, through its investments, is that all main socio-economic drivers such as schools, hospitals, transport hubs, public service providers and enterprises have access to future-oriented broadband connections by 2025 [6].

Despite the remarkable effort of the EU in encouraging the use of advanced technologies, EU businesses are not currently taking full advantage of them or of the innovative business models offered by the collaborative economy. There are also large disparities between large companies and SMEs. European companies are not still standing on AI and automation if compared to the US and Asia companies (China in particular). This happens as European companies are slowly testing automation and AI technologies and it also seems that the SMEs believe these technologies to be more appropriate to largest business [7]. Moreover, there is often a lack of a unified definition and a misuse of AI term from companies claiming that they are using it only to attract investments. A recent research found no evidence that AI was an important part of the products offered by 40% of Europe's 2,830 "AI start-ups" [8].
Although the capital invested in tech by European companies is four times more than five years ago [9], Europe needs to accelerate efforts to develop digital technology and, therefore, AI and automation. On the contrary, Europe may risk to fall further behind as the world's AI leaders - the US and China - continue to stress AI adoption and diffusion with Canada, Japan, and South Korea making strides [10].

To avoid missing out the growth of the DT potential, policy makers and business leaders must be prepared for it and put more effort towards a future permeated by DT. This needs to be done with the idea that DT is not only an enhancer of our current way to produce and deliver goods and services but a powerful change enabler that can transform the way how to create growth [11] and wellbeing.

The present study demonstrates that to achieve this goal organizations must embrace DT putting people at its centre, which also implies that the application of these technologies should not only be consistent with legal and regulatory prescriptions, but also be coherent to ethical principles and ensure that their implementations avoid unintended harm. The study's results emphasize that they should be built with the aim to enhancing people's abilities and not replace them [12].

1.2 The study design in brief

The current study starts by a widespread literature review and web search of ongoing and recently completed R&D activities both in Europe and overseas as well as relevant policy initiatives supporting and fostering R&D efforts towards Digital Transformation (DT). This section of the study is named Technology & Policy Observatory.

Then, the study develops through two additional conceptual steps.

The first one is a field analysis of the status of DT implementation and it is run by means of online questionnaires distributed to the main stakeholders in Europe and overseas. This section of the study is named Digital Transformation technological implementation, and it aims at selecting on the field best practices to be further investigated.

The last step of the study consists of the deep investigation of the selected best practices in the adoption of DT with the final aim of fostering DT benefits mitigating risks and concerns for the society as a whole.

This phase is named Digital Transformation exploitation and builds on online interviews and focus groups to go deeper in the analysis of the best identified use cases.

Every conceptual step has required specific research methods and tools o better grasp the information required to capture patterns, formulate hypotheses on the main drivers and barriers as well as elaborate recommendations. Methodology of each step and relevant results are further described in the next chapters.

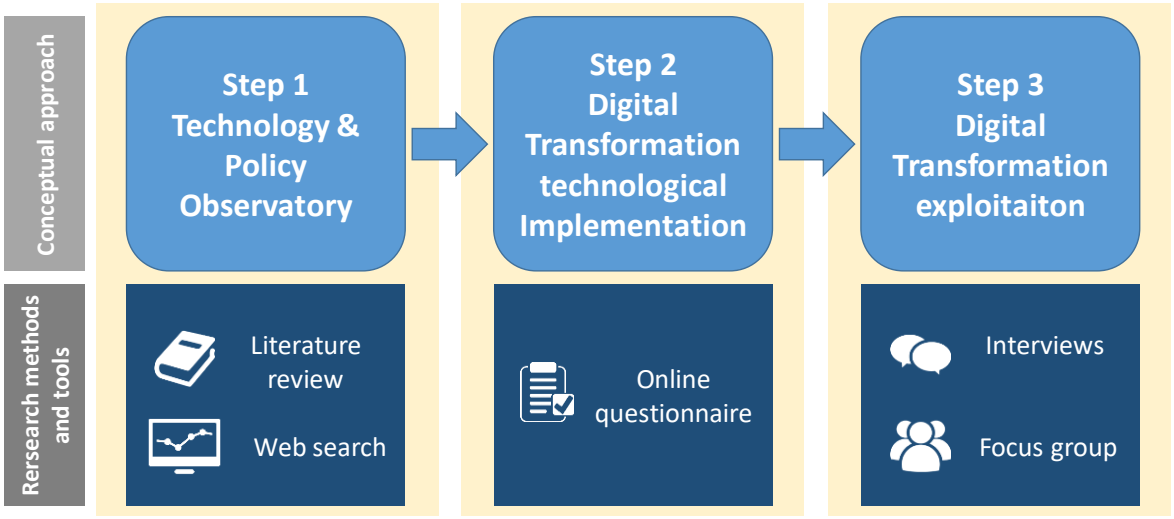


Figure 1. Conceptual and methodological steps of the study

1.3 Structure of this report

The present study is organized in 7 chapters and 6 annexes.

The next Chapter 2, "Technology and Policy Observatory", includes the relevant results of an extensive literature review and desk search aimed at identifying key enabling technologies, sectors most impacted by DT and key trends as well as exemplary projects and initiatives.

The results of the literature review and web search activities served as basis for the identification of good practices in DT as illustrated in the next chapter while details on the searches are reported in Annex 1 and Annex 2.

Chapter 3, "Overview of Digital Transformation in selected countries", addresses the general view coming from an online questionnaire administered to relevant stakeholders identified through a preliminary analysis of the desk research results. The first paragraph of this chapter describes the features of the selected stakeholders, while the second one illustrates the areas explored and the last paragraph reports main results.

Chapter 4, "Case studies deep investigation" illustrates the results of the field work conducted through a series of video interviews with key stakeholders and experts recruited among the questionnaire's respondents and two online focus groups where small teams of people, covering different roles in the selected organizations, have been invited to engage in an interactive conversation and dive deep into the changes produced by the DT process they are/have been involved in, their drivers and success factors.

Chapter 5 "Humans and DT" offers the readers a broad set of reflections and conclusions drawn from the study team with specific focus on the pathways and actions undertaken in such successful initiatives, focusing on the role that DT has/had in enabling better quality, products and services and how the

human factors are/have been taken into account in securing the smoothest integration and adaptation. A set of policy recommendations and key take-home messages are provided as well.

Chapter 6 “Conclusions” provides some final comments on the path of the study and the obtained results.

Chapter 7 “Bibliography” collects the numerous literature references.

Lastly, the Annexes contain respectively: (i) the detailed results of the literature review and web search (Annex 1 and 2); (ii) the online questionnaire and demographic/profiling information about the respondents (Annex 3 and 4); (iii) the interview protocol (Annex 5) and (iv) the brief focus group concept outline used to recruit stakeholders in the fieldwork phase (Annex 6).

2. Technology and Policy Observatory

The **Technology Observatory** and the **Policy Observatory**, as key components of the study, develop around two main research lines: literature review and web search. While the first line mainly tackles reached scientific evidence, the second one addresses live initiatives and projects.

2.1 Literature review

The final aim of this literature review is the selection of meaningful use cases in which DT has been applied on the field with positive effects to business and economics keeping central the human role. To address this final target, multiple steps have been implemented to refine the search.

As an intermediate aim, this review has been also used to identify the central aspects of the Digital Transformation (DT), which is affecting the production and provision of goods and services across sectors, to generate a common framework of DT positive and negative impacts to drive our own field research, carried on by means of questionnaires and interviews.

2.1.1 Methodology

The initial questions that we addressed in designing the frame of this literature review, to set the scene of current understanding of DT, were *1) "Which technologies drive and empower DT?"* and *2) "Which are the human related issues impacting the adoption of such technologies to implement DT in business and society?"*.

Indeed, if, on one side, DT needs technologies to develop, on the other one, DT strongly affects humans at work as well as in daily life, and the understanding of the factors facilitating or inhibiting DT adoption plays a key role in DT spreading and its societal efficacy. So, our search developed on two parallel search paths: 1) technologies and 2) societal issues.

This literature research is limited to the last five years (>2015). This time limit was set by investigating the appearances of the textual string "Digital Transformation" in Google Scholar. This search, run on 2nd January 2020 with no time limit, i.e. since January 1970, pointed out that a total amount of 56.600 papers refer to "Digital Transformation" and that 28.200 of them, i.e. around the 50%, have been published after 1st January 2015 and 23.600, i.e. around 42%, after 1st January 2018.

Referring to available search engines, we decided to focus our literature search on a single search engine that is Scopus. Scopus includes more than 75.000.000 records and it is a quite multidisciplinary titles database addressing health sciences (25% of the total amount of titles), life sciences (16%), physical sciences (27%) and social sciences (32%).

Searched keywords were on one side "Digital Transformation" AND "*selected technologies*" where selected technologies were, sequentially, all the technologies related to DT (e.g. "Digital Transformation" AND "Artificial Intelligence") and, on the other side, "Digital Transformation" AND "*social sphere elements*" where social sphere elements were the human factors in the process (e.g. "Digital Transformation" AND "privacy").

The search was performed on the fields "title", "abstract" and "keywords" of the Scopus database and the relevance of the selected papers was further assessed by the reading of the abstracts by two independent reviewers.

In the next paragraph an overview of the main results of our search with s**pecific focus to investigated use cases and identified good practices** is presented. A detailed description of all the performed searches and their contribution to the design of the study framework is reported in Annex 1.

2.1.2 Results

The panorama of the literature about the adoption of DT in Europe as well as worldwide is still flowing with ongoing debate on definitions [13][14][15] and key components [16][17][18][19]. Most of the current research is still focused on the **potential benefits of the new technologies** [20][21][22] and methods [23] or on the **new professional and working roles** [24][25][26][27[28].

A lot of investigation refers to research projects aiming at **profiling and planning a wide and effective DT adoption** e.g. the HUMAN (HUman MANufacturing) and MAN-MADE (MANufacturing through ergonoMic and safe Anthropocentric aDaptive workplacEs for context aware factories in EUROPE) projects [29] dealing with the role of Industry 4.0 at European level and centralizing the role of human operator. Also, initiatives in the area of steel production are investigated [30].

There is also a **strong nationwide interest** characterized by several papers focusing on the domestic context [31] including as well big countries such as Australia[32] and small countries such as Albania [33], Bulgaria [34], Hungary [35], Portugal [36], Czech Republic [37], Switzerland [38] and Romania [39]. In these trends of research a very interesting case is the one of the Russian Federation where a wide national digital plan has been launched [40] and researchers investigate its potential in several application areas ranging from banking [41] to agriculture [42] and mining [43] hypothesizing also devoted educational structures [44].

However, most of these papers still describe the phenomenon from a strict academic and theoretical point of view and lack the analysis of concrete use cases.

Indeed, when the analysis moves to the implementation ground, even if the available information is limited, there is evidence of **key differences in how the adoption process develop between big industries and Small and Medium Enterprises** (SMEs), as well as among "new" and "old" markets.

Manufacturing is one of the most active sectors in DT adoption as described by Bogner et al [45]. They analysed, by interviewing directors and managers, 211 manufacturing companies in Germany ranging from mechanical engineering to electrical engineering, from medical engineering to logistics and information and communication technology, all of them characterised by a medium or large size. The study pointed out a high level of automation in manufacturing department and a lower level in other industrial functions such as marketing and after sales. This analysis demonstrates how DT has difficulties to address the whole value chain even in large companies. Accordingly, the authors state that in only one quarter of the analysed firms the new industrial revolution will be effectively managed. The main barriers stay in the already well-established industrial process requiring a complete redesign.

Different obstacles emerge when looking at startup companies or SMEs. Berg et al [46] specifically investigated the case of how data analytics may help startups by interviewing 13 hardware startups in Europe. This paper, as others [47], clearly point out how **limited resources, not only in terms of financing, but also in terms of time and people, are perhaps the main barriers to DT adoption by small businesses**.

Also, the most "expensive" sectors (e.g. healthcare, characterized by the lowest level of digitalization compared to other industries [48]), requiring investments in terms of instruments and devices to

implement DT, are more reluctant to adoption than others (e.g. retail [49]), that just need to adopt additional software tools to run new processes rather than modifying the existing ones (e.g. online marketing and sales). Another interesting case is the one of railways [50] where the DT adoption does not impact on the existing structures but on the relationship with the customers, heavily improved by the digital means.

On the other side, the new businesses, such as for example mobile payments [51], are strongly facilitated in implementing DT because they do not need the transformation of already established working processes.

Sustainability is also becoming a key factor for DT adoption in different sectors [52] [53]. The end of rethinking processes, typical of DT, is expected to promote a sustainable approach moving from mass production to personalization. For example, additive manufacturing allows to move production from a traditional cascade flow to a circular digital one [54]. This new approach is expected to happen in different sectors ranging from automotive to aerospace and defense, from chemicals to food.

However, as previously already introduced, all these papers offer only a general level of investigation mediated by interviews to experts and general managers. Specific use cases are rarely addressed, probably also because of the lack of devoted tools for the assessment of the results of the DT adoption, still under investigation [55]. Early frameworks are becoming available for specific sectors such as manufacturing [56] and agriculture [57].

Moving at the small number of papers addressing specific uses cases, it has to be said that they address different business and industry sectors but, mainly, big companies.

For example, two studies investigate the **case of Husqvarna Group**, that is a leader in the production of gardening tools such as lawn mowers, garden tractors, watering systems and so on [58] [59]. Here an **innovative model of Enterprise Architecture Management (EAM) has been applied in marketing and sales**. However, the analysis is mainly focused on the theoretical approach rather than the concrete adoption in the production and business management. Another study addresses **Robert Bosch GmbH** [60] as an **example of automotive industry and effective application of lean production**.

A meaningful use case is also the one of **Hilti [61]**, one of the major players in the construction industry worldwide. Here the DT adoption developed on a time span of 15 years, from 2000 to 2014, **starting from redesigning internal processes and ending with a full digital maturity both in internal and external relationships.** From this case, it is clear that rethinking of work has to come before the introduction of the new technologies.

Another interest case in the **retail sector** is the one of the **Ahold-Delhaize merging** in 2016 [62]. Here **merging has been used as an opportunity to renovate processes and pushing DT implementation**.

In China, the case of **Haier** has been widely investigated [63] Here "digital twins" have been applied to improve the analysis and revision of the production process **moving the focus on the relationship with customers and internal competition**.

Looking at SMEs, the most interesting case of study was the investigation of the adoption of blockchain in a network of SMEs dealing with food tracking [64]. It is the case of **San Rocco Dairy cooperative** located close to Vicenza in Italy, composed by 19 SMEs. They are a group of breeders, founded in 1966, aiming at promoting **high quality local food**. Even if the paper mainly focuses on the veracity of

blockchain information depending on human intervention, it offers a significant picture of how small businesses may benefit from DT, especially in an already established cooperative in a traditionally not digital environment.

In the healthcare domain, it is investigated the case of an **Intensive Care Unit (ICU)** adopting a new commercially available system, the Vital Sync™ Virtual Patient Monitoring Platform 2.4 by **Medtronic** [65]. In this application area a key element is the commitment of the personnel, that requires an early involvement, which has emerged as a central success factor from the fieldwork too. Undoubtedly, **co-creation processes are demonstrating to be crucial in promoting the adoption of new systems in well-established environments**.

As in the case of Medtronic just discussed, there is a different approach when the DT is not developed and implemented for a specific use case, but it is related to the purchasing and personalization of a commercial product. In this case **a key role is played by success stories describing the adoption of the product to launch on the market**. From this point of view, it is interesting the approach applied by **Fujitsu** [66] **that reviewed their customer support systems organization to facilitate the DT adoption at their clients' sites**.

2.2 Web search

2.2.1 Methodology

In order to complement the findings of the previously illustrated literature review, the study team has performed an in-depth web search to identify grey literature sources relevant to the study purposes. The attention has been focused on articles, studies and reports which include information related to DT processes in place regardless the type of funding support received, if any, and information related to the overall political context and social implications the digital transformation brings about.

The large amount of non-academic articles and reports analyzed can be grouped in five main domains corresponding to the diverse aspects of the DT of production of good and services that they address:

1) Articles/reports that argument the **increased efficiency, productivity and capacity** enabling better offerings and operations to give a competitive edge in business performance and user satisfaction;
2) Articles/reports that investigate the **most promising technologies and cutting-edge developments**, being AI, robotics, IoT, big data and automation undoubtedly the most prominent ones;
3) Articles/reports analyzing the **sectors and types of organizations** that are taking the most benefits and the ones which are showing slower adaptation and transformation trends and are struggling more in coping with the fast evolution of technologies, services and business models;
4) Articles/reports that tackle the **political and economic contexts, drivers, barriers and supportive initiatives** which are bolstering the DT;
5) Articles/reports that debate the **concerns related to ethics, democracy and power asymmetry** that the complex array of DT impacts on workers and citizens raise thus pressuring tech companies and governments to set guardrails on its implementation.

Several non-scientific publications contain collections and catalogues of DT cases as well as interviews to experts and DT pioneers which has allowed, along with the analysis of EU projects and initiatives (Section 3.1 and Annex 2), to identify a wealth of example and relevant stakeholders.

Further details on the grey literature search methodology are provided in Annex 1.

2.2.2 Results

2.2.2.1 A wealth of opportunities that requires holistic thinking

There is a broad consensus about the opportunities that DT offers. By embarking on the DT journey, organizations make use of the growing benefits that DT has to offer. The core advantages of embracing DT are represented by the opportunity "to transform data into action" and take a comprehensive approach to systems integration. DT enables operations, finance, digital security, technology, and supply chain to collaborate and respond to the real-time needs of the ecosystem [67].

In general, experts agree that when organizations go through a successful DT implementation, risk is reduced, collaboration increases, and better decisions are made more quickly, thus efficiencies naturally occur. If enterprise resource management systems, customer resource management systems, and workflow automation systems are all connected, the entire organization works more efficiently. When information is shared across entire "systems of systems," miscommunication is reduced and a wealth of valuable knowledge is generated with correlated increases in quality and productivity.

Furthermore, digital technologies are proving to be determinant in the user journey optimization [68] provided that traditional silos in the value chains are broken to leave space for innovative business and service models [69]. This is true across all industries, e.g. retail, commercial, manufacturing, utilities – and other organizations managing complex value chains. No matter who the end users are, a DT strategy that results in accurate information being delivered to decision makers in real time is essential to sustained competitive advantage [70]. More varied and less unanimous the positions when it comes to discuss the most controversial aspects of DT such as its impacts on job market, the ethics, security and privacy related issues.

2.2.2.2 The technologies

The introduction of widespread **cloud computing** has democratized data collection and increased the capacity of enterprises, allowing companies of any size to forgo the need for costly IT infrastructures and cumbersome maintenance regimens. According to a TechRepublic survey, nearly 70% of companies are either using or considering cloud services [71].

The **Internet of Things (IoT)** refers to the exchange of data from real-world machines and sensors that communicate via the Internet. Both the IoT and the corresponding increase in the amount of data generated worldwide make it possible to better anticipate, regulate, and optimize more and more facets of human activity, including cities, transport, agriculture and energy, just to give some examples. While IoT focuses on consumer devices, like smartphones and smart appliances, transforming and improving manufacturing through production quality insights and production optimization is realized through the concept of **Industrial Internet of Things (IIoT)** [72] which connects machines and devices in industries. The importance of IoT for DT is confirmed in several studies and reports [73] which highlight its potential value in terms of businesses and services, such as the Vodafone IoT Barometer 2019 [74] revealing that over a third (34%) of businesses are now using IoT and confirming the trends illustrated in the previous edition where 66% of companies responding to the survey agreed that, without IoT, DT is impossible.

Back in 2016, Cisco called this new digital era the *Internet of Everything*. The IT giant has collected [75] the success stories of 100 innovative companies which are using IoT and IIoT to turn technology

into value. Among them: automotive manufacturers such as **Benteler Automobiltechnik GmbH** (Germany), the multinational engineering and electronics company, **Bosch**, retail companies using IoT to improve food traceability and combat counterfeiting such as **Barilla**, local authorities leading the most innovative smart cities across EU and the globe monitoring and analyzing air quality, noise levels, temperature, humidity, and traffic flow, only to mention a few examples.

Digital twins can make it easier to correlate data from multiple IoT devices for IIoT. In essence, a digital twin is the virtual representation of a physical product with data linking the two. Modern digital twin technology that brings in data from across different systems can help engineers achieve a more diverse set of goals. They can also make it easier to use machine learning to correlate a much wider set of data to look at relationships across assets to enable optimization. Cross-referencing data also makes it easier to detect and correct anomalies which makes this technology particularly valuable in an industrial setting, whereas digital twins are used to improve product design, monitor equipment health to identify potential degradation, simulate manufacturing operations, thus enabling predictive maintenance [76]. Digital twins needn't be restricted to designed, manufactural aspects of production. Twin modelling is also being used to create interactive models of the Earth to help enterprises make better predictions. **Descartes Labs Inc.** is building such a model by fusing data from satellites, logistics data from IoT devices on trucks and other sources to correlate commodity production with enterprise processes [77]. Entire cities such as Singapore, Glasgow and Boston have their digital twin [78].

Robots and unmanned vehicles are transforming the way how an increasing variety of tasks is performed. Robotics is a branch of technology that deals with physical robots. Robots are programmable machines that are usually able to carry out a series of actions autonomously, or semi-autonomously. One of the most explosive trends in robotics is collaborative robots (cobots) [79]. **Cobots** are gaining ground as a valuable tool due to their flexibility. Designed to work alongside employees, cobots take over strenuous and repetitive tasks, and free up workers to perform more rewarding duties in a large number of sectors. In an increasingly ageing society, cobots can be deployed, while the older employees take on higher value responsibilities involving critical thinking or problem-solving. For example, **Changi General Hospital** in Singapore uses a robot picker - a cobot that can pick a range of objects - including fragile items - from a shelf [80].

Artificial intelligence [81] has come to be a great enabler for businesses undergoing a DT for the potential areas of improvement [82] it can activate in an organization. In addition to enhance the customer experience and help increase employees' productivity, AI can help make informed data-backed decisions. Adopters are using a variety of AI technologies, including machine learning, deep learning, natural language processing, and computer vision.

Cyber-physical systems combine physical objects or systems with integrated computing facilities and data storage. CPSs find their application in many highly relevant areas to our society: smart manufacturing, smart energy [83], smart transport, smart city, and smart health among others [84].

Originally introduced with cryptocurrency [85] and still predominantly adopted in banking services [86], **blockchains** and their inherent combination of consensus algorithms, distributed data storage and secure protocols can be used to increase the robustness and reliability of CPS [87]. Several countries have already blockchain in their top five priorities [88]. Globally, firms from various industries are starting to adopt blockchain to optimize their operations and increase their profitability. At present, Chinese companies remain at the forefront of this innovation [89] across sectors. **Baidu**, China's

biggest search engine provider, launched a blockchain medical solution in September 2019 to securely distribute and share medical data. The open-source platform, called XuperChain, aims to store health records, diagnoses, treatments and prescriptions. Once fully functional, XuperChain will not only serve as a place to store medical data but also facilitate the processing of insurance claims when it moves from a small regional pilot to a nationwide rollout.

2.2.2.3 A revolution which has no sector boundaries

The European **manufacturing** sector includes approximately 2.1 million enterprises generating 31 million jobs and representing about 15% of the EU's GDP1. 59% of all enterprises within the sector are small and medium-sized enterprises (SMEs) [90]. Given that together these companies generate about 45% of the total added manufacturing value, they are an important pillar of the European economy. For Europe to remain competitive internationally, its companies must be able to benefit from digital opportunities. According to an extensive survey, 58% of automotive companies are using AI in their manufacturing plants [91].

Along with manufacturing, **aerospace** industry is leading the way to DT. Several examples of implementation are documented in the grey literature, such as **AirService Australia** [92] which is using a digital twin, combined with IoT and machine learning capabilities, to enhance flight routes, optimize takeoff times, and reduce delays. Since major investments in the manufacturing and aerospace industry go into industrial machinery and fleets of vehicles, **maintenance** is of critical importance in order to enable greater utilization and longer lifetime and thus maximizing the return on investment. However, existing maintenance processes are far from efficient. As a result, companies are turning to digital technologies such as the internet of things (IoT) and predictive analytics to unlock the streams of data coming from the industrial machinery and vehicles and turn this data into value. **EasyJet** went all-in on predictive maintenance and uses it for servicing its entire fleet of more than 300 planes after a successful pilot project [93]. **KONE** uses predictive maintenance to improve the servicing of its lifts and escalators to the customers and enabled 24/7 connected services with IoT [94]. It collects vast amounts of data about doors, temperature, and stopping accuracy and sends it wirelessly to the cloud platform. It then uses the insights to develop a predictive maintenance schedule with suggestions about which components to check or replace.

Energy and utilities are considered the leading adopters of AI and automation. The 2019 Global Digital Transformation Benefits report by **Schneider Electric** demonstrates a rich set of use cases where the business value of DT has been unlocked obtaining less energy and resources' consumption without sacrificing productivity or comfort [95].

Fashion and retail brands like **The North Face** [96] are leveraging AI-driven tech as well to bring the online and in-store experience closer together.

Logistic is witnessing an unprecedented rise of robots in warehousing driven by the volume growth stimulated by e-commerce. The majority of work done in warehouses — 70% to 80% — is still manual. Piece-picking robots and automatic guided vehicles (AGVs) which can intelligently sense the environment around them to assist workers with tasks such as picking, packing, and sorting are seeing first major deployments in logistics. **DHL** has been exploring how robots can enhance its logistics operations, especially mobile robots for materials handling applications [97]. DHL recently opened a 28,000-square-foot Americas Innovation Center in Chicago, where the enterprise showcases the latest

in logistics technology, including robotics. This is DHL's third innovation center, joining the initial center in Cologne, Germany, and a center in Singapore.

From the customer side, digital logistics service agents embedded as conversational interfaces in smart home devices (e.g., Amazon Alexa) can assist customers with real-time updates on the status of package deliveries, enable rescheduling, and notify of any delays. Interacting through voice allows users to seamlessly access logistics data. This can result in reduced customer support costs, increased user attention, and wider adoption of IoT (particularly among the elderly or disabled).

Financial services is a sector where traditionally data - including market data, risk data, client data and performance data - has been highly siloed, decision making processes is made slower by internal politics and employee engagement has been generally low. Where customer loyalty once meant something, easy access to an abundance of information and choice has led to customers demanding the best, no matter the provider, thus enhancing competition in all sectors of the financial services industry [98].

International banks are increasingly making use of AI-based solutions [99] and investing in financial analytics start-ups [100][101] that enable institutions to mine a wealth of big data and instantly answer millions of complex financial questions by automating previously human-intensive research.

A similar evolution is happening in **legal professions** [102] [103] although lawtech remains less mature than other areas of technological disruption [104]. The most established lawtech products are target eDiscovery and legal research with UK, Singapore, Hong Kong and the Netherlands on the verge [105].

The use of AI in the **pharma and biotech industry** has redefined how scientists develop new drugs, tackle disease, find suitable candidates for a clinical trial, increase adherence and more [106] [107]. Pharma businesses are using AI to increase the success rates of new drugs while decreasing operational costs at the same time as well as to detect certain patterns faster and support clinical decision making. Moreover, the advancements in AI technology are generating a renewed interest in rare disease treatments which pharma companies don't traditionally focus on because of the lower return on investment.

In the **healthcare** sector, the variety of DT applications is huge. Technology finds widespread adoption to increase patient safety in the hospitals. It is estimated that between 5 and 10 percent of hospital patients worldwide will acquire a new infection while in the hospital, and tens of thousands of people die from these infections every year. Robots that can efficiently disinfect hospitals using UV light and have proved to be helpful in slowing coronavirus spread. An interesting example is provided by the UVB Robots produced in Denmark by **Blue Ocean Robotics** [108]. They could be useful in schools, cruise ships, or any other relatively structured spaces [109].

AI is also transforming the **entertainment and creative industries** [110] and is deployed in **human resource management** across sectors. Using AI for recruitment has the potential to eliminate some of the behavioural and perceptive bias that is a common shortcoming of human interaction [111]. For employees, chatbots deliver an unmatched level of employee experience, from real time answers for HR questions to personalized learning and development [112]. Nevertheless, experts are still cautious about its application in talent acquisition and studies reveals that "organizations are comfortable with AI informing their hiring decisions but aren't comfortable with AI making those decisions" [113].

As for blockchain, fintech and healthcare are the sectors witnessing the largest amount of applications. However, Chinese organizations have started to incorporate technology for **charitable endeavors**. In

Europe, Netherlands based **Airbus**, renowned for its commitment to DT across the whole value chain, through its opensource project Heritage by its Foundation, is one of the few large companies outside of China to adopt a blockchain platform for philanthropy accepting donations in crypto currency [114].

2.2.2.4 Supportive initiatives and policies

Governments across the EU are encouraging manufacturing industry companies to invest in DT in an attempt to raise the economy to a more sustainable level. Government-owned development funding agencies, such as Tekes – the Finnish Funding Agency for Innovation, finance the DT of businesses. Similarly, Germany has launched a national project entitled Industrie 4.0 with the aim to employ digital transformation to improve the competitiveness of, for example, the manufacturing industry [115]. Noteworthy among the national efforts in this direction, German researchers [116] are in the process of establishing the *Industrial Data Space*, a virtual construct for secure data sharing based on standardized communication interfaces.

Many governments across the world have also developed formal AI frameworks to help spur economic and technological growth. These range from the US executive order on AI leadership and China's "Next Generation Artificial Intelligence Development Plan" to "AI Made in Germany" and the "Pan-Canadian Artificial Intelligence Strategy." [117] These strategies focus on talent and education, government investment, research, and collaborative partnerships. But governments face more than technological and economic challenges. Many are assessing how they can ensure privacy, safety, transparency, accountability, and control of AI-enabled systems without hampering innovation and its potential economic benefits. There are many estimates of total global AI spending, investment in AI start-ups, and the impact of AI technologies on the future economy. Most assessments agree that the United States and China are investing the most, with members of the European Union looking to quickly catch up [118].

In a view to bolster and support national efforts, a variety of programmes and instruments are put in place by the European Union. In this context, the Factories of the Future PPP is the European Union's collaborative, multi-sector initiative to support the transformation of manufacturing in Europe through pre-competitive research, development and innovation projects.

The PPP's overall objective is to increase the European Union's industrial competitiveness and sustainability through research, development and innovation, with the development of new knowledge-based production technologies and systems across multiple sectors. In 2017 the PPP reported Based on the information received from the companies that participated in projects, that **a leverage factor rate of approximately 4,65 has been achieved** [119]. Looking at the future, manufacturing research experts from academia and industry require a forum for collaboration at European level and the FoF PPP – or rather the planned successor "Made in Europe Partnership" - needs to further finetune its instruments to stimulate that need [120].

2.2.2.5 The controversial aspects

One of the most strikingly controversial topics is **the impact of DT on the human capital** and its possible **consequences on the labour market**. Results from studies, surveys and expert opinions diverge [121].

Some experts assume that human-robot collaboration will only last to a certain extent before human beings no longer need to be involved in the active production process [122]. In this scenario, production

will be handled exclusively by robots, while humans will only be responsible for the control of the processes. A recent report from Oxford Economics sheds new light on both the current impact of robots on manufacturing and services. The rise of the robots will boost productivity and economic growth. And it will lead to the creation of new jobs in yet-to-exist industries. But existing business models in many sectors will be seriously disrupted with potentially 20 million manufacturing jobs set to be lost to robots by 2030 [123].

Undoubtedly, some professions will suffer more from automation than others. Technological change shapes the evolution of the division of labour, by directly changing the production process and the types of labour input necessary [124]. The central point, therefore, is not the number of jobs lost, but qualitative structural changes in terms of activities and qualifications which call for a **human-centric approach to DT**.

It doesn't surprise then to see the reaction from both citizens and policy makers to the launch of delivery robots such as the one being tested by **Fedex** [125], **Roxo** [126], which is using AI, motion sensors and stair-climbing wheels.

In a global perspective, according to estimates from McKinsey Global Institute (2017) [127], 400–800 million jobs will be automated, and 75 million to 375 million workers (3 to 14 percent of the global workforce) will have to retrain or learn to do new jobs or acquire a new skill by 2030.

Secondly, it is well known that sprawling connectivity among personal devices, governments, businesses, and industrial equipment is fuelling **exponential growth in cyber and privacy risks** which require setting clear mitigation goals and actions to protect both device and data security and individuals' privacy [128]. Most organizations acknowledge that emerging technologies are critical for business, but fewer are very confident they have sufficient 'digital trust' controls in place, as a recent PwC Digital Trust Insights survey reveals [129].

Data security and confidentiality is a key issue in the IoT, as any connected object may be vulnerable to cyber-attacks. Manufacturers must realize the importance of securing connected objects from the very early stages of the design process [130] [131].

As part of the "Digital Deal" to come, business must accept **responsibility** and be prepared to be held accountable for their actions in the digital space [132]. As the environmental and climate change impacts of production are today seen as part of corporate responsibility, businesses will also be held accountable for the **social impact of AI and new technologies**. This becomes even truer as long as the promise of emotionally intelligent interfaces and hyper intuitive cognitive capabilities held by the next phase of digital evolution turns into reality. The last Deloitte Tech Trends 2020 report dedicates an entire chapter to "ethical technology and trust" [133]. What is making the pushback against potentially harmful AI [134] growing is especially the lack of reliable mechanisms in place to secure that intelligent systems are not optimized only from the perspective of (and to the benefit of) the business owners.

In the recent global AI survey conducted by Deloitte [135], early adopters in various countries expressed contrasting levels of concern about AI risks specifically in relation to potential cybersecurity vulnerabilities and **unpreparedness to face the huge skills gaps**, with Germany and China appearing to have a surplus of confidence compared to France, Australia and Canada.

2.2.2.6 The trends

Evolution and **convergence** [136][137] are the keywords which best explain the technological trends according to the experts. As innovative technologies evolve rapidly and vast arrays of new possibilities emerge from their convergence, knowledge and information silos are broken down thus leading to a **reconceptualisation of the relevance and positioning of knowledge management** [138] that is increasingly shaping the operation and business processes. The way data is stored, organized, and processed ultimately paves the way for how it can be ultimately consumed and used [139] to generate knowledge

Nevertheless, despite the significant potential impacts stated previously, Europe is still at an **early stage** in achieving the true potential of DT. For example, only 20% of the companies in the EU-28 are considered highly digitised and there are still many technological opportunities to be exploited especially by SMEs [140].

As for the economic impacts and the benefits on business performance, although studies and reports witness an exponential growth of investments in DT and witness that an increasing number of leading companies are moving beyond pilot projects and are investing in rolling out digital solutions [141], many organizations are reporting they are **still in testing mode**, and more than half of the executives are still either experimenting or testing on a limited basis around their organizations [142].

Furthermore, over the past 10 years, R&D investments of European software companies grew only by 5%, whereas the R&D spending of US software companies grew faster at a rate of 8.2% [143], calling for increasing attention [144] on the key role of software as the "glue that makes the digital services, devices, systems, ships, vehicles or spacecraft work intelligently by themselves".

McKinsey [145] defines a successful transformation as one that, according to the respondents to their 2018 survey, was very or completely successful in "both improving performance and equipping the organization to sustain improvements over time". As a result, their research show that **less than one-third of organizational transformations succeed** at improving a company's performance and sustaining those gains.

What emerges is that any DT process needs to be seen "through the human prism" [146] to be considered successful. While many studies confirm that automation of tasks is a core component of any organization's DT journey, our analysis highlights that the desired outcomes are not just about achieving greater productivity. Enterprises across sectors see the potential to **redirect the human effort saved through automation towards innovation** [147]. One way this is happening is through the rise of the so-called "superjobs" [148].

This **shift towards a human-centred manufacturing system** in which humans concentrate on life-long skill improvement and continuously create high-value-added work calls for a new paradigm incorporating human aspects within the existing notions of CPS and IIoT.

In the same direction, software will not be any more a tool for automating workflows and systems, but it will grow into the novel role of implementing highly complex systems that intimately interact with people in hybrid digital/virtual and physical ecosystems. By that, software and software developers will be increasingly confronted with social and ethical issues [149].

In general, there is increasing awareness that DT is driven by changes in the broader business and societal ecosystem which technologies must accompany as enabling factors.

3. Overview of Digital Transformation in selected countries

3.1 Stakeholders selection

As previously described, both the literature review and the web search were aimed at providing a picture of the current status of investigation on DT. Indeed, this study aims at enhancing the current vison of the phenomenon by deepening the analysis on the "human related" areas not yet sufficiently examined.

So, the results of the **literature search** were carefully analysed to identify authors that could contribute to a deepening of the content of their papers.

Looking at the published studies, selection criteria for authors to be contacted were the following ones:

1. Use cases, i.e. analysis of the adoption process in selected companies;
2. Field views, in terms of interviews of managers and workers of companies implementing DT;
3. Descriptions of local and national approaches to DT, with focus on companies involvement.

Within this sample, we contacted authors by personalized invitation mails to participate in our questionnaire.

When it comes to the **web search**, this has been done with the purpose of selecting a group of stakeholders by analyzing 3 types of sources:

1. *Articles and reports*. We decided to investigate into online available grey literature with the objective to understand what technologies empower and drive digital transformation and what are the related human issues impacting these technologies when implementing DT in business and society. The stakeholders have been selected when from the reading of the articles or reports emerged that:
    - ✓ The stakeholders have contributed to or are developing an interesting DT process to make organisations more competitive, effective and efficient.
    - ✓ The stakeholders are acknowledged for their expertise in the field of DT.
    - ✓ The stakeholders are innovative technology suppliers which means operating in the fields of technologies covered by the DT.
2. *Projects*. We decided to investigate into this source with the aim to understand what kind of research, development and innovation actions are being funded by public or philanthropic initiatives and what are the key players involved in such endeavours with the purpose to expand the list of questionnaire's recipients. The stakeholders selection has happened analyzing the following EU public/private funded categories of projects:
    - ✓ H2020 projects approved within the "Factories of Future" programme (Public-Private Partnership). It has been decided to select stakeholders from this category being the European Union's main programme for realising the next industrial revolution: materialising Factories 4.0. This way we have been able to select the stakeholders that participate or participated in kind of projects whose main goal is to finance the advanced manufacturing research and innovation, which is the purpose of this Public-Private Partnership.
    - ✓ H2020 projects approved within the Focus Area DT "Digitising and transforming European industry and services". It has been decided to select stakeholders from this category as the purpose of this funding stream is to finance projects that want to take advantage of the digitization of products, services and processes to transform industry.

- ✓ Applications Experiments funded under the frame of ICT Innovation 4 Manufacturing SMEs Phase 3. The I4MS is a program promoted by the European Commission to expand the digital innovation of manufacturing SMEs. We have selected stakeholders from this field being companies operating in digital transformation technology areas very important in the manufacturing sector such as (i) Additive Manufacturing, (ii) Cyber Physical System and Internet of Things, (ii) Robotics, (iv) High Performance Computing.
- ✓ H2020 projects approved in the frame of European Innovation Council (EIC) enhanced pilot that has been introduced by the EC to support high-risk and high impacts ideas. Our selection has been focused on stakeholders participating in projects awarded in the frame of the most recent Fast Track to Innovation (FTI) and SME instrument calls for proposals.

3. *Digital Innovation Hubs*. We decided to look into this category to ensure a selection of stakeholders that play a key role in supporting their users to get close to the digital innovations. It is important to say how the information given by the catalogue is the result of a self-declaration and so our selection is based on that.

Further details on the rationale for and outcomes of the projects' and DIHs' search are provided in Annex 2.

3.2 Online questionnaire structure and rationale

As previously already introduced, the results from the desk research described in Chapter 2 led to a good understanding of the current framework in DT and the identification of a bundle of topics worth to be further deepen.

The online questionnaire was designed to avoid repeating investigations already performed and to identify existing good practices in DT adoption with specific focus on human-technology relationship.

The questionnaire is implemented through three different sections.

Section 1 is aimed at profiling responders, in terms of competencies (background and expertise), industrial/business sector, role in their organization and geographical location.

The section aims at describing the current DT panorama by means of a bottom up approach driven by the people running the process.

Section 2 investigates the perception of DT by individuals as well as their organization. Through the description of ongoing experiences in the area, the section identifies perceived advantages and risks, existing drivers and barriers and actions to be taken in due account in designing successful interventions.

Section 3 identifies candidates for future interviewing. According to the aim of the study, these people, on which the study will build the deep analysis of exemplary best practices, have to show a wide knowledge of the field.

The questionnaire full text is provided in Annex 3.

3.3 Results

The questionnaire starts asking the respondents to select the main **drivers** pushing forward DT.

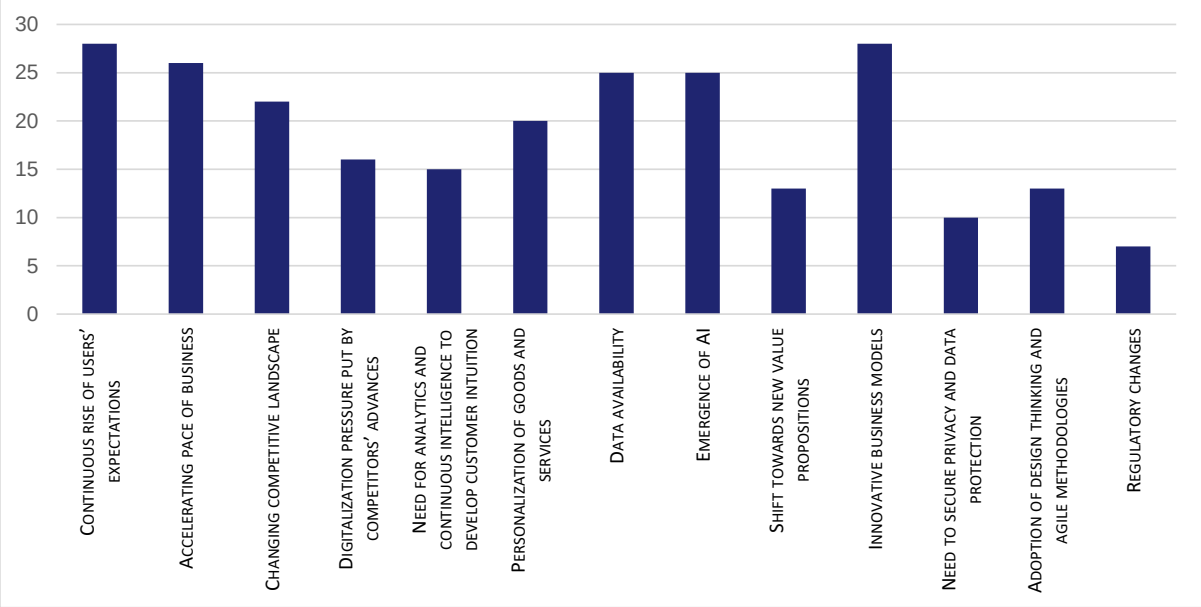


Figure 2. According to your experience, select the main drivers pushing forward DT

According to the figure above, the respondents have not expressed a marked preference when choosing the main drivers pushing forward DT. However, the more selected drivers are "**Continuous rise of users' expectations**", "**Accelerating pace of business**" as well as emerging "**Innovative business models**". When asked to stress other DT drivers not included in the pre-selected options, several of them emphasized the determinant role played by the **demands for innovation posed by current environmental sustainability, demographic and climate change challenges** as well as the global public health threats such as the current Covid-19 pandemic.

Novel operational models (such as e-commerce) and the hype witnessed by technologies such as AI, IoT as well as the potential brought in by 5G are also considered key drivers shaping the direction of DT processes.

Secondly, when asked to select the main **barriers** hindering DT, more than half of the respondents think the major obstacle is the "**Cultural and behavioral resistances**". The second-chosen barriers, among the proposed options, for the respondents result in a "**Lack of change-oriented mindset**" and "**Inadequate organizational resources**". Cultural resistance is intended as having a key influence of both the staff and the managerial side: as for the latter, the respondents emphasize that there is still a persistent "fear of change" which makes DT processes being initiated predominantly by either organizations that are going through crisis and thus need to undertake deep renovation initiatives to overcome those or very wealthy and innovative ones which are positioning themselves as pioneers in the DT landscape. Interestingly, the natural shifts in priorities to focus on Covid-19 impacts, formerly mentioned as a potential driver, is also perceived as a barrier referring to those organizations which most are suffering from the pandemic's short term consequences and have been forced to redirect resources, funding and staff to cope with the emergency downgrading innovation in their priorities' list. Lastly, the **need for huge infrastructure investments** and the insufficient economic resources are perceived as barriers as well.

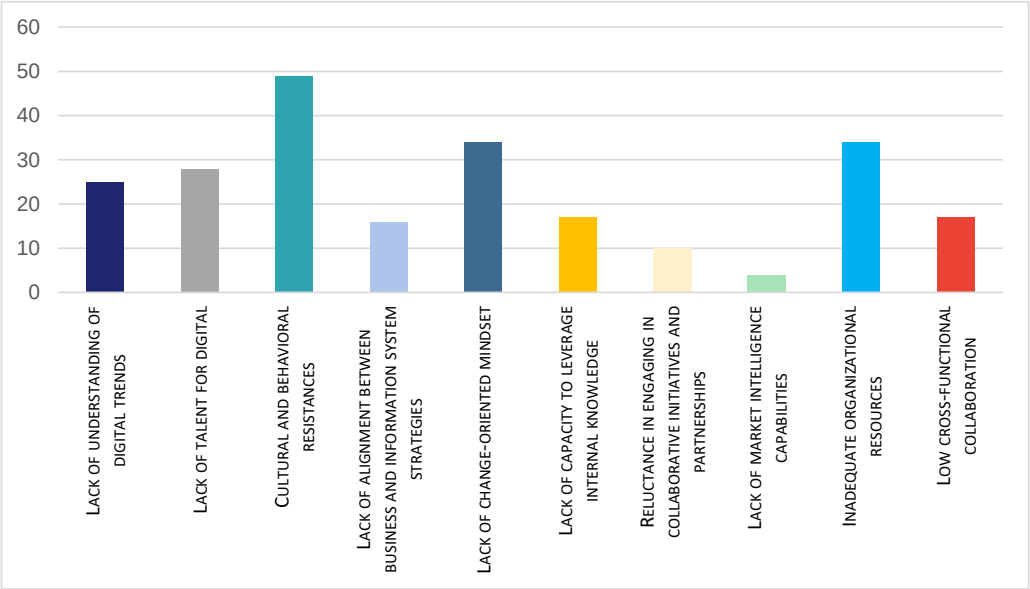


Figure 3. According to your experience, select the main barriers hindering DT

In the following set of questions we provided the respondents with a list of seven **advantages and risks** connected to DT application and asked them to rank those items from the most to the least preferred assigning each a score in a 7-point scale. The following tables show the resulting ranks. Moreover, participants have been asked to indicate whether according to their experiences other relevant advantages and risks should be taken into account.

Table 2. According to your experience, rank the main advantages related to DT application

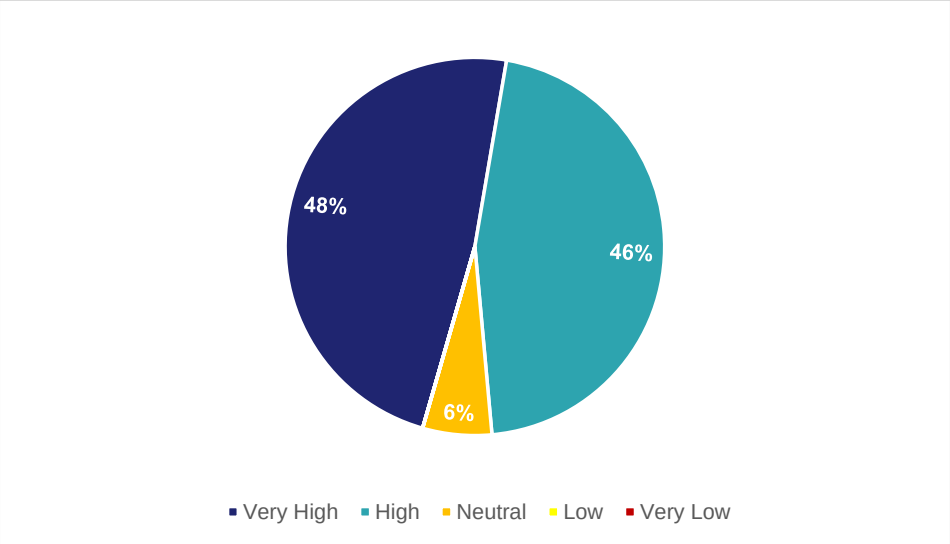
Advantages	Rank	Score
Improved quality of work results	1	454
Decreasing of the number of errors	2	387
Reduced working load	3	375
Improved quality of life in the working place	4	317
Decreasing of the risk of accidents	5	287
Increased qualification	6	283
Increased expertise	7	277

The table shows that the main advantage related to DT application is given by the possibility of getting **improved quality of work**. Respondents stress that the increase in quality and productivity is key to increase competitiveness, flexibility and capacity to adapt to changing demands and needs. As found in the literature and web search, the optimization of the user experience is also considered a crucial advantage. Also, quite large preference is given to the advantage related to the decreasing of the numbers of errors. The respondent think that the DT application does not increase the level of qualification and/or expertise.

Table 3. According to your experience, rank the main risks related to DT application

Risks	Rank	Score
Difficult adaptation to the new working practices	1	430
Need of high specialization	2	417
Work loss because of insufficient specialization	3	321
Reduced personal privacy	4	321
High mental load	5	310
Social isolation	6	293
Strong control by employers	7	288

The table shows that the main risk related to DT application is given by the **difficult adaptation to the new working practices**. Also, quite large preference is given to the risk related to the need of high specialization which is confirmed by the large agreement expressed about the need of acquiring new competences for achieving successful DT (see Figure 3 below). The scores show a considerable importance attributed to "social isolation" or "strong control by employers" as strong risk that prejudice the application of DT although those are the least preferred ones in the ranking, a result clearly in line with the stakeholders' selection modalities chosen that have not included workers in this phase of the study.



Figure

4. Based on your experience, score the importance of acquiring new competences for achieving successful DT

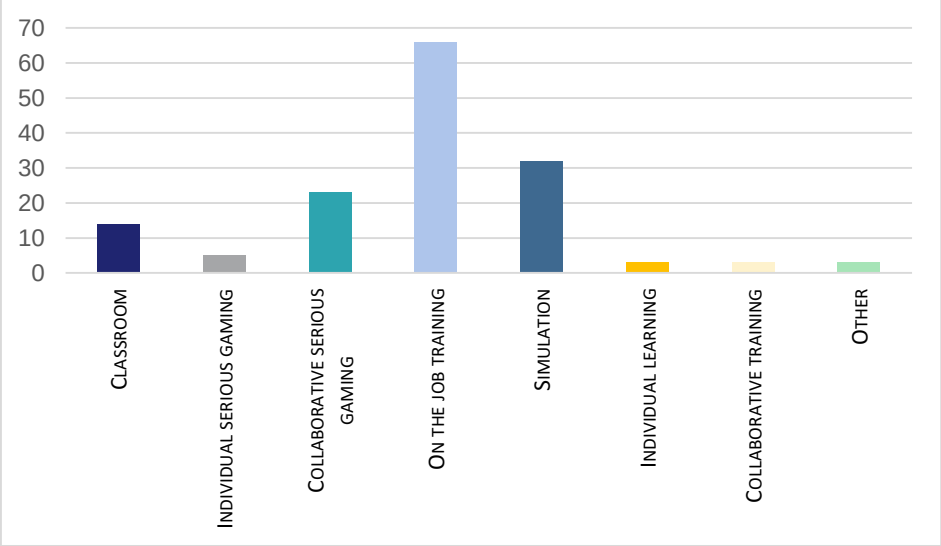


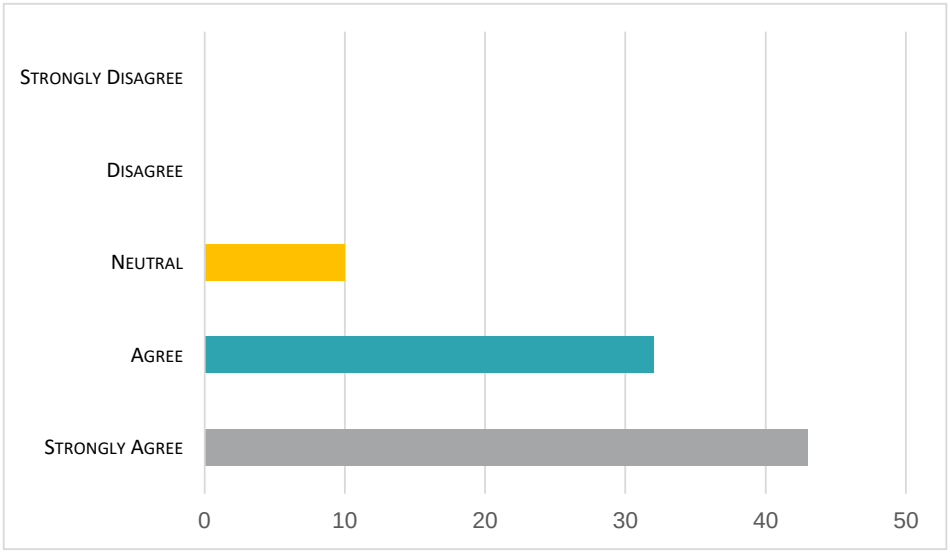
Figure 5. Select the most effective training and skills development practices according to your experience

The majority of the respondent have selected "On the job training" as most effective training and skill development practices in their experience. "Simulation" takes the second place in this final selection. An interesting comparative analysis between Germany and Japan highlighted the potential of the **"learning factory" model** which indeed is making predominantly use of training on the job and simulation modalities [150].

Table 4. According to your experience, rank the level of acceptance of potential actions to implement DT:

Level of acceptance	*Rank*	*Score*
Changing of work environment	**1**	**403**
Mandatory training	**2**	**399**
Wearing of sensors and devices	**3**	**338**
Having a robot or other machine as working mate	**4**	**335**
Changing of working mates	**5**	**315**
Changing working hours	**6**	**312**
Recording of personal physical data	**7**	**278**

The table shows how the respondents would be keen to a change of work environment as level of acceptance of potential actions to implement DT. Also, quite large preference is given to the "Mandatory training" while the respondents selected the "recording of personal physical data" as the least acceptable practice to implement DT. In general, and consistently with what stated above, all the respondents agree on the determinant role played by the attitude to change working practices (see Figure 5).



Figure

6. Please indicate whether you think that the attitude to change working practices is determinant in DT success

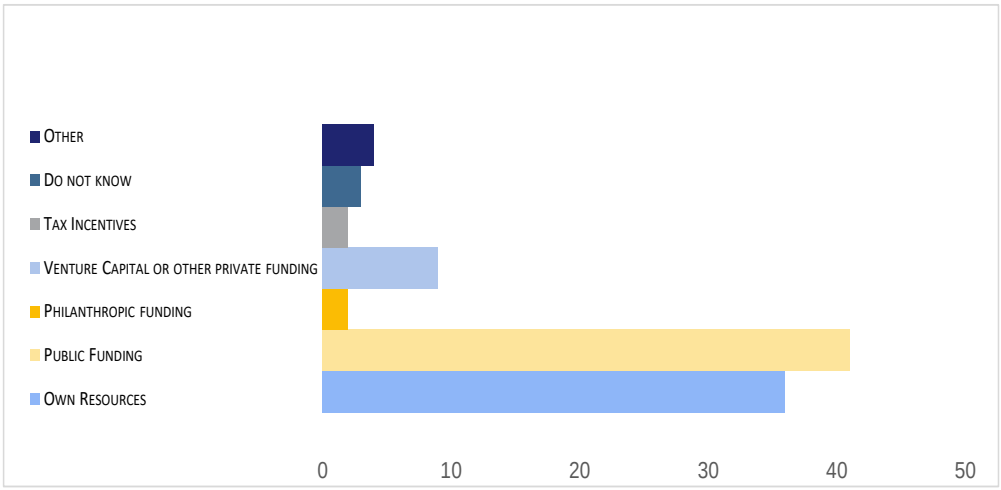


Figure 7. The DT process you are/have been involved in is supported by

As shown by the above figure, the DT processes which the respondents have been involved in are supported almost exclusively by own resources of the organizations or public funding. The third place in this rank is taken by the funding source "Venture capital or other private funding". Furthermore, more than two thirds of the respondents state that their organizations participation in Research, Development and Innovation projects to foster their DT strategy, thus confirming the determinant role played by publicly funded R&I initiatives (Figure 7).

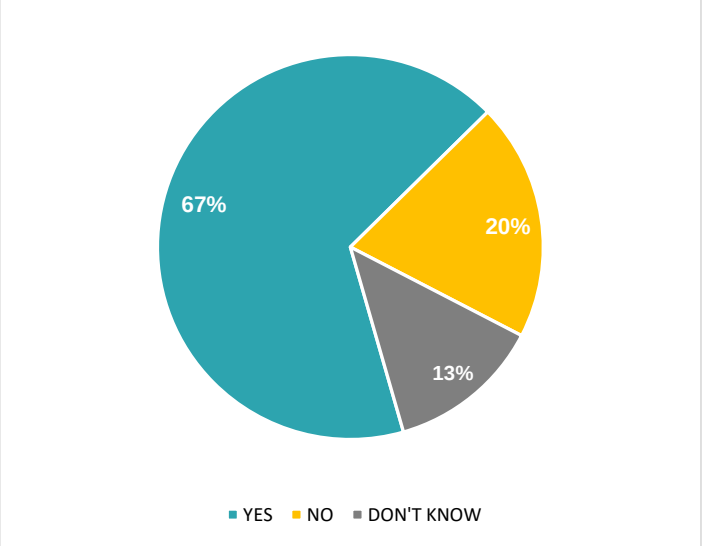


Figure 8. Does your organization participate in Research, Development and Innovation projects to bolster its DT process?

When moving to the analysis of the open questions aimed at depicting the frame of the current DT practices, the main application areas, already identified by the desk search, were confirmed.

Apart from responders working in companies aimed at fostering DT, who underlined the importance of actions to support companies, especially SMEs, the participating industry representatives were involved in two main areas of transformation. On one side, **manufacturing**, mainly supported by the introduction of robotic systems, and, on the other, **working processes renovation** mainly be means of Enterprise Resource Planning (ERP) including marketing, sales and human resources (HR) areas.

In the case of manufacturing, most of work is targeted to improve **human robot interaction** (including the adoption of **co-robots**) and to empower maintenance procedures and quality of the final products also by applying **IoT in production**. The role of **AI** is a key one in almost all the identified interventions.

When asked to mention other DT experiences, rather than the ones taking place in their own companies, most of responders share their feeling that DT is evolving everywhere, but they were rarely aware of other successful experiences.

The **time span of the intervention** is highly variable, ranging from **few months** (4-6 months) **to some years** (up to 6) with an average time span of about 3 years. In some sectors, for example Public Administration, the adoption process is very slow, in others, and mainly in the new software-based business experience, the process is immediate.

In all the transformation cases that the study participants illustrate in the questionnaire's open fields, an important role is played by **codesign**. As pointed out also by the previous literature and web search, involvement of stakeholders and workers since the early phases of the transformation process demonstrates to be a key factor in successful experiences, as well as an adequate training.

Also, it has to be said that in most of cases of DT adoption, **initial trigger has been represented by public funding at national or international level**. DT adoption is an expensive and heavy process, involving all the industrial/business sectors and, especially in SMEs, public support is an important incentive to get it started.

Overall, most of responders are happy with their experience in DT that they saw as an unavoidable and necessary process, given the advancement of technologies.

However, **technologies are just a mean for DT**, the key point is the **new design of underlying business and industrial processes**.

In this line, and consistently with the answers provided when asked about the DT drivers, some responders also see the **on-going pandemic crisis as a trigger for further advancement in DT**, given the need of rethinking work practices.

4. Case studies deep investigation

4.1 Methodology

Chapter 4 illustrates the outcomes of the third and last Step "Digital Transformation exploitation", i.e. the fieldwork. Based on the review of the answers provided by the questionnaire's respondents, the study team has selected a group of key stakeholders who have been invited to a semi-structured interview (interview protocol available in Annex 5). In this phase of the study we aimed to identify and review exemplary cases of DT processes in goods and / or services production and delivery with a specific view on how the human factors has been taken into account and the risks connected to implementation of such processes have been dealt with.

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We investigated specific "use cases", i.e. examples of Digital Transformation (DT) processes that, in the opinion of the selected experts and the study team, are to be considered successful because of e.g. the involvement of changes in leadership, the establishment of different thinking and cultural changes, the encouragement of innovation, the governance transformation and the adoption of new business models, the digitisation of assets and the increased use of technology to improve the experience of organisation's employees, customers, suppliers, partners and stakeholders.

Each interview has been thus to collect information, data and relevant insights that were gathered in a factsheet illustrating: a) the general context of the sector the case refers to, b) the description of the DT process, c) its main outcomes and impacts and d) the way how its effects on humans have been handled.

As a second step of the field work, some use cases were further explored by means of multiple interviews (Elettrotecnica ROLD) or focus groups with representatives of the main involved company professional categories and technology providers (SAS institute and Villa Beretta rehabilitation center) Full guidelines for the focus groups are provided in Annex 6.

4.2 Examined DT adoption settings

4.2.1 HEALTHCARE: Emergency Department

Name of the Interviewee	Dimitrios Katehakis
Affiliation	FORTH, Institute of Computer Science
Name of the organisation or company described in the interview	Thriasio General Hospital of Elefsina – Emergency Department
Country	Greece
Sector	Healthcare
Context (description of how the introduction of technologies is transforming the sector)	
Nowadays, the healthcare industry is highly impacted by DT which means that different technological tools and solutions are used to enhance the patient experience, service delivery, create new business models, and make communication more efficient. Technologies such as telemedicine, artificial intelligence (AI)-enabled medical devices, and blockchain electronic health records (EHR) are just a	

few concrete examples of digital transformation in healthcare. Rapidly evolving technologies, along with demographic and economic changes, are expected to disrupt hospitals worldwide. Already, a growing number of inpatient health care services are being pushed to the home and outpatient ambulatory facilities; however, many complex and very ill patients will continue to need acute inpatient services.

One of the most important and complex facilities that a hospital hosts are their Emergency Departments (EDs) which are considered the frontline service of the healthcare systems managing acute potentially fatal patients 24/7.

The experience of a digital change involving the EDs is highly needed especially during this historic moment when, due to the outbreak of COVID-19, all the limitations of the healthcare systems worldwide have emerged. It seems clear that the healthcare system needs to adopt an immediate digital revolution to face this crisis (but in general to improve its functioning).

One of the key problems of every EDs worldwide is that they easily get crowded due to the insufficient amount of resources available to serve the needs of the communities in their referral areas. **This problem is particularly relevant in EDs in Greece** due to:

- **increased healthcare demand** (e.g. ageing population; growing incidence of chronic diseases);
- **socio-economic factors** (e.g. low incomes on average; high number of migrants and refugees) which have lately worsened due to the 2010 financial crisis and the steadily increasing migration streams;
- **inappropriate use of EDs as a substitute of primary healthcare services**. Greece in particular, has a well-documented insufficiency in providing appropriate primary level healthcare coverage for the population while EDs remain the easiest option for all citizens needing access to a responsive, well-staffed, fully equipped secondary level hospital with presence of all the necessary medicine specialties, imaging, medical expertise in the same facility. In addition, hospital emergency on-call system is extremely complex in Athens where at each given time only 4 big hospitals from a pool of 12 are accepting emergency patients thus worsening the crowding effect.

The above-mentioned points threaten the quality indicators (e.g. safety, effectiveness, efficiency, responsiveness, patient-centeredness and fairness of the cure and care provided) **while patient and staff satisfaction are negatively affected**. In order to improve quality, one of the key pillars to invest in is the automation and DT of the Eds which allows to better predict and manage the ED's day-to-day workflow by keeping track of appropriate KPIs while auditing and monitoring continuously the improvement cycle.

Description of the case

As mentioned above, the case at hand is about the DT process carried out by the ED of the General Hospital of Eleysina-Thriasio which is a medium sized acute hospital in the Attica region (near the big suburban complex of Athens) in Greece.

The DT process started in the year 2016 **with the aim to improve the day-to-day function and adopt a set of reliable key performance indicators (KPIs)** to measure its impact.

The organization had completed the acquisition of an integrated Hospital Information System (HIS) in 2010. However, certain gaps continued existing in the workflow that required human intervention for improvement. This is the reason why a further process of DT started in the year 2016.

The DT project, led by Dr. Markella Charalampatou (Pulmonologist and Head of Emergency Department), was designed by the clinical director of the ED together with the vice director of the IT department of the hospital. It also involved the whole ED staff and the commercial partners and vendors that liaise with the hospital.

The project, coordinated by the Hospital of Eleysina-Thriasio, was undertaken in close collaboration with the following IT companies: *FORTH*: Patient flow management (arrival, triage, admission, medical records, etc.); *CCS*: Laboratory tests ordering; and *HealthCare Experience*: Imaging viewing, archiving (PACS[1]).

Overall, the project is deemed a significant success: the current digitized workflow experiences now a significantly improved use of automation and a very limited use of paper.

Though, some critical aspect had to be overcome:

- While the goals where clearly articulated in the design phase, the project run into some delays due to the insufficient collaboration by the management of the hospital in effectively considering the proposal for digital transformation. The delays were related not only in target setting but also in taking actions that would improve the quality of services.
- The other reasons that caused delays during the implementation phase were related to: collecting adequate funding; difficulty to map non-linear patient pathways and resistance to modify certain "bad habits" established in the healthcare system; hurdles in co-operation amongst IT industry partners and lack of interoperability of the IT solutions; lack of adoption and diffidence from some workers of the healthcare staff; lack of human resources.

However, the problems were promptly solved as:

- the appropriate level of funding was secured by the Executive Team of the hospital as they realized that this project would be essential for the future of the ED;
- the rate of the adoption of the technologies rose quickly after the staff realized the benefits in their everyday work offered by the automation solutions.
- the business partners found a common ground of collaboration.

Main outcomes of the DT implementation

The digital transformation process resulted in the introduction of technological innovations within the ED of the hospital such as:

- **Electronic systems for registering new patients**. From this database it has been possible to collect information relating to: arrivals of new patients in specific time windows, percentage of patients arriving by ambulance ("blue-light" patients), the age case-mix, number of patients who were covered by insurance, hourly attendance rate, arrivals per specialty and the percentage of admissions.
  In 2019, the ED received 61,907 patients, 16% of them blue-lighted. It is noted that:

[1] A picture archiving and communication system (PACS) is a medical imaging technology which provides economical storage and convenient access to images from multiple modalities.

- ✓ there is an established increase in the ED attendances with a sustained rate of increase (in fact the curve of blue-light patients is increasing). While the daily attendance rate graphs are following the same pattern as with previous years.
- ✓ the 43% of patients arrive in the first six hours of the day (08:00-14:00).
- ✓ for the year 2019, the average age of attendance was 45 years and one of four patients was older than 65 years.
- ✓ the percentage of admission was 14%.
- ✓ the 22% of patients arriving to the ED had no health insurance, which indicates that ED service is the only available healthcare facility for these vulnerable patients.

- **Electronic exchange of medical data between triage and rest of ED**. By achieving a real-time update of information between the triage and the rest of the ED treatment areas, healthcare staff are able to have an overview of how many people are waiting to be visited while the order of accepting them is now based on clinical severity rather than a "bureaucratic" time of arrival. This enables the ED to be as responsive as possible while reducing crowding.
- **Electronic collection of ED case-mix as presenting at the triage area**: 27% of patients are deemed not urgent and able to be treated at a primary care facility rather than a secondary/tertiary hospital.
- **Electronic recording of LENGTH OF STAY (LOS) for the patients who will eventually be admitted to the hospital**. For the year 2019 the mean time was 6 hours and 20 minutes. Just the 37% of patients are admitted within the 4-hour limit while the 18% of patients had to wait for more than 10 hours causing worse crowding and inability of the ED to deal with prospective attendances.
- **Electronic ordering of laboratory tests**: since April 2018, the ED has been connected electronically with the hospital biochemistry labs and radiology department enabling safe and quick ordering of tests while the results can be viewed by the doctors at the bed side. By the introduction of this system, the ED is now able to measure the waiting time of a given patient from the moment they arrive in ED to the moment of the first lab test ordered which can be considered as a proxy of the interval between the arrival and the first visit (DTDT Door to doctor time). This measurement is very important in life threatening and time critical pathologies. The mean time is 44min while 75% of patients are seen within 1 hour: there is about a 7% of patients that have to wait for more than 2 hours before being seen.
- **Mortality registration in ED**: based on the hospital data available in the year 2019 there were 110 deaths in ED. The number of deaths in 2019 was reduced by 3% when compared to 2018.
- **Electronic recording of attendances who do not wait or leave without being seen (LWBS).** This is an important measurement of an ED functionality and is a key indicator worldwide. It is considered safe when not exceeding 1% of the attendances. This index is at 10% in the ED of the general hospital of Eleysina-Thriasio and is correlated with the daily hourly attendance burden as well as the severity of cases at triage.
- **The laboratory tests ordering system is now connected to the national service of healthcare delivery** (called EOPYY – national insurance body) which allows a timely and detailed claiming of costs. At the same time, doctors are encouraged to do their prescription activity through the national e-prescribing system.

With regards to the financial sustainability of the ED, the digitization project allowed the connection with the main national insurance entity of Greece (EOPYY) and secured its financing. In 2019, 1.5 million euros were claimed from EOPYY for the total of the diagnostic examinations that were carried out.

It is worthwhile noting that in order to promote efficiency at a national level, the EOPPY in the recent years, had stopped paying any costs to the EDs nationwide until the hospitals would implement an electronic ordering of laboratory tests. The previous platform for reimbursing ED costs that was in place was clunky, time consuming and never really used by the healthcare staff.

The DT process put in place was more organizational and functional in nature and less technological as its development was driven by the need to measure KPIs that would allow the identification of situations where safety and quality were at risk.

The major technical difficulties identified during the process related to letting patients know about waiting times and activating electronic signing of healthcare staff.

Human factor

As a result of the DT, **the majority of the health professionals at the ED have generally improved the quality of the services they render due to the introduction of the new tools and processes**: in fact, after the initial distrust and reluctant approach, the ED staff accepted with satisfaction the DT process as it enabled them (i) to work in a safer environment, (ii) to become more efficient and (iii) to gradually improve the time to treat patients thus reducing tensions in the ED (although these latter improvements are not really quantifiable as the hospital has not included methods of patient reported outcomes or staff satisfaction/outcomes yet). Also, it has surely improved the relationships with the patients and their relatives as inherent dysfunctionalities (e.g. delays in lab tests, carers trying to help unnecessarily etc.) ceased to exist.

All these improvements have been possible thanks to the **training sessions** delivered to the ED staff. It was deemed strictly necessary and was carried out by the (i) industry partners that undertook the project of DT, (ii) the IT Department of the hospital and (iii) the clinical lead of the ED.

However, the collaboration between the ED staff and the administrative staff has not improved to a desired level and hopefully will be enhanced by the forthcoming activation of the electronic patient record in ED and the interoperability at the level of the hospital wards.

One more positive aspect is that the processes of DT were the subject of informative and participatory discussions with the ED staff and their suggestions and contribution to the improvement of the systems were significant. Their main ideas involved the mapping process of the patient pathway and how to facilitate the flow of patients.

The tangible improvements in the healthcare services of the ED are reflected and measured by the following KPI indices:

- **Reliable recording of the ED resources needed**. An average annual increase of 4% has been recorded in the last two years (2017-2019). During the same period, the percentage of patients arriving by ambulance showed an average annual increase of 11%.
- **The systematic recording of the hourly attendances** in the last 3 years allowed the optimal allocation of staff during the day when hospital is on-call (42% of arrivals are recorded in the first six hours of the day 08:00-14:00)

- Although patient attendance is increasing, improvement is being recorded in key patient flow indicators. More specifically for the two years 2018 and 2019:
  - ✓ The time from the patient's arrival to the first contact with the clinician (Door to doctor time-DTDT) showed a decrease of 9%.
  - ✓ The length of stay in ED of admitted patients decreased by 26% and the percentage of admitted patients who complete their stay in the ED in less than 4 hours increased by 72% but remained low (only 37% of future admissions remain in the ED for less than 4 hours causing congestion and overcrowding).
- **Regarding the efficacy indices** analyzed for a 2-year period (2018 and 2019), mortality decreased by 3% while there was no significant and sizeable reduction of the percentage of patients leaving without being examined.

It is worth to note that the funding of the project was based exclusively on public funds already attributed to the yearly Hospital budget.

4.2.2 WHITE GOODS INDUSTRY: components manufacturing

This was an extended case of investigation, three different company units were analysed, specifically: the production unit where the DT was adopted, the industrial unit, in charge of marketing and selling the DT process to other companies, and the R&D unit applying DT to products design. The different roles are described in the next two interviews, one with the responsible of the industrial unit, Luca Cremona, and one with the academic consultant of the R&D Unit, Marita Canina from Politecnico di Milano.

4.2.2.1 Process innovation (interview 1)

Name of the Interviewee	Luca Cremona
Affiliation	Elettrotecnica ROLD srl, Nerviano (Milano), Italy
Name of the organisation or company described in the interview	Elettrotecnica ROLD srl
Country	Italy
Sector	Manufacturing
Context (description of how the introduction of technologies is transforming the sector)	

Elettrotecnica ROLD srl was born in 1963 to manufacture components for white goods (e.g. selection knobs, door lock switches).

It is a family company, now in its second generation. With three plants in the Milan area, 240 employees, 40M Euro turnover, and export over the 85%, ROLD is a key player in the area. Digital Transformation has been

starting around 10 years ago to optimise internal processes (quality and efficiency) and to create, in the time, a DT product exploitable out of the company's plants.

Today the company has two divisions: appliances (developing the "historical" products, i.e. components for white goods) and industrial, taking care of the exploitation of the DT product and service. A third entity is RLAB (described in the next interview with a researcher from the Politecnico di Milano), focusing on appliance products innovation.

Description of the case

Initially, around 2010, the focus of the DT was the optimization of the processes and the reskilling of the personnel so as to create a single IT architecture including both sense making and decision making which the staff, adequately trained, could take full advantage of. The intervention was also aimed at a better visibility of the processes to the big players in white goods, customers of the company, when visiting the plant with auditing purposes.

The DT process was promoted by the company owners with the support of the production managers by using internal IT resources (initially allocated to appliance products development).

When the governance of the company moved to the second generation, digital technologies were initially applied in the innovation of the products (e.g. lightening systems).

However, once the IT competencies have been acquired in the company, they have also been used to apply Digital Transformation to the internal processes through the introduction of a new application for the execution and monitoring of the production process.

Main outcomes of the DT implementation

Key issues of the implementation success, both internally and externally, were the choice of using consumer technologies (a partnership with Samsung is in place) and the design of the platform starting from the needs of the end users, i.e. the workers. The newly introduced **"SmartFab" application** for tracking and documenting the manufacturing chain (which is a kind of advanced and customised Manufacturing Execution System (MES)) is a **fully in-house designed and developed** product. It has been progressively refined and has become a new product that today ROLD is commercialising to companies characterised by similar manufacturing needs. Indeed, the know-how was and is property of the sole company.

From the manufacturing point of view, the intervention has allowed to comply with a production quality index of 4-40 defective parts on 1 million pieces. The required production volume is around 3 thousand pieces/hours.

The intervention was initially applied, as a proof of concept, to one machine in the assembly line (2017) and later scaled to all the three plants of the company.

Today the platform is scaled to the 75% of the machines and the information is available in real time to planning.

The use of the production data is not yet completely developed and the manipulation and analysis of the collected data still need refinement.

The ambitious idea to convert SmartFab **from an internal asset to a market-ready product** that could be successfully commercialised to other companies is part of the open and forward-looking mindset of ROLD's management that started to learn from international customers. Also, being a

partner of Assolombarda, which is the largest territorial association of the entire Italian entrepreneurial system, ROLD was able to demonstrate its processes to several companies ranging from big industries to SMEs.

The choice to transform SmartFab in a product to be sold required the creation of the devoted "industrial division", to take care of selling a service rather than a physical product. New expertise and competencies were acquired to manage this new line of market. In the last two years, SmartFab became a product for manufacturing companies, including different vertical shapes for different production areas (e.g. energy). Several modules are also available.

A **partnership with Microsoft** has been started to run the underlying cloud platform.

Also, an agreement with an integrator has been setup for integration of the platform with customers' plants and data analytics modules have been developed.

All the design and development have been funded by the company itself that yearly spends around the 8% in R&D to continue improving the platform.

Human factor

At the beginning of the DT, the company management was supported by Marketing and Human Resources (HR) units to facilitate involvement and acceptance by the workers: Marketing supporting internal communication and HR taking care of workers training.

The role of the Marketing in communication was strategical to foster acceptance by the operators, not accustomed to have a screen on site showing the results of the production process.

Workers have been involved in the process since the early phases. Discussion groups were created among the workers to share their experiences and a key role was given to "early adopters" to transfer the acquired knowledge to the others.

The initial resistance to the change of the workers was overcome by suitable multidisciplinary and continuous training. All the workers were reskilled, there was no job loss and a constructive dialogue with unions was established along the process. Furthermore, workers' bonuses are defined according to the performances measured by the platform.

A circular model, based on the Agile methodology, has been applied in design and development and a devoted instrument has been used to collect needs, opinions and suggestions from workers as they were "internal customers".

The availability of an internal testbed is an added value also for the industrial division that may test its innovations before releasing.

Also, the demonstration of SmartFab to external visitors happens in the plants, on the production line. The operators are directly involved also in these activities.

The plant of Cerro Maggiore is today listed as a "lighthouse" by the World Economic Forum [151 which, in collaboration with McKinsey and Company, has identified 16 production sites which are world leaders in the successful adoption and integration of the cutting-edge technologies of the Fourth Industrial Revolution. To date, the Italian company is the only SME in this list.

Nevertheless, the strategic and organisational shift from being a company 100% devoted to produce and commercialise physical components to a service-oriented business model is a still an ongoing and complex process.

4.2.2.2 Product innovation (interview 2)

Name of the Interviewee	Marita Canina
Affiliation	Politecnico di Milano
Name of the organisation or company described in the interview	Elettrotecnica ROLD srl
Country	Italy
Sector	Manufacturing

Context (description of how the introduction of technologies is transforming the sector)

Elettrotecnica ROLD srl, already introduced, pursues two lines of Digital Transformation: Digital Transformation in the production process and Digital Transformation in the design of new physical products.

DT in the production process and related impact on the market and workers are detailed in the previous interview with the responsible person of the industrial unit.

However, the need of renovation and the open mind of the management also impacted the design of the products.

To this purpose the company created the R-Lab, that is the innovation and applied research center of ROLD focusing on innovation in mechatronics, advanced materials, electronics and emerging technologies. Within this center, the company rethinks its historical products and investigates new markets, also in terms of new user interfaces for white goods, considering new materials and new senses.

Indeed, the manufacturing of new products starts from their design and the Digital Transformation may be applied also to this creative phase, looking at the innovation potential offered by the application of new digital technologies.

Renovation of physical products in a digital age is a new challenge that few SMEs address because of the impact on all the industrial processes and related investments.

Description of the case

R-Lab is the new multidisciplinary idea-laboratory of Applied Research led by a team of ROLD Engineers, working in collaboration with universities, companies and experts, ranging from Advanced Mechatronics to Human Machine Interactions, from Applications & Smart Devices to Advanced Materials.

ROLD has a broad collaboration with Politecnico di Milano, Politecnico di Torino, Santa Chiara Lab University of Siena and other organisations.

The R-Lab pursues both the renovation of existing markets and the creation of new ones.

Designers from Politecnico di Milano interact with the R-Lab to stimulate creativity in the identification and development of ideas of new products.

In this collaboration the focus is on new interfacing modalities to be proposed to the existing market of white goods producers.

The cooperation with the designers points out an approach based on scenarios identification (use cases) as starting point for the design of new products accompanied by a deep overview of on the edge technologies to know potential materials\electronic components\algorithms to be applied.

For example, an initial scenario was the provision of beverages in a working environment.

Once identified also suitable technologies, the next step consists of the prototype design and manufacturing. In this case, it was a dispenser of beverages mixing different ingredients according to the stress level of the worker looking for the drink. The developed prototype was demonstrated at external companies and won an innovation award.

This design approach targets new potential markets through demonstration of internal creativeness and innovation capabilities.

Main outcomes of the DT implementation

The R-Lab itself is the main outcome of the collaboration with Politecnico which was based on Digital Transformation approach.

It was originated by an initial experience within the Politecnico di Milano in 2010, Rold Research (http://www.roldresearch.org/), consisting in research activities of a multi-disciplinary team shared with other two complementary companies.

Few years later the multi-disciplinary approach was replicated internally in ROLD as a successful experience to be further developed. This enabled a more effective connection between fundamental research and industrial development.

Its main aim is the identification of new potential solutions which will allow to address new markets, pursuing a continuous innovation of product.

The final result is a best practice in origination and consolidation of innovative ideas.

Human factor

In this case the human factor is two-fold.

The workers of the company are the main actors of the laboratory and are involved in the whole design process, starting from ad hoc training and devoted workshops in the academy to acquire a new mindset.

Always at company level, students and stagers are involved in the laboratory to contribute to an open mind approach.

The R-Lab is an asset of the company and it is fully appreciated by the involved workers who have the opportunity of continuous updating and training on new technologies.

The second human factor is the one of the potential end users of the new products. In this case, the company does not directly address them, and the role is played by the consultants, i.e. the designers from the Politecnico di Milano.

This is because the end users of the company are their customers, i.e. the producers of white goods, but, in the design phase, it is needed also to consider the users of the final products, i.e. the final consumers.

4.2.3 AGRIFOOD: horticulture

Name of the Interviewee	Erik Pekkeriet
Affiliation	University of Wageningen
Name of the organisation or company described in the interview	Redstar
Country	The Netherlands
Sector	AgriFood – Green house vegetables sector
Context (description of how the introduction of technologies is transforming the sector)	
The horticulture sector has expanded a lot during the last decades in The Netherlands as new facilities have been brought in and new digital solutions adopted. The enterprise resource planning (ERP) is a great example of digitalization though which the organizations use a system of integrated applications to manage the business and automate many functions related to technology, services and human resources. The expansion of the sector has in turn enabled to convert the incomes in (i) new activities, (ii) hiring people, (iii) investing in new facilities, (iv) improving existing process (above all packaging). Due to digitalization the whole sector has been able to better organize the sales due to a very good connection to the Internet of Thing (IoTs) world. This enables the reach out of different markets: still few varieties but high volume with the result that turnover and branding are increased. In the Netherlands the most advanced large growers are getting bigger since their products are more competitive and easier to sell thanks to the combined use of technologies such as IoT, big data and AI. Highest production quality, better exchange of information and increased efficiency in logistics are assured due to an efficient combination of different digital technologies, which in turn contribute to shorten value chains, as a recent report from the European Parliament has confirmed [152].	
Description of the case	
The case illustrated below is about RedStar, a Dutch company specialised in the production of tomatoes operating for more than 65 years. RedStar grows, packages, and sells fresh tomatoes during the whole year. RedStar, starting as a family company in 1953, expanded over the years and in 1996 started to trade under the official name RedStar, one of the first company who puts brand to the tomatoes. The company had 4-5 facilities around the years 1990-2000 where the activities of production and packaging were carried out too. Afterwards they decided to bring the raw materials only to one site - the packaging and distribution center Poortcamp in De Lier - that made the packaging activities much more flexible and enabled the company to serve different retail markets on a daily basis and react quickly to the demands of customers.	

The expansion and the changed process had an impact on the tasks of workers that are now carried out with different and more efficient modalities. They could this way take care of the production, packaging and supply the different customers in the same day (while years before this resulted impossible due to the lack of time and the different packaging location). This has had a significant impact in controlling the processes and increasing the sales: the turnover amounted almost to 100 million euros in 2017. In addition to the growing locations in the Netherlands, RedStar has joint ventures with growing locations in England and Morocco.

Today RedStar can supply its customers all year round with a total range of tasty tomatoes of consistently high quality. The various locations employ a total of around 150 permanent staff, which can increase to 700 with temporary staff during peak times.

Main outcomes of the DT implementation

The main outcomes of the DT implementation have enabled RedStar to broadly scale up the chain of supply, to improve (i) the sales, (ii) the internal work and (iii) the relationship with client. More details are provided hereafter.

Scaling up of the chain

The growers are expanding very fast thanks to the digitalization that has enabled them to better communicate with the retail suppliers.

In the past the process of selling had to go through multiple chains: (i) the growers, (ii) the auctions, (iii) the distributors and (iv) the retailers.

The use of ICT means that growers make their products and have a much stronger position from a contractual side as they can negotiate directly with the retailers. ICT does shorten the chain which in turn means to have a stronger contractual power and more efficient management of the processes.

Improved control of the greenhouses

RedStar, by implementing a broad DT process, has adopted new systems:

- for air circulation, as many of the new greenhouses are indoors therefore, there is a high need of a continuous refresh of the air;
- for controlling and keeping the right temperature and humidity through IoT sensor networks installed within the facilities. To maximise production, they are able to keep a an optimal temperature (+30 degrees) at high humidities (+80%) by keeping windows closed while ensuring plants' wellbeing is maintained;
- for making the dry air fall down onto the plants and get a drier climate which, added to the high humidity, means to get higher production;
- for assuring that insects do not fly in and vector-born diseases do not put the production at risk. This is done thanks to a new blown air system;
- for controlling the quality of work of the through ICT systems which allow to know how much a worker has produced and the quality of the work and establish an assessment system to evaluate workers' performance: this way they can understand who is better at what and eventually praise or replace the worker. ICT has become essential especially in a sector that lack today of direct relationship between the management and the workers.

They are able to monitor all these processes due to the introduction of IoT sensors that facilitate the tracking of all the variables connected to the quality and quantity of production. They can also track the quality of the job carried out by the workers (with a delay of a few hours).

Satisfying the demand of customers due to ICT and Improved control of the sales

This market is highly customer-demand driven: customers lead the demand in terms of quantity and variety of product. RedStar distinguishes itself by cultivating in a customer-oriented way, packaging tomatoes sustainably and continuously innovating at the product level: thus, there is a high need of flexible production and packaging. They have been able to establish a continuous flow of product and are now able to have the right volume at right time and be ready for the market demand.

RedStar has also recently start a pilot with a start-up in the field of robotization to analyse plants' health status with smart cameras.

More efficient way to hire and train workers

Through digital communication means, RedStar is able to provide training to workers who most of the time come from other countries (Romania, Bulgaria, Poland). They provide guidelines in their language explaining the ask that need to be executed.

The owner most probably needed to know everyone 20 years ago while today is very easy to source workers (form different countries) due also to the help of specialised agencies: they are trying to improve and open up more this process to ICT with the aim to scale up more the activity of hiring of new workers.

All the advantages above are the result of a process that cannot be identified as a one-day-thing or one-time-investment: RedStar has started this process years ago and has taken the right steps toward

a continuous improvement, through setting an innovation group within the company that is able to formulate and effectuate innovation projects. What could improve digitalization in the sector of agriculture is the demonstration: people could learn a lot more through organized trainings that should be carried out in a real setting or through the implementation of innovation hubs. Another way Redstar is opening up to digitalization is the obtainment of public funds like those belonging to Common Agriculture Policy for new investments in digital solutions.
Human factor
Although the workers start to benefit from the process of digitalization that companies such as RedStar are going through, this process has been so far mainly business-driven and haven't taken much into account the worker perspective. The preparation of the product for distribution and delivery requires the most manpower within the horticultural business, therefore digital advancements that could protect and/or improve the work environment are essential to keep this sector sustainable. Personnel demand also largely depends on peak times, such as summer harvest periods. The labor demand in these peak periods is largely covered by temporary workers, 90% of those being migrant workers and most of them do not belong to the younger generation. This is due to the economic growth in the various sectors and the associated decrease in unemployment, as well as the improved conditions in the home countries of labor migrants working in Dutch horticultural businesses, which are all conditions which are going to make Dutch horticultural companies increasingly facing with a shortage of personnel in the near future [153]. For these reasons, automation and mechanization of certain processes is something really needed in order to foster the replacement of the physical work with logistic carriers (Automated Guided Vehicles, AGVs), although machines are still too underdeveloped for this to happen in the short term. At the same time, in order to retain or recruit workers in the future, it is important to make work in the primary process more attractive, commit to bonding to the company and improving working conditions. Employees can be served with optimal ergonomic measures to improve productivity and ensure or increase job satisfaction. In a recent study developed by the research team led by the interviewee, six transition paths are identified for this purpose in this study, namely: (i) Facilitate social interaction; (ii) Promote a shift from "quantitative" to "qualitative" employee; (iii) move the employee from primary to secondary process; (iv) get broader insight into good employment practices; (v) build a pleasant workplace and (iv) develop specialized functions.

4.2.4 METAL PROCESSING: tools production

Name of the Interviewee	Martin Wifling
Affiliation	Virtual Vehicle Research GmbH
Name of the organisation or company described in the interview	EMO Orodjarna
Country	Slovenia
Sector	Metal processing industry
Context (description of how the introduction of technologies is transforming the sector)	

Digital Transformation (DT) holds a hope for the Slovenia's machining and metalworking sector as manufacturers increasingly commit to efficient technology practices which have been making the sector one of the most resistant-recession industries in Europe.

With respect to labour productivity, all major manufacturers are working to upgrade facilities and invest in new projects: increased experience and knowledge of employees give companies an edge through innovative solutions that are the main drivers to continuing improvements of manufacturing processes.

The information that in the year 2018, **62.500 people were employed by over 3.280 machining and tooling companies** explains the progress in the development of modern technologies and their application to a lean-manufacturing environment. The revenues generated in 2018 - €9.1 billion - by this sector are a further indication of its continuous growth.

Staff training is highly important as it makes the processes less expensive, faster and more efficient which in turn means improved competitiveness: different educational institutions create knowledge that enhances the productivity of the metals industry and develop its human resource base.

Currently some 3,300 students are enrolled in undergraduate courses for occupations in the machining and metalworking industry. The number of students in secondary schools for metallurgy and mechanical engineering is nearly 9.100.

Description of the case

The case illustrated below is about the Slovenian toolshop company EMO Orodjarna located in the city of Celje and founded in the year 1894.

The company has approximately 200 employees and the core business focus on the development and production of progressive and transfer tools for deep drawing of sheet metal.

The company's main customers are the automotive and aviation industries and their suppliers to which EMO Orodjarna delivers tools for large presses. These tools are produced in many different versions and in small numbers.

To innovatively satisfy market needs, they strive to obtain a harmonious match of the buyers needs on a hand and the interests of all participants on the other hand.

They have come close to the processes of DT as during the activities of manufacturing, assembly, quality control and maintenance, the workers need all relevant information in real time, presented in

a smart way that does not interfere with their work. They also needed the opportunity to promptly communicate and report important incidents.

The implementation of new technologies took approximately 5 years: on one hand the expectation on the outcome of the introduction of new processes were really high but on the other hand it still took time and effort to introduce such processes and such work organization where the technology completely change within: it was hard to keep up with the speed of this technological change, sometimes it has been needed to change the architecture of the new processes to follow up with the new introduced technologies.

The actions to implement the new DT processes were fostered by different categories of actors in the company:

1. Workers who have been the promoters of the introduction of those tools and process;
2. CEO who positively contributed to the introduction of these processes;
3. Middle management: they were supportive and open to process changes that in some cases required and open mindset to welcome and accept novel distributions of responsibilities and controlling roles in view of the workers' empowerment and upskilling that the DT brings about.

The development of the prototype has been possible thanks to the participation of the company in the H2020 funded project "FACTS4WORKERS – Worker Centric Workplaces for Smart Factories", coordinated by the interviewee. The prototype is available in open source for any supplier willing to advance its implementation into serial production processes.

Main outcomes of the DT implementation

The principal aims of the implementation of DT processes within the company were the improvement of (i) work satisfaction amongst workers, (ii) productivity and (iii) quality of production.

Communication improved

The company had as one of its main objectives the establishment of a new communication tool (that works through a tablet): they wanted to improve firstly the poor communication between the engineers with the shop floor workers and with the planning group: the flow of information wanted to rapidly answers to questions such as "who is planning the work?", "where do we keep up with the current parts to produce?"; also they wanted to improve the flow of communication between workers of different line of production or assembly so as to quickly be able to know who is working on a particular piece of the tool or who is the responsible person or team to fix or replace certain pieces.

Productivity and quality of production

The FACTS4WORKERS prototype also allows to report incidents online, thus paving the way for a progressive elimination of relevant data and information produced and stored in paper format.

All the information are now documented in one-type format and are available to everyone.

The worker can now power up his tablet, log in and check the status of the production process, especially which parts are still waiting to be assembled. The worker uses the tool to find the parts grouped into logical compartments according to the sequence in which they can be assembled: he/her can see the packages that are ready to be assembled and those that are still waiting for parts. Once the worker has finished, all the progresses can be documented in the system and if he/she cannot work on the tool any longer, as the next important part is still in production, the system tells him/her who is

working on the part and when to expect the completion of the machining processes (if it takes too long to wait for the arrival of the parts, the worker can decide to switch to another tool and inform, through the tablet, the group leader about the need to switch to another tool). This takes only a matter of minutes, even though the worker does not know where his group leader physically is. The same mechanism is used to report failures of machines operation and to document the errors.

Preventive maintenance

When a machine issues a warning, the worker can look up the error in the database (through the tablet) by scanning the QR-code which is attached at the machine. This preventive maintenance procedure is demonstrated by a training video and the worker can also quickly retrieve it from a repository system where step-by-step guides are stored and updated anytime was an error is triggered. This procedure gives confidence to the operators who can manage the repair on his own.

Impact on customers

The impacts, that these new technologies had on workers, have certainly had an impact on the customers too: all these changes improved those situations where the toolshop had particular problems in meeting the lead time of their tools with their customers. The company found out that one of the main causes was that the workers did not know exactly where to find and which data are needed to produce a subcomponent.

The introduction of these new technologies wanted to provide solutions to quickly react on problems and to take decision at the lowest possible level to in turn reduce downtimes, question times and to improve the communication flow: at the end this is all together with customer satisfaction.

To implement the new tool and take advantage of it, it has been necessary to:

- Hire IT specialists to implement solutions: in truth the company underestimate a but the relevance of IT support within the organization.
- Train the staff for the use of the new tools: initially the company had strategies to train peer users and primary users but also training to all other users afterwards. Therefore, the training participators were peers with the management involved to show the effectiveness of those processes: if the functionality of the tool was proven, it was then quite easy to follow up with the other workers and training them to use those tools and other processes.
  The training was quite useful as most of the workers had already contact with the technology and were almost already trained when the prototype was installed and introduced.

Unintended effect

The implementation of DT has brought to light some effects that were not expected to happen. For example, the work processes were not fit enough for DT and this is something that the company had to do manage beforehand. More than an intended effect this could be considered as necessary pain that the company have to go through to uncover this lack of readiness of the system of the current way of producing and doing things.

Human factor

The introduction of new technologies and processes in the FACTS4WORKERS overall approach is intended to valorize and take stock of the workers' skills and enhance their capacity to provide accurate data about the quality of the produced piece and assure the quality standard were fulfilled.

The successful experimentation has resulted in a partial handover of responsibilities from the quality department to the workers directly. This has been induced by the possibilities granted to the workers enabled to solve problems with a higher degree of autonomy thanks to the implementation of the novel communication tools (i.e. modifying parameters on a machine, fetching info which is required to produce components and tracking quality). Of course, empowerment requires time, commitment and openness to change from all levels of the chain and fears to lose control on processes may understandably raise and require positive leadership and transparent communication flows to be overcome. The workers didn't show specific concerns with reference of the potential threats that the DT could bring, instead they were quite happy to take these new responsibilities with the aim to contribute to a more efficient and holistic problem solving process. Besides this, what really has been increased is the work satisfaction: specific KPIs have been introduced to measure in general work satisfaction and innovation readiness of the workers that have revealed very good results obtained also thanks to the training and upskilling plans that accompanied the introduction of the technology, ultimately bringing as well to productivity increase.

It was great to see that the introduction of new technologies promoted by the management (that obviously aim to increase productivity or effectiveness) did not make the workforce reluctant to the adoption of the new processes, which is something that usually happen. This has happened because workers were involved from beginning and the management considered their needs, suggestions, opinions before big changes happened.

4.2.5 STEEL INDUSTRY: workers safety

Name of the Interviewee	Maria, Maddalena Murri
Affiliation	RINA Consulting - Centro Sviluppo Materiali S.p.A.
Name of the organisation or company described in the interview	DROMOSPLAN Project – Use case defined at ILVA s.p.a. plant in Taranto
Country	Italy
Sector	Steel industry

Context (description of how the introduction of technologies is transforming the sector)

The European steel industry has an annual turnover of EUR 166 billion and it provides the 1.3% of EU GDP. In 2015, it provided 328,000 direct jobs with an even greater number of dependent jobs.

The steel industry is already supported by high levels of automation in its processes.

The introduction of automation in the industrial processes in this area started already some decades ago mainly for

the production process optimisation, but, at same time, to alleviate the workload and improve the safety of the workers. This makes easier the introduction of additional new technologies, impacting the entire production flow moving from existing plants automation to full production digitalization.

The continuous adoption of digital transformation in this area drives also a strong renovation of the workforce not only attracting new talents but also reskilling the existing workforce by means of continuous training.

The ESSA (European Steel Skills Agenda,) project has recently pointed out the urgent need of qualifying the workforce in the steel sector, to support adoption of digital transformation in production processes, together with the setup of new working practices.

DT in this sector is mainly adopted by big industries (e.g. Dalmine, Italy) also thanks to the support of public funding such as the Research Fund for Coal and Steel (RFCS) at European level.

This leads to a difference in the adoption between the various European countries: for example, Italy is a little behind compared to other countries, due to the small size of most of its industrial groups in this sector. As the Roadmap accompanying the proposal for a European Partnership on Clean Steel highlights, DT is expected to act as a driver for clean steel production by contributing to the reduction of CO_2 emission and circular economy, e.g. by using steelmaking slags as fertilizer in agriculture.

Description of the case

Wide industrial plants often include areas difficult or hazardous to access by humans. The inspection and the maintenance activities in such areas expose workers to risks.

Indeed, the steel sector is characterised by several hazardous conditions for humans, asking to identify alternative solution to human presence, for example in inspection tasks.

Unmanned Aerial Vehicles (UAVs) may lower human presence in several inspection tasks, also increasing the frequency of inspections.

UAVs represent a high innovative technology, initially used mainly in the military field and, later on, in few civil applications, but rarely in steel industry.

DROMOSPLAN is a research and innovation action (RIA) funded by the European Commission through the Research Fund for Coal and Steel (RFCS) coordinated by RINA Consulting - Centro Sviluppo Materiali S.p.A. and involving other six partners including, as representatives of the steel industry, Thyssenkrupp Steel Europe AG in Duisburg, Germany and ILVA spa in Taranto, Italy (as subcontractor).

The goal of the DROMOSPLAN project is to substitute men in complex and expensive operations, as those related to the monitoring, maintenance and safety of steel plant infrastructures. Within the pilot run in ILVA plant, the DROMOSPLAN project aimed at monitoring and inspecting steel plants with autonomous flying drones to improve the safety of workers involved in inspection tasks.

Drones, equipped with high resolution cameras and devoted sensors, are used to **improve surveillance while relieving workers from accessing hazardous areas** by flying over the plants for inspection.

Main outcomes of the DT implementation

The design of the application required the participation of both drones' producers and end users (workers) to design a solution suitable for the specific use case addressing safety requirements while

respecting workers privacy. Indeed, privacy is a key issue to clear for applying any kind of surveillance system.

A wide analysis of technical, economic, legal and social framework conditions was required before implementation. Impact on workers was also involved in the design of the use case.

Also, employee surveys were applied to evaluate the acceptance and social aspects of modern drone technology at the workplace. The described digital transformation was favourable received both by the employers and the employees.

Timely and effective inspection of plants remain a key issue in the steel industry and the use of the DROMOSPLAN drones allows, at the same time, to increase the safety of workers previously performing inspection in hazardous areas, and the quality of the inspection itself by making it more timely and repeatably.

Human factor

The human factor was a key issue in the DROMOSPLAN development, even before piloting in steel plants. Specific tasks in the project were aimed at analysing the human factor in the implementation of the system.

During the implementation, two main aspects arose:

- The safety of workers is a key issue in any industrial environment and particularly in environments characterised by hard and hazardous conditions as the one of steel.

  However, the surveillance of plants by drones equipped with cameras raises ethical issues related with the workers privacy.

  Indeed, there are still many **open ethical issues referring to the usage of drones** in any civil application and they apply also in this case.

  The protection of workers privacy has to be assured by a proper processing of the images acquired by the drone to provide only information about plants and not humans.

- Also, DT in inspection tasks require a reskilling of the workers that have to become used to a totally new way of performing inspection, by an aerial view never explored before. This means the need of training programs to create new skills.

  However, the new training represents not only a contribution to the competitiveness of the involved company, but also of the workers themselves.

  The ESSA project is being developed to meet these needs. The Agenda will present a strategy for meeting current and future skills demands and pilot the development of modules and tools for building awareness and implementing new skills for a globally competitive industry and workers. The aim is to be ready to anticipate new skills demands and to develop pro-active practical activities to prepare workers for the future requirements of the industry.

4.2.6 PHARMACEUTICS: digital prototyping

Name of the Interviewee	Alessandro Colombo
Affiliation	TAG - Talent Garden S.p.A.
Name of the organisation or company described in the interview	Roche Italia
Country	Italy
Sector	Pharma

Context (description of how the introduction of technologies is transforming the sector)

Founded in Brescia, Italy, in 2011, Talent Garden is now the leading European coworking network and educational institute for the digital and tech community. Their network spans 21 campuses in 7 countries (Austria, Denmark, Ireland, Italy, Lithuania, Romania, Spain).

To support the community, they launched in 2015 the Talent Garden Innovation School, an innovative educational institute offering training programs and courses for both individuals and companies, focusing on five key areas: coding, data, marketing, design and business.

Moreover, they guide and support Corporates who are on a path of exploration and development in the world of digital transformation and connect them with a European network of talents and partners in the technology industry as in this case.

Roche is the biggest biotechnology company in the world, strongly research-oriented and with a pioneering vision in the field of health due to the ability to combine diagnostic and pharmaceutical excellence.

Today Roche Italia expresses all its skills, from pharmaceuticals to diagnostics and to systems and services for diabetes management, thanks to the work of 1,200 employees who every day support patients and those who take care of them, by offering solutions able to prevent, diagnose, monitor and treat serious diseases, making a sustainable contribution to society.

This case of DT starts from the interest of the pharmaceutical sector to explore digital health solutions that may complement traditional pharma products.

The market requires to develop innovative services with a high added value for the consumer.

However, the approach to digital health requires a change of mindset, well supported by the digital and consulting competencies of TAG.

Description of the case

The DT refers to prototyping of digital products in the pharmaceutical area by means of sprints (Agile software developments) of 4 weeks. The main aim, however, is not on the designed prototypes, but on the needed competencies to address design and development using an innovative, digital based, process.

The cross-functional team consists of 8-12 people from Roche Italia from different departments (marketing, legal, home delivery, etc.), including an Innovation Manager and a Team Leader. 3-4 people from TAG complete the team, including experts of the topic and digital specialists (user experience designer, user interface designer, service designer, etc.).

Strategic support is offered by a task force of "digital champions", some internal and others external to the company.

Each intervention is organised on an overall period of around 3 months, including sprints of 4 weeks anticipated by a training week, to share the approach to this digital prototyping method. The focus is on the concept of "human centred design".

Within the lockdown period, the overall time duration was increased because of organizational needs to run it remotely and so it was more difficult to involve people.

The intervention starts with a goal, a "mission statement", set by the Innovation Manager and the Team Leader. During the 4 weeks sprint, end users are involved (clinicians, patients associations, healthcare providers, regional bodies, etc.). Interviews are run to identify the issues and generate solutions. A digital prototype is then developed and discussed again with the stakeholders.

A second round of prototyping follows.

Main outcomes of the DT implementation

The objectives are two: an output, consisting of the digital artefact, and an outcome, consisting in a new mindset in design.

The acquisition of a suitable mindset for Agile digital prototyping is the main goal.

The digital challenges require a new "modus operandi", that needs to be acquired mainly by managers used to other means of design and development.

The focus needs to be put on experimentation as a mean of exploration of potential solutions. However, failure (resulting in a not appreciated or accepted digital tool) must be taken into account as possible result of the sprint.

Indeed, within the sprints run up to now, one was fully successful, leading to a solution potentially transferable to the market, while another one was unsuccessful and the solution was not accepted by the stakeholders (patients).

Human factor

The human factor plays a key role in this experimentation and Agile way to address digital products design.

Here the DT affects the design itself and the digital means allow fast prototyping of the solution, developing artefacts to be used in co-design practices with the stakeholders.

All the people involved demonstrated high commitment to end users.

The key factor of success showed to be the behaviour of the team managers, who defined initially the mission statement, and the engagement that they get from the team.

Overall, the experimentation through sprints improves the relationships within the team, both in terms of acquired knowledge and collaboration.

4.2.7 EDUCATION: vocational courses

Name of the Interviewee	Anna Zotova
Affiliation	Samara State University of Economics – SSEU
Name of the organisation or company described in the interview	Samara State University of Economics – SSEU (Russia)
Country	Russia
Sector	Education (coping with Covid-19 pandemic)
Context (description of how the introduction of technologies is transforming the sector)	

The Covid-19 pandemic has forced 190 countries across the world to complete or partial closure of their schools and universities. With many different approaches adopted worldwide, digital technology represents the most critical and effective tool to support remote learning when learners are forced to remain outside the educational facilities.

The World Bank Edtech team has collected resources, initiatives, programs and solutions put in place during the initial response of the education systems.

The selected case study relates to the experience of the Samara State University of Economics (SSEU) founded in 1931 in Russia. Today SSEU is the leading university in the Volga region, with high quality educational programs in the field of economics, management or law.

A practice-oriented approach in teaching is implemented in this University. SSEU has basic departments at regional enterprises, that allows the students to be involved into the practical activity during the educational process, e.g. students have industrial placement internship, write course works, diploma theses and projects, scientific works according to specific tasks of the enterprises and companies.

The University is constantly developing innovative methodologies, involving foreign teachers into the educational process, promoting international internships and double degree programs.

Due to the spread of the Covid-19 pandemic, SSEU had to implement a digitalization of its vocational education training (VET) courses.

These are intensive courses, usually lasting 6 months and ending with a final project.
Description of the case
As the Russian Higher Education and Science Ministry has recommended all universities to switch to online courses as part of coronavirus infection lockdown measures, the unexpected need to suddenly adapt the training courses to the situation created by the pandemic placed the University in front of the challenge of the Digital Transformation. SSEU had to rethink the organization of the vocational trainings with digital tools and platforms (like Zoom or Microsoft Teams), and the trainers had to improve their digital skills and change their approach and method. In particular, the shift to online educational modalities affected VET courses for professionals, mainly from the medical sphere, but also from engineering (heavy machinery and spacecraft industry) and IT business, that started at the beginning of the year. The courses train future candidates for managerial, administrative and organizational roles (such as CEOs or commercial directors).At the beginning of the process, the online business training was difficult for the lecturers, but then they found ways to make the educational training more successful, e.g. by introducing simulation games and simulation activities. The course ended during the lockdown in online mode and also the final discussions of the projects took place online.
Main outcomes of the DT implementation
Thanks to this process, the teachers realized, on the one hand, that the online training is both feasible, especially in the case of automatic, repetition or financial skills training, and cheaper for the University and, on the other hand, that some specific training activities, like the soft skills ones (administrative, communication, strategic and vision skills), are better performed face to face than remotely. So, for the future, the University considers that probably the training course will be delivered half online, paying more attention to the personal communication between the teacher and the students, and half still requiring live attendance. Moreover, both the listeners and the lecturers hinted that they would neither be keen nor ready to undertake a fully online course.
Human factor
The “customers”, i.e. the students, were involved in the choice of platforms to be used and in the decision of postponing the course rather than continuing it online. Moreover, at the end of the training, they were asked for feedback on the DT of the course. The analysis of these answers is still ongoing, but the preliminary results are overall positive. The only problems that arose were related to the inadequate internet connections of some learners. In general, the costumers were satisfied with the online course, adapted to the situation and all initial fears were lost during the process.

In fact, the students got higher grades and made better projects (60% was rated as "good project"), thanks to more time to prepare the exam, more independence during the study and more confidence in taking the exam from home. Also, the trainers were satisfied, despite the initial organizational difficulties and the need to learn new instruments and methods.

4.2.8 MANUFACTURING: furniture industry

Name of the Interviewee	Marco Galanti[2]
Affiliation	T2i – Digital Innovation Hub
Name of the organisation or company described in the interview	BNP SRL (Italy), leader of the HPS4MAN project
Country	Italy
Sector	Industrial manufacturing
Context (description of how the introduction of technologies is transforming the sector)	
The industrial sector has a highly specialised and competitive manufacturing base, mostly comprised of SMEs. According to Unioncamere Veneto data, in the 1st quarter of 2020 the region had more than 427,000 registered companies: 12% in industry, 14% in construction and 56% in the service sector. Veneto is characterised by the presence of a variety of "industrial districts": mechanics, agro-food industry and printing and publishing in Verona; textiles in Treviso and Vicenza; food industry in Rovigo; glasses production in Cadore and Belluno; gold and jewellery in Vicenza, electrical appliances in Conegliano, furniture in Bassano del Grappa. Smart manufacturing represents one of the key areas selected within the regional Smart Specialisation Strategy and hence represent a crucial pillar of the regional RTDI policies. In particular, advanced manufacturing is strategic for an already rich territory of small and medium sized manufacturing firms that need to be sustained in gaining efficiency in the production of high-quality products. This is necessary especially in companies organized according to the most traditional systems. The introduction of innovative aspects through DT processes in such structures means allowing them to increase their competitiveness both domestically and internationally. t2i technology transfer and innovation is the innovation agency promoted by the Chambers of commerce of Treviso, Verona and Venice established in 2014 from the merging of activities, projects, personnel and facilities of two other entities: 'Treviso Tecnologia' and 'Polesine Innovazione'. In 2016 also 'Verona Innovazione' joined t2i thus extending the services also in Verona district. t2i supports companies in defining and developing innovative pathways through the establishment of networks for technology transfer and the deployment of value-added services for industries and organisations also by means of co-funding programmes at local and european level.	
Description of the case	

[2] The information provided by the expert has been integrated and complemented by the study team via desk search across relevant publicly available sources.

The specific case described hereafter refers to the DT process put in place thanks to the collaboration of four companies BNP SRL (project leader and producer of ergonomic solutions for the assembly and tightening phases in manufacturing sector industrial processes), SOGEA SRL (specialised in development of tailored software solutions for SMEs), MILPER SAS (active since 1998 in the production of industrial machinery for different sectors such as food, packaging, engineering, textile, marble, wood) and DAMO SRL, operating in the field of linear units' production.

The objective of the project "HPS4MAN - HUMAN PREDICTIVE SYSTEM FOR ADAPTIVE MANUFACTURING PROCESSES", carried out with the contribution of the Veneto Region through the Regional Operation Programme backed by the **European Fund for Regional Development** tool, was to create an adaptive ergonomic workstation in which aspects of ergonomics, collaborative robotics, machine learning, physiological measurements of the operator converge, in order to create a solution in which the system adapts to the needs of the operators, helping them in the manual assembly activities, improving the performance, quality and well-being of the operators.

The "experimental" station of the HPS4MAN project, currently inserted in the production context of BNP SRL, combines ergonomics, collaborative robotics, production quality and process control.

The workstations have been installed in the factory of Anodica Trevigiana SpA a manufacturing company active in co-design and in the supply of aesthetic components for the household appliance and car industry and are suitable for flexible adaptation to other production contexts and sectors.

Main outcomes of the DT implementation

Through the project it was possible to create an island consisting of two twin adaptive workstations, in which the system adapts to the characteristics of the environment and the operator.

At the stations:

- the height of the work surface adapts to the anthropometric characteristics of the operator;
- the light adapts according to the age of the operator, the task to be performed and the general lighting conditions;
- there is a collaborative robot ("YuMI") that helps the operator in the assembly activities, placing the components at an ergonomic height.

All components are controlled by a control unit that communicates with the software on the island's PCs.

A new zero gravity balancing system has been developed, as well as a user-friendly pick-to-light system.

The Smart Manufacturing Manager (SMM) system, developed in collaboration with SOGEA SRL, has found application in this company, which aims to enhance the human / machine interaction, attributing to the human operator the actions with greater added value and creating ergonomic working conditions. from a physical and cognitive point of view. It also allows data traceability for process quality control, thanks to an intuitive use for the operator who can operate directly on the touch screen. Each station thus becomes adaptable to different processing cycles, in response to the needs of production flexibility required by the market.

The collaborative work islands have allowed the company to reduce the number of workstations, lower product defects, certify the production process and offer its employees a workplace that is attentive to health and safety. The use of a simplified and easy to understand software interface has also made it possible to significantly reduce the "tacktime" (the time between the entry into production of one piece and that of the next piece). The entire production line was therefore reworked with a view to *lean* production, allowing to reduce costs and production times, reduce defects and offer full traceability as a quality control for customers.
Human factor
The tech supplier has performed a preliminary usability analysis on the operator's workstation, focusing especially on problems that operators encountered at work: the innovative workstations were therefore designed embedding elements of automation and robotics to also take into account operator's fatigue. There was, thus, a specific attention to the human aspect since the DT was planned having as a goal, among others, the empowerment of physically less strong or older workers or women who could do this type of activity and make it less heavy and repetitive for them. The work island is a human-sized solution, which respects the principles of ergonomics in the work environment, thanks to the use of the collaborative robot and a lighting system that can be adapted to specific needs. YuMi - ABB's collaborative robot integrated in the workstation - performs repetitive functions instead of humans, while the operator remains in the task of quality and aesthetic control of satin-finished handles for household appliances, favoured by an adaptable lighting system suitable for this type of activity. The system also adjusts its speed based on the characteristics of the operator, through a specially developed algorithm. This case is a relevant example of convergence of different and complementary technologies that are jointly contributing to transform the way industrial tasks are performed by workers along with generating clear advantages in terms of increased efficiency, productivity and flexibility. Robotics and automation are exploited to give value to the essential contribution of the human operator.

4.2.9 HEALTHCARE: surgery

Name of the Interviewee	Marc Sales
Affiliation	Essentia Health Management (formerly Surgical Process Engineer at Vall d'Hebron University Hospital)
Name of the organisation or company described in the interview	Vall d'Hebron University Hospital
Country	Spain
Sector	Healthcare
Context (description of how the introduction of technologies is transforming the sector)	

Healthcare has been identified as one of the sectors with the greatest potential for the intelligent use of data. Having in mind the enormous array of opportunities that the Digital Transformation is opening in this sector, the Digital Health Strategy for Catalonia (*Departament de Salut* 2017) has been designed not just a technology update, but as a "framework for the management of the data and for architecture of the information systems that corresponds to and, in some cases, anticipates the changes taking place in the care model with regard to citizen relations with the health system, in the work processes and in the relationships between professionals"[154].

In this context, a variety of successful initiatives are taking place in Catalan hospitals and health and social care organisations.

The Vall d'Hebron University Hospital (HUVH) digital transformation project is part of the e-health objective of the Digital Agenda for a digital society and healthcare improvement promote by the Health Care Catalan Government (Generalitat de Catalunya). Moreover, it's also aligned with 2016-2020 Health Plan of the *Departament de Salut* (Catalan Healthcare Department) since it contributes to the improvement and transformation of the healthcare system through the intensive introduction of new technologies and patient centred approach.

This operation contributes to activate IT sector in Catalonia and Barcelona, by demanding the market innovative solutions for e-health and is therefore aligned with the Catalan Government Research and Innovation / Smart Specialisation Strategy (RIS3CAT).

Description of the case

HUVH is the largest hospital campus in Catalonia managed by the Catalan Health Institute (Institut Català de la Salut – ICS). The Campus has 22 buildings where more than 45,000 people visit daily and serves a great variety of patients counting on 9,000 professionals.

This transformation project, which started in 2016 and will culminate in 2021, has received a co-financing of 4 million euros from the European Regional Development Funds (ERDF), of a total of 8 million euros that will be invested. The project 'Digital Transformation of the Vall d'Hebron Hospital at the service of the patient' has been recognized as a good practice of actions co-financed by the ERDF Operational Programme (OP) Catalonia 2014-2020.

In particular, ERDF funds are being used for two major actions: *SmartCare*, which takes advantage of new technologies to improve treatment and the patient experience, and *SmartProcess*, which improves processes through digitization, emphasizing the elimination of paper and the integration of all clinical data in the electronic history of the patient. The new real-time patient and asset traceability systems make it possible to automate processes in critical areas of the hospital to be more efficient, safe and generate information that also serves professionals.

During the interview we focused our attention on the latter. In particular, the project of Real-Time Location (RTL) of patients and assets stands out among those of *SmartProcess*. A patient and asset identification, location and traceability system has been implemented to know both their physical location and where they are in the healthcare process. The objective is to have more complete information in real time, and to implement tools that automate the surgical process. The overall goal was to improve security for the patients, enhance the quality and excellence of the clinical practice and increase the efficiency of the overall system in place in the surgical block which is renowned for its huge costs but also it's the one generating the highest revenues and value.

In short, a safer, more efficient and more satisfactory process has been achieved for patients and professionals.

Main outcomes of the DT implementation

Among the vast amount of innovations introduced, a **Real Time Location System (RTLS) for patients and assets** – designed and developed by MYSPHERA in the frame of the H2020 OR4.0 project - has helped to digitalize the surgical process.

RTLSs are used to automatically identify and track the location of objects or people in real time, usually within a building or other delimited area. Wireless tags are attached to objects or worn by people, and in most RTLS, fixed landmarks receive wireless signals from the tags to determine their location. Tags and fixed reference points can be transmitters, receivers, or both, resulting in numerous possible technology combinations.

By launching tasks and alert messages and thus automatizing the process and securely identifying patients, medical equipment and their location, this system ensures a more stable and safer process and a much better communication between all the professionals involved.

Depending on how the patient pathway evolves (provided by the RTL system) specific tasks are initiated e.g. Operating Room (OR) cleaning, patient transport and family's information system (Virtual waiting room project) thus improving the whole workflow as well as increasing patients' and professionals' safety and satisfaction. The general hospital Surgical Block (with 19 ORs) has been the first pilot of this innovative solution that is being extended to the remaining three surgical blocks (which contain 30 ORs).

RTLS used as a tool to digitalize the OR and patients' pathway is an innovative solution, not yet frequently used in hospitals, that ensures the stability, safety and quality of the OR process.

Surgery is the core business of a hospital and an intensive production area. Therefore, all improvements made in the OR process are key to both patients and professionals and contribute heavily to the overall performance of the block as testified by the decreased number of surgeries cancelled or rescheduled and the improvement in efficiency and logistics indicators. As a

consequence, the hospital has seen a huge increase of the number of the surgical interventions performed (+15%).

The measurement of such improvement has been made possible based on the availability of more precise and reliable information and the definition of a set of specific indicators and the introduction of an in-depth monitoring systems that has allowed to quickly identify those parts of the process that were inefficient or too time consuming and thus suitable for improvements.

Furthermore, the overall DT process, combining the two strands *SmartCare* and *SmartProcess*, has also stimulated a rethinking of any function and process happening in the hospital.

Finally, from the technological supply side, the solution co-created by MYSPHERA in collaboration with HUVH has been further deployed and is currently being rolled out across different countries (e.g., Spain, Portugal, France, Belgium, UK), thus having a decisive impact on the future and direction of the company.

Human factor

The main goal of the DT put in place at HUVH is to improve patient's experience as well as humanise healthcare.

New technologies, IT and mobility solutions are being introduced to fulfil the challenge of providing personalized healthcare while ensuring the continuum of healthcare within the healthcare ecosystem.

In such a complex and big facility, carrying out 36,000 surgical interventions per year, the leadership from the hospital management has been determinant to secure cohesion in the process and clarity in terms of objectives and expectations.

Another crucial aspect has been represented by the **participatory and bottom up approach adopted across every step of the needs' identification, solutions' co-design, testing and implementation**. In each step, a variety of stakeholders has been engaged which includes healthcare professionals, managerial staff, patients and families as well as the IT providers that have designed, developed and customised the most fitting-for-purpose solutions.

Thanks to the engagement of all the actors involved in the provision of the surgical services, it has been possible to disentangle any aspect of uncertainty and variability of the existing processes and identify rooms for improvement.

This case demonstrates once more that the DT processes in healthcare are more likely to be successful whereas the actors promoting the change first undertake a profound, **comprehensive and collaborative analysis of the current ways of working well before focusing their attention on the selection of the appropriate technologies to deploy**. The adoption of a *lean* methodology intended to transform processes so as to optimize people, resources, effort, and energy toward creating value must be necessarily the first step in any DT processes in order to be then able to choose and adapt the enabling technologies to the specific needs and contexts.

To this purpose, at HUVH key success factors have been represented by the **creation of a process improvement team** composed by representatives of all functions and roles affected by the DT and the delivery of **training sessions aimed to foster the needed cultural change, transmit trust and motivation** at all levels of the staff involved and mitigate the initial concerns felt by workers in relation to the risks of being more and continuously "controlled" through the technologies. Having

been able to gather in the same working team the diverse profiles working in the surgical block (i.e. hospital managers, doctors, nurses, auxiliary and cleaning staff as well as porters and most importantly "expert patients" who had previously gone through a surgical intervention and thus had a hands on knowledge of the whole patient experience) and make them overcome their initial reluctancy and concerns has been the most challenging and at the same time rewarding step undertaken.

4.2.10 AUTOMOTIVE: quality control

This was an extended case of study. After the initial interview with the Integration manager and coordinator of the European project, the study proceeded with a focus group involving the different actors of the process, i.e. the same project coordinator, an industrial end user and two development managers. See here below the two fact sheets.

Name of the Interviewee	Cristina Cristalli
Affiliation	Loccioni, Italy
Name of the organisation or company described in the interview	GO0D MAN project, Volkswagen Autoeuropa
Country	Portugal
Sector	Automotive /quality control
Context (description of how the introduction of technologies is transforming the sector)	

Volkswagen Autoeuropa is a production plant of Volkswagen Group and it is the largest automotive manufacturing facility in Portugal.

The plant employs around 3600 workers and, indirectly, it employs close to 8000 people through more than 800 suppliers that provide materials, components, and parts to the facility. The plant is one of Europe's most modern automotive production facilities. It was designed using advanced technology and continue to implement the latest developments in automation and digital production control, in order to meet the highest standards required on manufacturing a quality product.

The quality of the final product is crucial for the whole manufacturing industry, in particular for the automotive sector. While quality control on the final product is state-of-art, the trend is clearly to introduce more and more controls upstream the production process. Quality control requires measurements, involve automatic as well human operated instrumentation and provides a large amount of output data.

DT adoption supports in many ways in this delicate phases of the manufacturing process. The real time and early **identification of deviations and trends, supported by DT,** is expected to prevent the generation of defects at single stage and their propagation to down-stream processes.

Digital technology sets the foundations for quality control at factory level, provides the tools for developing data analytics and digital twins, and even qualifies the role of the operator in the perspective of augmented humanity, thus contributing to fight work loss.

Description of the case

The **GO0D MAN project**, funded by the European R&I H2020 Framework Programme, constitutes a real world implementation of the **Industry 4.0 paradigm**, through the integration and convergence of technologies for **measurement and quality control,** for **data analysis and management,** at single process and at factory level.

The ultimate goal is to develop a production strategy that can guarantee **high quality of products** without interfering, actually improving, the **production efficiency** of the entire system.

Specifically, in the case of Volkswagen Autoeuropa, the focus was on the quality control of the final assembly of the car. Today, the "gap and flush" is measured by means of a caliper managed by the operator. The current process is qualitative, and the performed measurement is not recorded anyway.

To answer the needs of the company, a new tool, exploiting a laser triangulation system integrated to a mobile phone, was implemented. The measure is now quantitative, and it is saved in the company server for further quality analysis. The tool is managed by the operator that remains part of the loop while being connected to the factory network.

The new technological solution was completely developed within the project, protected by a patent, and it is now ready for industrialization and integration in the production process.

Loccioni was involved in the process as integrator of the prototype, while the Università Politecnica delle Marche developed the instrument. A spin off has been setup for engineering and commercialization.

Main outcomes of the DT implementation

Volkswagen Autoeuropa entered the project by proposing a clear functional objective, i.e. tracking of the results of the gap and flush measurement at the end of the assembly process, pointing out the limitations of the current practice.

Within the GO0D MAN project, in 2019, the initial prototype was developed and tested by the potential customer (Volkswagen Autoeuropa) that confirmed its interest in applying it to the production process. The industrial prototype is expected at the end of 2020.

The European funding has been successfully used to create a new device with advantages for both the end user (i.e. Volkswagen Autoeuropa) and the technology supplier (leading to the creation of a devoted spinoff).

Looking at the impacts, the applied DT implies a reduction of the operation time. Today the operator is assessing gap and flush separately, while the new tool allows to measure them together.

The still open challenge, related to the availability of quantitative data describing the process, is now their processing and usage in the control and management of the entire production process. This is a common issue in the manufacturing sector, and it is still not completely solved.

While the predictive analysis is now widely used on the field, the process analysis is still in its infancy.

Data interpretation relies not only on the data scientist (that may be external at the company), but it requires the participation of personnel expert of the process. To further improve the success of the DT, also the IT services of the company have to be involved to develop the needed architecture.
Human factor
The DT adoption, pushed by the G0ODMAN project, and applied at Volkswagen Autoeuropa, takes into due consideration the role of the workers and does not aim at their substitution by machines, but rather at their reskilling and qualification by introducing new technologies (i.e. new measurement instruments) to be used in daily work. The training is quite fast, and the device manages safety issues by switching on the laser light only when really needed. Workers have been involved in the design process since the early phases and were interested in the solution. Digital Transformation is accepted as far as the production time is not affected. Privacy issues still need to be taken in due account. Issues with connectivity still depends on the maturity of the technology (robustness). Also, the vulnerability of the data is still a critical point to address. In this specific case, digitalization is supporting workers involved in heavy occupations by reducing the needed physical effort and operation time. This is specifically important for older workers who have spent many years performing fatiguing operations and find themselves in the need for either technological aids to continue their activities or a change of duties in the company organization. This second choice is harder to be implemented in terms of reskilling and, also, to be accepted by the worker.

Names and roles of the participants	a. Cristina Cristalli: GO0D MAN project Coordinator Loccioni b. Gisela Garcia: Innovation management specialist Volkswagen c. Nicola Paone: Professor UNIVPM d. Paolo Chiarotti: Research Associate UNIVPM
Affiliations	a. Loccioni b. Volkswagen Autoeuropa Lda c. Università Politecnica delle Marche d. Università Politecnica delle Marche
Name of the organisation or company described in the focus group	Volkswagen Autoeuropa Lda
Country	Portugal
Sector	Automotive
1. Were you among the originators of the DT idea or when were you involved in the process? Which has been your role?	
a. GO0D MAN project Coordinator: project coordinator and Integration manager	

The initial idea came from an EU H2020 project proposal (later funded) aiming at empowering measurement in manufacturing to reduce defects in production. Research aims and users needs were matched to develop concrete applications.

While developing the tool, the focus was on keeping the man-in-the-loop by providing the operator with a portable measurement device connected to the factory network. Safety and ergonomics were priorities, at the same level as measurement performance. In fact, the system uses a laser and so it is important that the device is active only when the laser is pointing the target. Other sensors are added to avoid accidental errors.

b. Innovation management specialist Volkswagen: industrial end user

Volkswagen was interested to improve current way of assessing gap and flush in automotive production.

Today gap is measured by a devoted tool (Rosetta) while flush is "measured" simply by moving a finger on the surface. Results of the measurement are not saved anywhere, while data are needed for better running the line detecting failures as soon as possible. The developed tool addresses this problem adding also a saving of time being gap and flush measured at the same time.

Currently, there exist automatic stations at the beginning of the process for the assessment of these quantities, but they are not portable tools. Also, they are mainly aimed at quality check and not to provide real time feedback to production process.

During the testing with the workers, it was pointed out the importance of the portability and easy use of the tool, so the initial tool that was based on a smartphone might not be the best solution. Additional analysis is still needed.

In the design of the tool also the IT department of Volkswagen was involved, in order to connect the tool to their internal network.

c. Professor UNIVPM: measurement systems development manager

Within the GO0D MAN project, there were considered different end users representing different industrial sectors. Together with Volkswagen there were Electrolux Professionals, producing professional ovens, and Zannini, an industrial workshop producing metal parts for the automotive sector. Loccioni was acting as system integrator.

The initial analysis pointed out that in many phases of the production workers cannot be simply substituted by robots. When there is a variety of products, humans show to be better in assembly and control. There is a gap between DT expectations and reality.

Providing the operator with a measurement instrument offers a feedback to the worker and shares the measurement results for further analysis.

d. Research Associate UNIVPM: measurement systems development manager

The worker was put at the center of the development, also the choice of developing the system starting from a smartphone was in this direction, with the aim of providing the workers with a tool they were accustomed to.

There is an open technological challenge in developing tools to be used by humans and not by robots. Tools have to be able to cope with uncertainty. Humans are less repeatable than robots. The tool has been designed to get an added value by the human presence.

The plant engineers tested different prototypes together with the workers to find the best solution.

Students from UNIVPM went to the plant to meet the workers. There was a continuous direct contact with the process engineer.

2. Have been your initial expectations fulfilled by the final result?

a. GO0D MAN project Coordinator: project coordinator and Integration manager

Zero defects manufacturing is a complex approach that requires the collaboration of several disciplines. At the current time, it is difficult to find a third party for future production.

b. Innovation management specialist Volkswagen: industrial end user

The project was able to provide concrete results and not only scientific knowledge. This is very important for an industrial partner. Volkswagen was satisfied with the tool and is willing to go further, looking for a third party to scale up it to apply in the entire Volkswagen group.

c. Professor UNIVPM: measurement systems development manager

Further steps are still needed to move from the idea to the manufacturing. Publications and patens are there, but it is needed to find or setup a company to bring the idea to the market. A spin-off company may be an agile way to enter the market.

d. Research Associate UNIVPM: measurement systems development manager

Nothing to add.

3. Was this experience also an opportunity for your personal growth?

a. GO0D MAN project Coordinator: project coordinator and Integration manager

The coordination of a complex project is always very demanding and stressful, but also allows to get new knowledge and experience.

b. Innovation management specialist Volkswagen: industrial end user

It was my first EU funded project and the opportunity to work with international partners was very rich to understand different ways of thinking, for example SMEs that are very agile.

Also, internal collaboration was changed, for example with the IT department to setup the architecture, and this allowed to acquire new competencies.

There are differences between academic and industrial partners that were needed to learn.

Also, the innovation process includes failure as a normal step, but industry is not educated to fail, so it was a very interesting new approach to learn.

It was an end user-oriented project and there was a need to build effective relationships among people.

c. Professor UNIVPM: measurement systems development manager

European projects are always stimulating for the team. Also, these projects need a clear scheduling of tasks and timing that still is not usual for universities.

d. Research Associate UNIVPM: measurement systems development manager

The project was very application oriented, while the research in the universities is normally more theoretical. Stepping within the production line is a challenging and interesting experience.

4. Are the work activities/responsibilities/relationships in the company changed? How?

a. GO0D MAN project Coordinator: project coordinator and Integration manager

Loccioni had to adapt its approach to the production line. It was necessary to understand how to work at process level, not only at system level.

b. Innovation management specialist Volkswagen: industrial end user

Within Volkswagen the process will change because of data collection, that will allow to setup a local analysis to understand what is really going on and react quickly.

Also, workers may better know what they are doing, looking at the results of the most experienced people. Employees are becoming more aware and this is important also for the training of new workers.

c. Professor UNIVPM: measurement systems development manager

The university work became very much industry oriented. Universities are not well structured for highly applied projects. Within a project, permanent staff is only a limited part of the entire working staff, because the focus of the university is education rather than development.

The spin-off, collecting the results of the project, may be a way to overcome this limitation.

d. Research Associate UNIVPM: measurement systems development manager

Nothing to add.

4.2.11 INFORMATION TECHNOLOGY: human resources (HR)

This was an extended case of study. After the initial interview with the Business Development Manager of the technology supplier, the study proceeded with a focus group involving the different actors of the process, i.e. the HR manager, the Project Manager, a developer and a tester/ end user. See here below the two fact sheets.

Name of the Interviewee	Alessandro Crea - Business Development Manager
Affiliation	BID Company S.r.l.
Name of the organisation or company described in the interview	SAS Institute
Country	Italy
Sector	Information Technology

Context (description of how the introduction of technologies is transforming the sector)

SAS is the leader in analytics. It is an US trusted analytics powerhouse for organizations seeking immediate value from their data.

SAS has customers in 149 countries, 14,052 worldwide employees and their software is installed at more than 83,000 business, government and university sites.

They have been applying analytics to the toughest business problems for more than four decades.

With user-friendly interfaces that accommodate different skills – from business analysts to data scientists – all costumers' key players can speak analytics. Their flexibility drives the customers' productivity.

They invest in technology and innovation, as Artificial Intelligence and Internet of Things, that improve the businesses.

By applying data science to humanitarian causes, SAS joins organizations around the world in a Data for Good movement to solve issues around poverty, health, human rights, education and the environment.

BID, a start-up founded in 2016, is one of the first Italian players to provide the market with the value of data, through distinctive skills, assets and solutions in the fields of Analytics and Artificial Intelligence.

They transfer value to the customers by adopting an Agile, flexible and customer-centric approach that guarantees the best design, development and implementation of innovative solutions and services.

They transform data into knowledge by generating insights to support decision making and achievement of business objectives. They do this through the following three services: education, consultancy and both third party and proprietary software implementation.

SAS started this Digital Transformation two years ago from the need for a digital tool to understand the business process and to maximize the engagement and performance of employees. In fact, they had already collected a lot of operational data (e.g. data on talent acquisition, development and retention), to analyse and predict employees' performances and churn risks. These models did not analysed any information about the human aspect and the perception of employees' experience, and at some point they realized that these data was essential to boost the accuracy of analytical models and to be able to maximize business outcomes by identifying the right solutions.

So they started an ambitious project by deciding to adopt a new digital tool for maximizing engagement and psycho-physical well-being in the workplace through digital solutions aimed at listening expectations and issues, rewarding great behaviours and performances, and customizing growth plans in line with personal career goals.

BID collaborated as technology provider and market consultant.

Description of the case

The project was developed in the third quarter of 2019, starting from all Italian offices to be immediately scaled in the SEMEA area.

The aim of the HR team of SAS, adopting the reward and recognition platform YESALLRIGHT to start empowering the People Analytics solution, was to obtain an indicator of workers engagement and to measure and stimulate it.

The project involved in first place professors Silvia Gilardi and Marco Guerci from the Università Statale di Milano, business organization experts, whose goal has been to define an innovative high-performance work system model.

Then, BID was involved for technical support and begun the co-design of possible solutions.

The project was carried out on two levels:

- offline: the continuous confrontation of the project team with a subset of workers involved in testing and the continuous collection of feedbacks and suggestions;
- online: the development and the modification of the app by BID, following the information continuously provided by SAS.

An omnichannel communication and advertising plan was organized for the launch of the YESALLRIGHT app to all employees.

The platform aims at introducing a peer to peer rewards and recognitions digital process: in fact, through the app, each worker can reward either the virtuous behaviour or performance of a colleague among three different programs.

A person can receive a digital award for his/her alignment with corporate values or outstanding business performance; in one program awards can be given to any other worker regardless of his/her position, while in the other twos rewards can only be given according to a top-down scheme.

This app is the first step of the SAS project, whose final goal is to implement the extended people experience and analytics platform, BeYOU^{XP}.

This platform will work on the following three levels:

1. reward and recognition of the virtuous behaviours and outstanding performance
2. continuous listening to every worker's needs and suggestions
3. personalized, realistic and supportive growth plans to customize the employee experience.

The co-design of this app is actually involving several HR managers from other companies, in order to collect as many feedbacks as possible from different industries and organisational models.

This project aims to maximize the empowerment people in the workplace, by enhancing them to be who they are and, consequently, to maximize their engagement and business performance.

Main outcomes of the DT implementation

What has been created is a special tool based on Artificial Intelligence to process customized information with respect to the customer's needs and does not have only the purpose of generating a lot of data, which often are useless for the user.

The whole process is done so that the workplace is more and more human-centred and there are more interactions between workers and knowledge of the colleagues' profiles, for the improvement of the performances.

The encountered difficulties, already foreseen, were: for BID, those relating to the release of the app to all employees and, for SAS, the scalability to the SEMEA and EMEA area.

The transition was successful, despite cultural and approach differences, thanks to the robustness of the results and the feedbacks.

In a future similar DT process, the interviewer would probably change the release modality, foreseeing more releases involving small groups of people, to avoid a single big release, and then would immediately implement the transition to the second module, to give everyone an overview of the project.

Human factor
The human factor is the key in this DT process, which aims to evaluate and improve the experience, the engagement and the human relationships in the workplace, to improve business results. In fact, the employees were involved from the earliest stages of the project. Every aspect has been carefully managed to avoid the fear of control by the company and too much competition among workers, rewarding only positive behaviours and not the negative ones. An important communication and advertising plan was organized, with also events and award ceremonies. This was greatly appreciated by the workers, who understood the meaning of the project and felt involved and valued. Interpersonal relationships have also improved, thanks to the recognition of the attitudes and strengths of colleagues. With the lockdown for the Covid-19 pandemic there was a stalemate, due to less interest and absence of human contact, then the app was relaunched by other communication campaigns and was again appreciated and used, even at a distance. On the other hand, the pandemic did not change the expected timing for the new BeYOU^{XP} app, because the project was approached in Agile mode. This app will be released with all employees still in "smart-working", so this will be a new challenge and testing opportunity.

Names and roles of the participants	a. Amedeo Falcone: EMEA Principal Innovation and Program Manager SAS b. Mara Rivela: HR Business Partner SAS c. Christian Scquizzato: Advanced Analytics & AI Manager BID d. Milo Faccenda: Business Development Manager BID
Affiliations	a. SAS Institute b. SAS Institute c. BID Company S.r.l. d. BID Company S.r.l.
Name of the organisation or company described in the focus group	SAS Institute
Country	Italy
Sector	Information Technology
1. Were you among the originators of the DT idea or when were you involved in the process? Which has been your role?	
a. HR Manager SAS: originator I was among the originators of DT, as Project Manager in SAS that deals with transformations, fundamental for the company. We started with People Analytics and then we realized the need for technological support to develop our ideas. At this point we involved BID as technology provider.	

The purpose of the project was clear from the beginning: a summary indicator of employee engagement.

The project was built on various pillars of recognition:

- ValueAward: rewards with respect to alignment with corporate values
- ExtraMile: positive and measurable work performance
- SuperStarAward: top-down rewarding.

The YESALLRIGHT app, generated by this project, also serves to thank colleagues, even afterwards, and congratulate them.

b. HR team SAS: user

I was involved in the pre-release phase of the app and was made aware of the purpose and the steps of the whole project.

I helped for the testing: in fact, I gave contributions on usability, clarity and interface of the app and feelings and emotions regarding this project.

I also collected all the feedbacks from colleagues.

c. Developer BID: technology provider

I provide advice and develop the technological solution.

I have been involved since the beginning of the project: I listened to the customer's needs and then designed and implemented the solution, with respect to the result to be obtained and in agreement with the PM of BID.

Starting from the PM's ideas, I looked for a practical and feasible solution and developed the app.

d. PM BID: project manager

Involved as soon as SAS chose the technological partner, I started from People Analytics to look for something more advanced, predictive and customizable.

I tried to understand which new values need to be configured on standard structures of reward programs.

Also, I managed all steps involving the workers, to personalize both the HR side and the other employee's side.

To find a solution, I wondered how the HR team could approach other employees in order to understand relationships and increase their engagement.

I'm also participating in a university study to get feedback from the HR managers of other companies and look for other information that may be useful to this DT.

The app is constantly evolving and improving thanks to listening and feedback. In fact, starting from the first YESALLRIGHT app and listening to the customer's needs, we decided to configure and make the BeYOU^{XP} platform available to SAS, as the second step of the project.

2. Have been your initial expectations fulfilled by the final result?

a. HR Manager SAS: originator

The initial expectations were met.

At the beginning there was fear and scepticism among the employees, so we have carefully organized a communication plan and the events and discussed them with the management.

We had very high expectations, including a constant growth in the number of users and interactions between different teams and nations.

The process has been positive, and this was seen in the responses and participation in the events, even if some critical aspects emerged, which are already being improved.

For example, during the 2019 Christmas event, some workers who had not even downloaded the app were awarded: this generated amazement and motivation in these people, for receiving unexpected recognition from colleagues.

b. HR team SAS: user

Initially I expected both enthusiasm and doubts from my colleagues. Then I realized that continuous communication and advertising had a great impact. The result was very positive.

After the app release, there was a first round of feedback from all employees, who at the beginning asked the reason for the digitalization of the relationships and if an extra tool was actually needed.

At the second request for feedback, the workers realized that this app takes nothing away from their relationships and therefore they were much more positive.

This app improves relationships because, in addition to the vote, it is necessary to specify the reason for the recognition and only positive votes are allowed.

At this point the project was implemented also for colleagues from other countries.

c. Developer BID: technology provider

Usually the user is only of one "category", while here there are a lot of different types of workers and different countries, therefore it was also a challenge from a technological point of view.

d. PM BID: project manager

I have known and obtained even more than what I expected.

For example, the analysis of the recognitions made us understand also the educational path to be undertaken.

At the beginning there were also fake rewards, so some changes were made and then we noticed that a cultural and transparency change happened in the employees.

There were also doubts about adoption in other countries, but SAS HR team intervened with reinforcement communication actions and this was truly impactful.

3. Was this experience also an opportunity for your personal growth?

a. HR Manager SAS: originator

It was a complex project that brought me a personal growth: it was challenging to try to have a collective vision, both as SAS and in the relationship with BID and improve the results more and more, also with new modules we are developing with BID.

I learned that the peer-to-peer relationship is very useful and brings tangible benefits, in addition to the top-down one.

Technology itself is useless, it must support people.

b. HR team SAS: user

As HR team, I learned how to correctly convey and communicate a big project.

Instead, as a user, I learned how important it is to give a feedback to a colleague and how positive recognition can spur, help him/her and even change his/her day and the way he/she works.

The app is an important tool for everyday work.

c. Developer BID: technology provider

We are a small and young company and for me the biggest baggage was understanding how to apply HR logic to our reality.

d. PM BID: project manager

I learned how to say "thank you" to colleagues.

Our company was born with the four values of "innovation, passion, trust and performance" and, thanks for example to the amazement generated by the recognitions, we understood the great importance of relationships between people. This is crucial in team relationships.

4. Are the work activities/responsibilities/relationships in the company changed? How?

a. HR Manager SAS: originator

Now the percentage of use is around 76%, even if there are countries where greater resistance is found, such as the Middle East, but there are no differences in the use between the various company levels.

SAS has focused on the recognitions between peer-to-peer workers with different functions, to avoid a clear division between departments within the company.

For example, during the lockdown I had some online project meetings with a team of people from other departments and the app was very useful allowing me to give them recognitions.

DT is a present opportunity for everyone, and technologies are an extraordinary support for every worker at all company levels.

This DT also addresses an issue of ethical use of technology, helpful for improving people's work and, for example, for retention policies.

b. HR team SAS: user

Despite the Covid-19 pandemic, we were able to carry out the celebration event in digital form, to do data analysis of the results and to continue the project digitally.

Company changes and the feedbacks from others are always moments of growth, they give input to be encouraged to re-propose a virtuous way of working. They have a strong and continuous impact and stimulate to repeat a positive behaviour.

The impact has been noted, for example, by the fact that many workers have posted the rewards obtained on their personal social networks.

We understood that it is essential to explain and communicate the project correctly to everyone, because the project can have a huge potential but must be conveyed well, otherwise the risk of misunderstanding and failure is very high.

c. Developer BID: technology provider

During the months of lockdown, the most difficult thing was to train new junior figures completely at a distance and only with digital tools.

d. PM BID: project manager

The competences and soft skills developed during these months of Covid-19 pandemic are an important gain.

4.2.12 HEALTHCARE: rehabilitation

This was an extended case of study. After the initial interview with the responsible of the bioengineering department, the study proceeded with a focus group involving the different actors of the process, i.e. the same responsible person, a clinician, the head of the nursing, the project manager of the technology provider and the technological professional in charge of training. See here below the two fact sheets.

Name of the Interviewee	Mauro Rossini
Affiliation	Villa Beretta Rehabilitation Center of Valduce Hospital
Name of the organisation or company described in the interview	Villa Beretta Rehabilitation Center of Valduce Hospital
Country	Italy
Sector	Healthcare
Context (description of how the introduction of technologies is transforming the sector)	

VALDUCE is a not-for-profit organization owned by the "Congregation of Addolorata Nursing Sisters". In 1974 the Lombardy Region authorities assigned to VALDUCE the qualification of General Zone Hospital. From then on this hospital is a "Classified Hospital", which means that it is considered as if it were a public hospital for the National Healthcare System. In 2005 VALDUCE obtains the UNI EN ISO 9001-2008 certification, issued by Det Norske Veritas (DNV), responding to the quality system and management according to international standards.

The Villa Beretta Rehabilitation Centre, Department of Rehabilitation Medicine of VALDUCE, is a structure dedicated to the best possible functional recovery of people with problems deriving from disability due to genetic or acquired neurological diseases. Villa Beretta is equipped with high technological devices for evaluation of patients' functions as well as for rehabilitation treatment for both the lower and upper limb.

From the clinical perspective, the most advanced set of technologies is used, from diagnosis to monitoring to aids and personal tutors and orthosis, to robotics, augmented reality, virtual reality and home-care systems in order to follow patient when they go back home.

Each patient goes through a specific diagnostic process which may include (depending on the case): identification of general clinical condition of the patient; neuro-motor assessment (posture balance, upper/lower limb functionality, trunk control); neuro-muscular instrumental evaluation (dynamic electromyography, movement analysis, kinematics, kinetics); nutrition assessment (nutrition index, deglutition structure and function); urinary system clinical and functional evaluation, neurological

assessment of pelvic floor; assessment of respiratory function; neuro-psychological and cognitive assessment; clinical scales application depending on the specific pathology.

After the completion of the diagnosis main treatment combinations may include: Chemodenervation using traditional as well as innovative pharmaceutical products (botulinum toxin); Neuro/orthopedics surgery for functional or cosmetics purposes; Direct programmable system of intrathecal infusion; Robotic assisted physiotherapy; Traditional physiotherapy; Psychological support/treatment; Speech therapy and/or neuro-cognitive treatments for aphasia, neglect, dysarthria, problem solving, alternative augmentative communication; Respiratory functional support/recovery; Taylor-made orthosis and assistive devices; Nutritional treatments; Urinary system functioning treatments; Specific skin ulcers prevention and treatment.

Description of the case

The hospital decided to move from a paper based health record to an electronic one (EHR) in 2008, when there were very few commercial products in the area, then, in 2018, a second step was done to integrate new legal constraints and to adapt the process to the new available ubiquitous digital technologies. Ubiquity is particularly important in a rehabilitation context, because the patients are continuously transferred among the different rehabilitation facilities.

The main aim of an EHR is to make the patients' data available in any place and at any time, together with a better control on data correctness.

The transformation was strongly supported by the Director of the rehabilitation center, passionately in favour of technological innovation and well aware of its potentialities.

All the clinical professionals (physicians, therapists and nurses) were involved in the design, together with the bioengineering team already set in the institution. Indeed, the internal engineering team was in a privileged position to act as a link to external IT developers knowing both the sides of the matter (clinical and technical ones).

Overall, the main efforts were put on the organizational side, in terms of the needed revision of the clinical processes and procedures to keep them conform to the regulations and traceable by the IT tool.

The needed technological training was particularly important in the initial step, when the shift from paper to electronic means required higher adaptation to the new technologies.

Main outcomes of the DT implementation

The DT was aimed at a robust management and documentation of the recovery of the patient.

In the initial step, the focus was mainly on the data, to make the information on the patients and their cares always available to all the involved professionals.

In the second step, the development effort was also focused on the management of the process and its robustness. Clinical processes are accompanied by heavy regulatory aspects that may be well managed by an IT based process.

In the second version, the interaction among clinicians, therapists and nurses was pushed by means of a shared agenda allowing a clear view of all the treatments scheduling and the usage of rehabilitation devices.

A strongly technologically supported function is the administration of pharmaceuticals that is now performed by means of barcode reading to avoid any human error. In the first version, the development was in charge of an external software house, while, in the second phase, the development has been managed by the IT services of the hospital (trained by the external software house), that were able to supply a better view and knowledge of the already running processes.
Human factor
In the initial step, it was necessary a devoted training to improve digital literacy of the personnel. Indeed, in 2008 it was not common even to have a PC at home. In both steps, training was however mainly on the standardised procedures to be applied in daily clinical practice. While in the initial step the need to move to an electronic mean was very clear to all the involved professionals, in the second step there were more initially resistances, because of the difficulties to understand the need of revising an already existing digital tool. These, however, were easily solved by clearly explaining the need to further improve the safety of the patients and the traceability of the process, by reducing the possibility of making trivial errors in the process management and documentation. Also, it was made clear to all the personnel that the EHR was not to be considered a static tool, but rather a living one to be upgraded according to the evolution of the clinical practice. It was very important to clarify that the technology had to serve the clinics. Also, the support of the EHR to cope with human errors was very appreciated, especially in delicate and critical actions such as the administration of medicines. The success of the initiative was mainly in the involvement of the professionals in the design of the operational processes, keeping the IT implementation on the background, transparent to the end users.

Focus Group participants	a. Mauro Rossini: Bioengineer Villa Beretta b. Samuela Canobbio: Physiatrist Villa Beretta c. Giovanna Mannu: Nursing coordinator Villa Beretta d. Alessandro Barni: Senior IT Project Manager Rekeep e. Rita Siniscalchi: Junior IT Project Manager Rekeep
Affiliations	a. Villa Beretta Rehabilitation Center of Valduce Hospital b. Villa Beretta Rehabilitation Center of Valduce Hospital c. Villa Beretta Rehabilitation Center of Valduce Hospital d. Rekeep Digital Srl e. Rekeep Digital Srl
Name of the organisation or company described in the focus group	Villa Beretta Rehabilitation Center of Valduce Hospital
Country	Italy

Sector	Healthcare: rehabilitation

1. Were you among the originators of the DT idea or when were you involved in the process? Which has been your role?

a. Bioengineer Villa Beretta: responsible of the project

I was involved in the initiation, design and implementation of both the first and the second version of the EHR. My role was to act as a bridge between clinical and technical people and I was involved in the analysis of the processes.

b. Physiatrist Villa Beretta: end user

I am a physician and I was involved in the implementation of the second version of the EHR both in the phase of the design and analysis of the clinical processes and as end user in the daily practice.

c. Nursing coordinator Villa Beretta: end user

I am the responsible of the nurses and the health and rehabilitation technicians of the hospital and I was involved in the analysis of the requirements and processes, bringing the view of the nurses and therapists. I am also an end user.

d. Senior IT Project Manager Rekeep: IT project manager

I am in charge of the IT systems of the Valduce Hospital as external technology provider. At the beginning of the second phase I was acting as Service Manager; while during the implementation I became responsible of the Rekeep health department, but I continued to work on the project.

e. Junior IT Project Manager Rekeep: trainer

I entered the project in the second phase to configure the EHR and train the end users.

2. Have been your initial expectations fulfilled by the final result?

a. Bioengineer Villa Beretta: responsible of the project

Focusing on the second phase of the project, that is the one shared with the other participants of this focus group, the challenge was to improve an existing tool looking no more only at data collection but at the implementation of an organization and management tool, flexible enough to serve future changes. To get this target, that I think it was overall reached, there were difficulties, because of the complexity of the system itself and different views from involved clinicians.

b. Physiatrist Villa Beretta: end user

The expectation was the availability of a tool to make data collection easier (thanks to portable devices) and smooth some steps in the process. The final result is very good, but it is still an ongoing process as it is the clinical practice. The design phase pointed out some gaps in the process management to be solved. At the beginning, the impact with the new technological devices required some adaptation. The key added value is the obligation to verify the process while running it.

c. Nursing coordinator Villa Beretta: end user

The expectation was on the overcoming of the existing limits (initial version of the EHR), mainly the possibility of updating data. A lot of requests were made in the phase of the requirements collection and they were fulfilled. However, the path to the final result was not very easy, mainly because of difficulties in relationships and collaboration, both within the hospital and in the relation with the external IT specialists. The younger nurses had less difficulties in adapting to the technological devices than their older colleagues. Referring to the previous version there were complains on the increased number of “clicks” needed to perform operations before it was explained that it was necessary to increase safety.

d. Senior IT Project Manager Rekeep: IT project manager

The expectation was to be able to supply a product able to be a clear improvement on the previous one, and I am confident that the result was reached. The improvement on the process management has been reached by continuous tuning and it is still on going.

e. Junior IT Project Manager Rekeep: trainer

Looking at the configuration of the system, the requests went on to change along the time. At the beginning the focus was on the improvement of the care path management. Later on, we focused also on interfacing aspects such as the design of reports and the setup of alerts.

At the beginning we encountered some resistance to the change of practice by the end users.

3. Was this experience also an opportunity for your personal growth?

a. Bioengineer Villa Beretta: responsible of the project

As usual in multidisciplinary projects, the main personal satisfaction and growth was in the interfacing of clinical and technical worlds.

b. Physiatrist Villa Beretta: end user

The need to uniform the processes required to develop new relationship modalities with the colleagues. This implied a personal growth in the management of interpersonal relationships.

Also, working on the complexity of the processes led to deep knowledge of them.

c. Nursing coordinator Villa Beretta: end user

The awareness that the new tool allows a safer management of the processes implies higher tranquillity, being more confident on the correct implementation of the processes (being responsible of them).

d. Senior IT Project Manager Rekeep: IT project manager

I increased my knowledge on the clinical environment. A lot of expertise was also obtained on the management of complex processes including legal aspects.

e. Junior IT Project Manager Rekeep: trainer

It was my first experience of relationship with the end users. It was very interesting and useful also at personal level in terms of management of human relationships.

4. Are the work activities/responsibilities/relationships in the company changed? How?

a. Bioengineer Villa Beretta: responsible of the project

The role of technicians is a key one to assure a correct running of the new implemented processes. Sometimes it was necessary to impose rules in the performing process to all the clinical personnel.

The clinical process is a standardised one, so the technology is somehow on the background, serving the process as it is for medical reasons.

Issues with technology are often not clear to the clinical people and are hard to be made understood.

b. Physiatrist Villa Beretta: end user

I had new responsibilities related to the design of the processes. I had to modify my relationship with the colleagues to become their spokesperson. These relationships were hard to manage.

Continuous updating is not so fast as it was expected.

c. Nursing coordinator Villa Beretta: end user

My role did not change, still a lot of time is devoted to the hospital. At the beginning the relationships with the colleagues were a little difficult because of the need to impose myself to oblige them to follow the new procedures. Now everything is solved, and they are quite satisfied with the new tool.

Looking at the relationships with the external technical people, it was made difficult by the high turnover of their personnel.

d. Senior IT Project Manager Rekeep: IT project manager

Because of the change of my role within the company, now I have a more direct and effective relationship with the end users.

There are also issues related to the IT environment (e.g. Wi-Fi connection) that impact on the system, but the clinical people are not able to understand the cause of the error.

e. Junior IT Project Manager Rekeep: trainer

The relationship with the end users is improving because of weekly face to face meetings, more effective than the remote ones.

5. Humans and DT

5.1 DT champions

This study went through a well-defined conceptual pipeline to move from literature search to the detailed analysis of specific use cases. Champions of a positive DT implementation, able to empower humans, have been searched and investigated.

In the following, the exemplary cases presented in section 4 are discussed in light of the insights obtained from the previous study phases.

The preliminary results from the scientific and grey literature review confirmed that DT is permeating all industrial and commercial sectors, including services, even if with different nuances through application areas and companies size. All the study sources lead to the same basic concepts even if with some small differences.

While the DT phenomenon is witnessing a fast evolution, the scientific literature is still lagging behind in the description of best practices and successful use cases. On the contrary, web search and questionnaires have returned a richer number of successful experiences.

Apart from some resistance in well-established environments characterized by steady processes, all the explored business experiences show high awareness of the potentialities of the new technologies. Overall, the collected experiences support the statement that the DT may improve the working practices, boost the quality of final products and even open new business opportunities when the human is put at the center.

Likewise, all the results converge on acknowledging that the key point of an effective DT adoption stays in the ability of the industrial management to revise processes and redesign them. Technology, without rethinking of the underlying process, has demonstrated to be vain.

The early set of cases, initially identified through desk research, mainly refer to few big companies. Nevertheless,the questionnaires and the web have confirmed the growing importance of DT for SMEs which represent the 99% of all businesses in Europe, thus making their capacity to profit from a wider use of technology crucial for the overall economic growth and prosperity of the European Union. However, limited resources at company level are still slowing down this process. Public and private incentives are demonstrating to be the key to increase the number of European firms benefiting of DT.

Renewed working processes, together with innovative businesses supported by appropriate technologies are crucial elements towards more sustainable products and services.

By means of the interviews and the focus groups, we further concentrated on the analysis of the design and implementation phases, where the human participation makes the difference.

The finally selected case studies range on a wide span of business sectors, from industry to services.

In the industrial area, the cases relate to different sectors like the manufacturing of components for the white goods industry and the manufacturing of tools for household appliance, metal crafting, the automotive, the steel industry, the agri-food area and the software (analytics) development. Also, the addressed organizational functions are different: production, maintenance, workers safety, human resources, training, administration.

On the services side, healthcare is widely represented through different departments and functions.

In most of the analysed cases, the humans were empowered in their working functions. The adoption often required a devoted training and some adjustments of the practice, but nobody lost their job.

Among the others, a very interesting case was the one of Elettronica ROLD that embraces DT as company mission, not only looking both at innovation of the process and the product, but also making the developed DT as an opportunity of new business.

Indeed, ROLD started to implement DT in manufacturing, to fulfill the internal need of improved quality and rate of production. Plants were initially revised to improve quality of the produced molded parts. The innovation was started on a pilot machine and then scaled to all the company plants, improving production and providing additional information on the quality of the whole process.

Meanwhile, the company realized that the redesigned process (in terms of production data collection and quality control) might potentially benefit other manufacturing companies, working in other areas. The value of the idea was successfully demonstrated in visits and fairs and the management decided to start a new business, bringing to the market what initially developed for internal purposes.

Once experienced the added value of DT in manufacturing processes, and opened new business opportunity, the company further pushed their innovation potential forward looking at the products. DT is now also applied to product design with the same methodological approach previously applied in process innovation, i.e. technology scouting in product design.

Other relevant cases of identification of processes' bottlenecks and collaborative redesign of the whole chains of production and service delivery may be identified in the healthcare sector, such as the DT put in place in the Emergency Department of the Thriasio General Hospital of Elefsina (Greece) and the introduction of Real Time Location System (RTLS) for patients and assets to digitalize the surgical process at the Vall d'Hebron Hospital (Spain).

Overall, the analysis on the field addressed a variety of sectors and functions, but despite the diversity of needs and objectives, all the successful cases shared **clarity of objectives**, **codesign** practices, wide and tailored **communication to the workers**, extensive **involvement of the management**.

There is also evidence of the need of suitable Key Performance Indicators to prove the success of the DT adoption. Indeed, the selection of these indicators is many times already part of a well formulated definition of objectives, while when the adoption process is strongly technology driven, it becomes harder to assess the result on the human and organizational side.

A last point to be further detailed in the next sections, is the role of unexpected exceptional external events as it is the current COVID-19 pandemic.

If, on one side, this study suffers the mobility limitations due to the lockdown and the still running restrictions (in terms of stakeholders reaction time and availability), on the other side most of the involved stakeholders depicted the lockdown as an opportunity or at least a facilitator to push the DT.

Indeed, the pandemic is rapidly changing working practices and venues and the central role of the technology is forcing a wide and fast DT in an assortment of business sectors.

5.2 Key steps to a successful DT adoption

As previously introduced, a successful DT adoption requires the setup of a clear process from conceptualisation to implementation with human centricity as guiding principle.

Here below, the description of the three key steps, according to our results: initiation, development, communication.

5.2.1 **The initiation**: where the DT comes from?

The initial concept at the basis of a DT process may originate from a person in the organization as well as from an external consultant. Sometimes, it is also the case of externally funded initiatives, such as international research projects, where researchers from various disciplines propose and collaboratively develop a new technology to be introduced in a manufacturing or service environment.

Wherever the idea comes from, it is essential that the development is "market driven" instead of "technology driven". The most successful DT implementation experiences are led by one specific need of either the customers (in the case of product and service innovation) or the workers and/or the organization (when the DT affects internal processes).

The respective role of "technology" and "human/organizational" need is a key point in a successful DT adoption. Often, in innovation, we face "technology driven" interventions. When innovation is purely technology driven, there may be concrete risks of unsuccess. The technology per se may be very appealing, acceptable and functionally responding to the users' needs. Its successful adoption ultimately depends upon its adaptability to the intended application and not vice versa.

Some exemplary situations have been described in section 3

In the HR department of a multinational company (SAS), there was an already going on process on "people analytics" aimed at improving performance and reducing abandon rate. The ongoing process was already supported by a technology provider, expert in data analytics and well aware of the company needs, after few years of collaboration. While running this initial process, it becomes evident the importance of engagement to increase interaction among workers. The idea of developing an app for engaging people by means of recognition mechanisms was shared by the HR management and the technology provider, leading to the complete adoption process. This is an exemplary case of market driven process supported by a technology supplier already aware of the company organization and its specificities which demonstrated to be an added value in speeding up the DT adoption.

On the other side, the cases of the GO0D MAN and the FACT4WORKERS projects demonstrate how external public funds play a critical role in serving innovation. The research project aimed at addressing some open needs in the manufacturing industry and requirements were collected from potential testbeds to assess their matching to the diverse technologies offered by the partners of the consortium. The automotive company (Volkswagen) identified an area of potential innovation and technology was customized together to address the open need.

Lesson learnt: to start an effective DT: 1) the priorities established by the company undergoing the adoption process as well as the needs explicated by its workforce have to drive the DT design, 2) technology is not the driver for the process redesign and optimization, instead it is the powerful enabler for improved processes and working practices, 3) the objectives have to be clearly defined and shared by the company and the technology providers.

5.2.2 **The development**: what to do while designing the solution?

As stressed above, regardless of whether the aim of the DT is offering a better product/service to the customers or achieving an optimized work organization within the company, the prerequisite for a successful transformation is the revision of the existing working flow or the design of new ones.

In both circumstances, users have to be put at the center of the design. Participatory design (codesign) is the best means to develop processes and products that may be appreciated by the end users.

The first step of the design is the analysis of the working flow. The modifications to the process due to the technological adoption need to be kept limited. Humans should be kept clearly in mind. The way an existing process is modified may cause resistance in the users when the change is not justified.

In order to maximise acceptance users need to comprehend the reasons behind any choice made along the process design so as to support its later technological implementation.

The cases related to Villa Beretta Rehabilitation Center as well as the Thriasio General Hospital of Elefsina clearly demonstrate this point.

In the first case, the adoption of the Electronic Health Record (EHR) was rolled out in two different phases: initially from the paper based version to the electronic one and, some years later, from an obsolete IT infrastructure composed only of desktop PC and few laptops to more performant interfacing tools such as mobiles and tablets. In the first phase the technological impact was quite high because of the limited computer literacy of many workers. However, these purely technological barriers were overcome by a suitable training without strong resistance from the workers. The understanding of the benefits coming from the new solution (mainly in terms of reduction of potential human errors), and the consistency of the new process with the old one made the adoption quite smooth. In the second step, main resistance came from small modifications in the process not appreciated by the workers already used to the first version and unwilling to understand the need of additional modification in the way of working with no evident benefit for them.

It is also important to note that industry-academia collaborations are flourishing across Europe. In some cases, codesign was also used to include professional or academic views external to the organisation.

In both the above quoted cases, experts in work organization and health flows management were involved.

Lesson learnt: to implement an effective DT: 1) start from the workflow and its revision; 2) use codesign techniques to involve all potential users since the beginning, 3) training the workers on the conceptual change, the motivation and the advantage of the DT makes easier to promote technology acceptance and should precede hands on training on how to use the technology.

5.2.3 **The communication**: how to push adoption?

Even in well prepared codesign workshop, only representatives of workers are participating. A good practice is to involve representatives of all the workers categories and functions but, of course, not the entire workforce. However, the DT adoption is aimed at a much wider audience.

A well-planned communication campaign inside the organisation may make the difference in a successful adoption.

Communication needs to start with the DT implementation. Workers need to know that the process is started, and which are the objectives.

Engagement of the workers is a key element in any organization, when a change is coming it becomes still more crucial.

The HR department in SAS kept communication active and clear all along the whole process. Even while developing a fully digital instrument, the communication used live events to let people meet and discuss.

This raises expectations and participation; workers were very well prepared, ready to test the tool and prone to accept it and the changes it conveyed.

Indeed, the marketing department was involved in this phase to enhance as much as possible internal communication.

In other cases, the workers were trained to the new way of working even before the adoption of the DT, also in this case it was a matter of successful communication to make the objectives shared.

The role of managers demonstrated to be a key one in several cases, in manufacturing (ROLD) as well as in healthcare, proving that positive leadership is a central factor in any change management process.

On one side, in many cases managers act as positive and inspirational examples to overcome workers' resistances. On the other side, several successful DT experiences witness an early and deep engagement of workers in the identification of the rooms for improvement along the production chain, such as in the FACTS4WORKERS project, that resulted in an increase of responsibilities for the workers themselves due to a shift of quality control tasks, which were formerly carried out by the middle management.

Lesson learnt: to enable the adoption of the DT it is of utmost importance: 1) to share the objectives of the DT with the workers that have to use it; 2) to keep people informed in any step; 3) to involve the management in the adoption; 4) to rely on managers acting as inspirational role models for workers.

5.2.4 COVID-19 as a driver to DT adoption

As a last point, it is worthwhile to make some considerations on how COVID-19 pandemic impacted on DT, both in ongoing processes and in pushing new ones.

One clear impact is connected to the significant shift to remote or smart working which has become suddenly mandatory to keep several activities alive during the lockdown. Most of services were moved remotely.

In our study we get views from two areas, heavily involved in this process, vocational training and administrative professions.

Online training was abruptly widely adopted. In this case, the human factor played a central role, both on the teacher and student sides. A simple recording of lectures is not DT, but a revised organization of contents and more efficient means for their administration is DT. In the case of Samara University in Russia, the COVID-19 became an opportunity to revise programs of professional training for workers, considering on line training not a backup solution but an opportunity to better manage different typologies of courses on the university side and to better manage time on the student side.

With regard to administration and clerical activities, the pandemic working emergency, leveraged by means of digital tools, led to deep revision in processes and tasks that are suitable to be continued afterwards. Indeed, administrative professions are among the early ones to have adopted digital tools. They are considered as professions at risk because of the ongoing technology introduction. Indeed, technology in the area is mature and already in place in several organizations (e.g. ERP already in place for 20 years) although with many differences across countries and regions.

In this area, there are several new challenges associated to COVID-19 emergency. Whilst a change in the employees' mindset is certainly playing an important role as people working in the administration and service provision sectors had to adapt to homeworking, experiment new modalities of work-life balance and this requires personal attitudes to change, resilience and flexibility, it must be reckoned that disparities in access to telework add to existing dimensions of income inequality and adequate measures are needed to equalise opportunities and tackles problems such as lack of childcare, unsuitable working spaces and ICT tools [155].

During the pandemic, all kinds of businesses had to change rapidly and to adapt, being forced to modify the way they contact potential clients, interact with them and in many cases the processes through which they produce, sell, and even deliver their goods and the services.

At the same time, citizens were also incentivized to change their purchasing habits, switching to online shopping.

On the services side, employees had to learn to manage a completely new time balance between family and work and adapt to a new working environment.

In the case of SAS, where the HR app had been distributed just before the lockdown, it increased its adoption and became a means to foster interaction also on the distance.

Whereas in sectors such as retail, administration, entertainment and others, we can conclude that the containment measures acted as a trigger to overcome the resistance to change and have provoked an unprecedented shift to online services and telework, in other industrial sectors, such as manufacturing and utilities, the pandemic will be likely to accelerate other profound changes in the labour market. Recent analyses on the post-pandemic economy have forecast a large overlap between jobs at risk due to COVID-19 in the short term and jobs displaced by automation in the longer term with 94 million European workers in the need of being reskilled [156].

5.3 Policy recommendations

In the Final report of the Industry 2030 high level industrial roundtable, "A vision for the European industry until 2030" (June 2019), it is stated that "*In 2030, European industry will be a global leader that will responsibly deliver value for society, the environment and the economy. By 2030, the EU will successfully become an innovative, sustainable, competitive and human-centred collaborative economy in an increasingly populated, resource-constrained and interconnected world*" [157].

Today, in the face of the huge economic impacts of the COVID-19 crisis which are likely to be long lasting in several European regions, such a proactive vision must still serve as guidance towards the development of a European industrial system that is capable to cope with the increasingly complex societal challenges in front of us and built around the three strategic imperatives of sustainable growth, competitiveness in the global scene and social inclusiveness.

The present study brought to light a wealth of information about the crucial role of DT as the key enabler for this systemic change which cannot be left to the responsibility and isolated initiative of visionary managers and entrepreneurs.

Whereas at the level of businesses and organisations it clearly emerges that digital maturity is mainly the product of the human component which has proved to be determinant to make the needed strategic, cultural and leadership changes happen, **when looking at systemic level, supportive and coordinated policies, financial incentives and programmes fostering place-based as well as sector-based innovation are essential** to ensure that the digital transformation fundamentally impacts all aspects of business and society.

This is even more true in the current economic scenario whereas, in spite of the enormous uncertainty, it is possible to define a number of key recommendations:

- **Joint public-private initiatives** have the potential to foster the market uptake and large-scale roll-out of technologies and raise awareness among both public and private industry players that need to adapt and change their processes. The strengthened role of public-private partnerships in the next R&I European Framework Programme "Horizon Europe" is indeed welcomed in any sector being it pivotal to promote truly participatory strategic agendas which could successfully drive the operations of the newly constituted partnerships balancing the need to serve societal missions along with the private sector interests.
- **From R&I to implementation: Public funding, injected in the industrial fabric either through EU targeted initiatives or integrated in national and regional investment strategies**, are urgently needed to support investments by small and medium-sized enterprises and help capture digital's potential to the benefit of all citizens. **Innovative funding schemes** should promote **blended finance** and pursue longer term impacts in order to support the later stage of large-scale implementation in the innovation journey. Research &Innovation funds have the undoubted capacity to help plant the seed of the innovation by supporting the design, development, testing and piloting of digital solutions, as the Factories of the Future programme – among many others - has largely demonstrated. On the other side, the large scale roll-out of mature DT processes is being made possible in many companies and organisation thanks to the financial support of the European Structural and Investment Funds allocated in accordance with regional strategies and operational programmes. It is thus desirable a stronger coordination and the creation of innovative mechanisms to bridge programmes and decision-making levels. Looking at the most recent macroeconomic simulation [158], without public intervention, both economic and labour effects are likely to impact countries and regions unevenly, favouring the economies that are already most advanced.
- It is fundamental to put in place frameworks and tools to help countries and regions to orchestrate validated place-based approaches (such as the Smart Specialisation Strategies (S3)) with sector- or mission-oriented policies and connected funding streams. Departing from the assumption that the only way ahead is a "twin" (both ecological and digital) transition, this recommendation is in line with the approach proposed by the JRC Expert Group on 'Linking smart specialisation and mission-oriented policy for sustainable development' that is supporting a shift in policy logic from S3 to "**smart specialisation strategies for sustainable and inclusive growth**" [159].

- **Education and training**: The educational systems is facing the most unpredictable and disruptive revolution ever and many changes will stay in place after the pandemic. This is an **unprecedented opportunity to encourage the integration of cross-sectoral training, skills enrichment and cultural change** supporting DT in educational and training curricula as well as the creation of life-long educational models. Furthermore, in addition to the huge numbers of workers who will see their job at risk due to the pandemic and thus will need to be reskilled, specific industrial sectors require investments in centres of excellence for specific digital skillsets. In this direction, the new EU programming period holds the promise of a better and deeper coordination between diverse programmes and levels of funding including a renovated emphasis on the contribution of the novel European Social Fund Plus to drive **investments in reskilling and upskilling plans** able to provide equal opportunities to workers and strengthen the support to youth employment and entrepreneurship.

6. Conclusions

DT is permeating different businesses and sectors, as clearly shown daily in the press. The society is experiencing a time of continuous and fascinating technological innovation, but technology transfer from research to industry and services is still lacking behind. DT adoption in working environments is developing slowing. The focus is still mainly on the technology per se rather than its business application. There are still few documented examples of success and, often, they are not supported by clear performance indicators demonstrating their potentialities.

Also, when addressing high-tech innovation, little room is left to the investigation of the human role while it stays central to the whole process.

To foster the DT adoption, European organisations and companies may benefit from learning about positive cases of implementation to better understand the value of the ongoing technological transformation.

In the view of investigating the role of humans in the DT adoption and making them central to it, the current study was aimed to describe and analyse emblematic field cases of DT adoption, where the humans make the difference, showing how collaboration between humans and machines may lead to success in a variety of contexts, sectors and geographic settings.

The study started from scientific and grey literature investigation to set the scene of the research, then moved to the field to talk with stakeholders and to investigate concrete exemplary adoption settings.

The identified cases ranged from manufacturing to healthcare, from human resources, to quality control, covering a wide span of sectors as well as functions.

However, all of them shared some communalities, all of these pointing out that business and production processes are designed, managed and executed by humans, who will ultimately determine the acceptance of the implemented change. Thus, the processes, not the technologies, must represent the kernel of the DT intervention.

Most of the cases share a typical development path to cope with existing needs of the organization, potentially fulfilled by digital technologies. The development process has to be market driven rather than technology driven.

In addition, most of the DT does not address the innovation of the product, indeed only a couple of cases went in such a direction, but the innovation of the process, may it be in production, vocational training or any other working function.

Working processes are strongly human centered and their purposeful revision naturally requires a human centered design. This is reached, in most of cases, thanks to a wide use of codesign practices. When humans are driving the transformation of the process, adoption is smoother and faster.

Effective change management is pivotal for DT as well as for any other organizational transformation. The cases presented in this study demonstrate how resistance to change, accompanying most of the innovations, can be overcome.

However, the way to a widely spread DT is still long and require efforts from all the involved stakeholders, including policy makers, expected to pave the way to an effective DT adoption through forward-looking actions, preparing Europe for the necessary “twin” (both digital and ecological) transition to come.

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Annex 1: Literature review and desk search detailed results

Digital Transformation and Technologies

The first search we started was by joining the words “Digital Transformation” to widespread technological areas, i.e. “artificial intelligence”, “internet of things”, “cyber-physical systems”, “robotics” OR “robot”, “big data” and “automation” as well as their interfacing to humans, i.e. “human machine interaction” OR “human computer interaction” (Table 5).

Table 5: Results of search "Digital Transformation" AND "selected technologies"

Digital transformation & technologies		
AND	*ARTIFICIAL INTELLIGENCE*	166
AND	*INTERNET OF THINGS*	229
AND	*HUMAN MACHINE INTERACTION or HUMAN COMPUTER INTERACTION*	38
AND	*CYBER-PHYSICAL SYSTEMS*	57
AND	*ROBOTICS or ROBOT*	66
AND	*BIG DATA*	204
AND	*AUTOMATION*	154
	Total	**914**

The search returned a total of 914 results, most of them related to “internet of things” (25,05%) and “big data” (22,32%), “artificial intelligence” (18,16%) and “automation” (16,85%) (Figure 9).

The limited amount of results related to robotics and cyber-physical systems points out as these two technological areas are still lagging behind the others. The initial feeling, browsing the retrieved papers is that this is not due to a limited interest towards these technologies rather to their more complex adaptation: artificial intelligence as well as the analysis of big data may be implemented on an existing PC; internet of things develops on small and quite cheap sensors and devices; robots and cyber-physical systems require the purchase of devoted and expensive hardware as well as the setup of suitable physical spaces.

The specific issue of “human machine interaction” OR “human computer interaction”, that does not represent a technology per se, but rather the main connection between technologies and humans, accounts only for the 4,16% of results pointing out a still limited scientific interest to the adoption of digital technologies in everyday life, i.e. their application in industry as well as in business.

This initial selection of technologies was driven by the specifications of the tender itself, that pointed out these fields as the most promising for the study. However, because of the fast evolving of technologies, we decided to check the raising of other technologies, becoming more relevant in the last years. To do this, we run a search of the last year (i.e. 2019) papers addressing DT. The search pointed out a total of 2000 papers in the last year, 1150 of them relevant to our purposes. The qualitative analysis of the abstracts of these papers identified some other potentially relevant technologies, specifically “blockchain”, “bitcoin” OR “cryptocurrency” and “cybersecurity”.

So, we decided to run again the initial search by adding these technologies.

However, this search only slightly increases the total number of results to 1002 (+88 items), pointing out a very limited investigation of these topics on the five years' time span (Figure 10). This may be due to the novelty of the topics, making them still only partially addressed.

Figure 9: Statistical distribution of results of the search "digital transformation" AND "selected technologies"

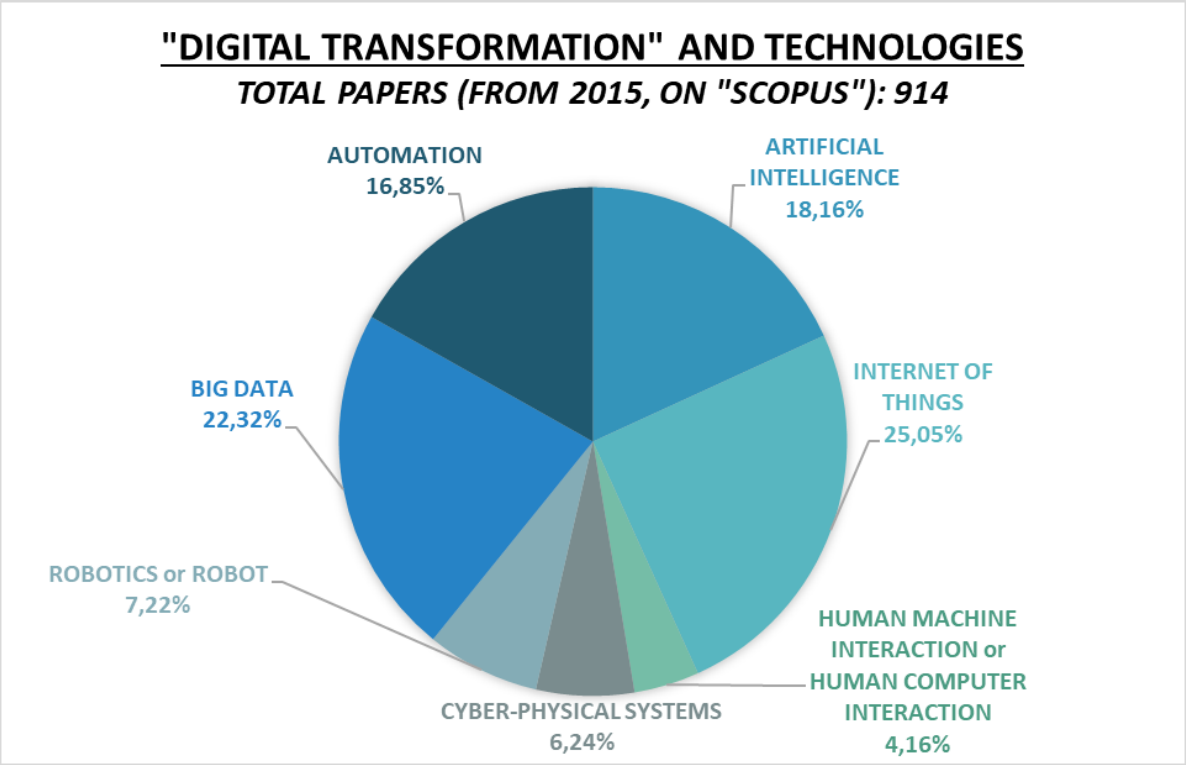


Table 6: Results of extended search "Digital Transformation" AND "selected technologies"

Digital transformation & technologies (additional areas)		
AND	*ARTIFICIAL INTELLIGENCE*	166
AND	*INTERNET OF THINGS*	229
AND	*HUMAN MACHINE INTERACTION or HUMAN COMPUTER INTERACTION*	38
AND	*CYBER-PHYSICAL SYSTEMS*	57
AND	*ROBOTICS or ROBOT*	66
AND	*BIG DATA*	204
AND	*AUTOMATION*	154
AND	*BLOCKCHAIN*	50
AND	*BITCOIN or CRYPTOCURRENCY*	11
AND	*CYBERSECURITY*	27
	Total	**1002**

As a last step in this overview of the relation between DT and technological areas, we decided to enter in some more details, such as the impact of specific critical issues on the already investigated

technological areas. Selected technological areas, i.e. “artificial intelligence”, “cyber-physical systems”, and “robotics” OR “robots”, underwent a joined search with the terms “autonomy”, “decision-making” and “machine responsibility”, pointing out some relevant issues risen by the listed technologies with very few relevant results (Table 7). Also, “big data” was searched joined to “data protection”, given the relevance of this issue for the technological area, but only 4 results were found.

The unsatisfactory results of these joined searches pointed out how the existing literature is still mainly focused to the investigation of the technologies per se, with limited interest to their relation to “soft issues” that do not represent a technological challenge, but rather a society related one. To fill this existing gap, the current study will not enter in much detail the technological implementation, rather will addresses the repercussions impacting DT adoption to depict potential best practices in its daily use in industry and business.

Figure 10: Statistical distribution of results of the extended search "digital transformation" AND "selected technologies"

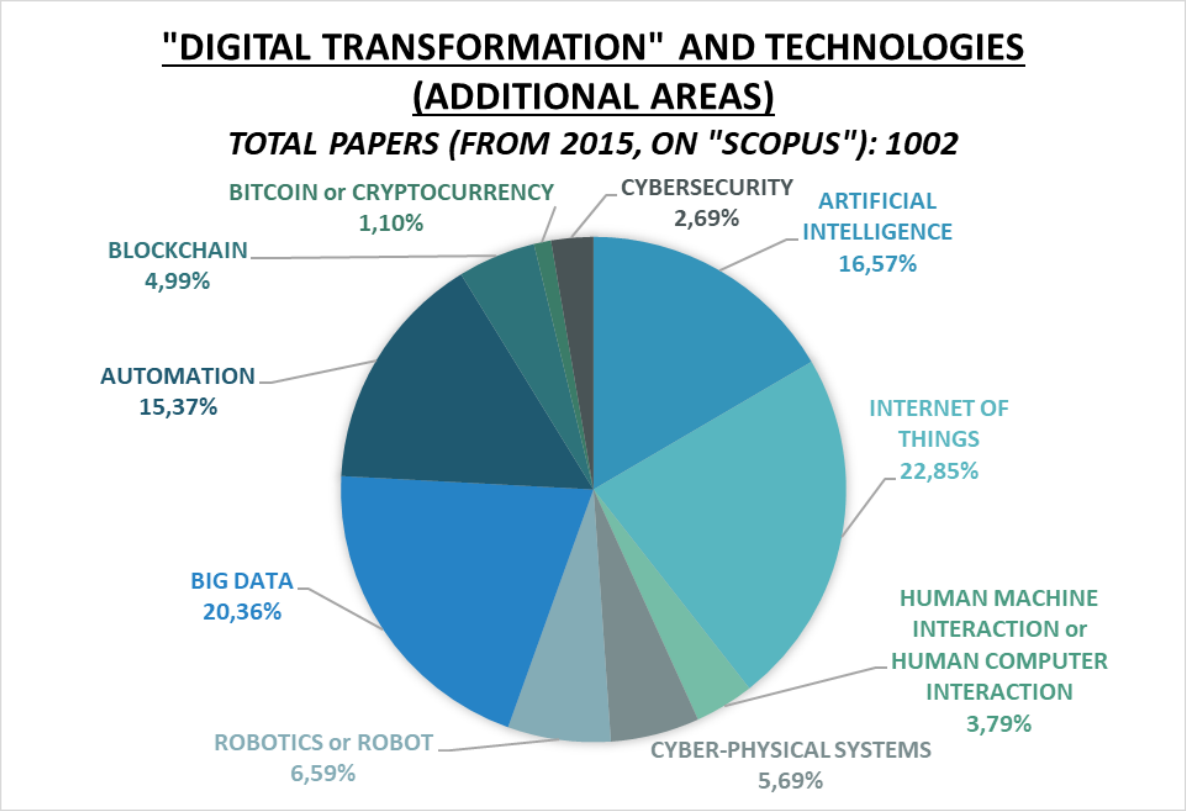


Table 7: Results of more detailed search joining "Digital Transformation" AND "artificial intelligence/cyber-physical systems/robotics or robots" AND “selected critical issues”

Digital transformation & artificial intelligence/Cyber-physical systems/Robotics or Robot & technology's critical issues		
AND	*AUTONOMY*	3
AND	*DECISION-MAKING*	24
AND	*MACHINE RESPONSIBILITY*	0
	Total	**27**

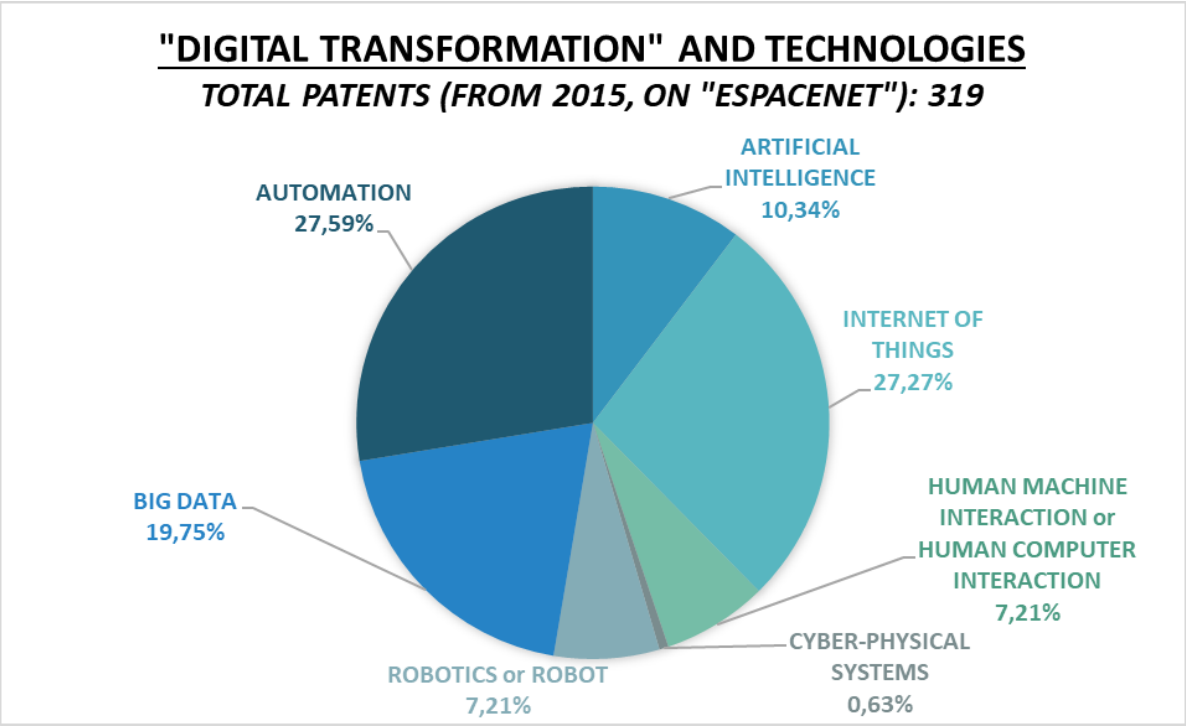
Added value of patents repositories

To be sure to take in the due account all the technological areas related to DT phenomenon, we performed a parallel search on EspaceNet looking at the same technologies already listed (Figure 11). EspaceNet is the most relevant database of patents in Europe.

The performed search confirmed the central role of "automation" (27,59%), "internet of things" (27,27%), "big data" (19,75%) and "artificial intelligence" (10,34%).

The already identified boundary topic, i.e. "human machine interaction" OR "human computer interaction" is less addressed (7,21%).

Figure 11: Results of "digital transformation" and "selected technologies" on EspaceNet



Digital Transformation and Society

The review of the relations between selected technological areas and DT, described in the previous paragraphs, already pointed out a scarce interest of the scientific literature for the aspects of the phenomenon linking humans and technologies.

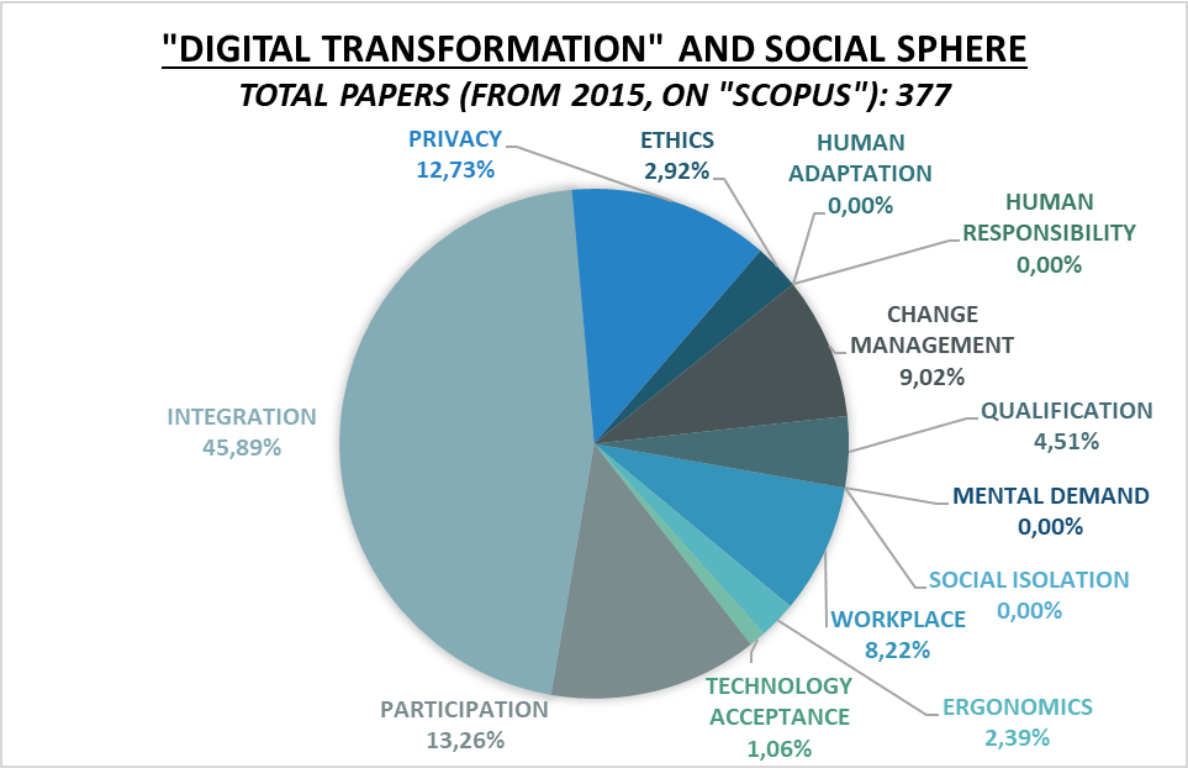
Then, we moved a step forward and investigated how DT is studied in relation to the main social elements affecting working and daily life that we gathered under the title "social sphere".

We investigated the occurrence of the following terms: "participation", "integration", "technology acceptance", "ergonomics", "workplace", "social isolation", "privacy", "ethics", "human adaptation", "human responsibility", "change management", "qualification", "mental demand". All these terms identify issues involved in the relation of humans with machines, that is the key point to be addressed and positively solved for an effective spreading of DT in society.

Table 8: Results of search "Digital Transformation" AND "social sphere elements"

Digital transformation & social sphere		
AND	WORKPLACE	31
AND	ERGONOMICS	9
AND	TECHNOLOGY ACCEPTANCE	4
AND	PARTICIPATION	50
AND	INTEGRATION	173
AND	PRIVACY	48
AND	ETHICS	11
AND	HUMAN ADAPTATION	0
AND	HUMAN RESPONSIBILITY	0
AND	CHANGE MANAGEMENT	34
AND	QUALIFICATION	17
AND	MENTAL DEMAND	0
AND	SOCIAL ISOLATION	0
	Total	**377**

Figure 12: Statistical distribution of results of the search "digital transformation" AND "social sphere elements"



The literature search of these terms revealed to be trickier because some of them (e.g. integration) have multiple meanings relating both to the “social sphere” as well as to the technological development.

Table 9: Existing relations between technological areas and specific human related issues

Digital transformation & technologies & social sphere		ARTIFICIAL INTELLIGENCE	INTERNET OF THINGS	HUMAN MACHINE INTERACTION or HUMAN COMPUTER INTERACTION	CYBER-PHYSICAL SYSTEMS	ROBOTICS or ROBOT	BIG DATA	AUTOMATION	BLOCKCHAIN	BITCOIN or CRYPTOCURRENCY	CYBERSECURITY	Total
AND	WORKPLACE	1	0	3	0	2	2	0	1	0	0	**9**
AND	ERGONOMICS	0	2	2	2	0	2	1	0	0	0	**9**
AND	TECHNOLOGY ACCEPTANCE	0	0	0	0	0	0	1	0	0	0	**1**
AND	PARTICIPATION	4	2	2	0	0	1	4	1	0	0	**14**
AND	INTEGRATION	11	29	0	11	8	19	16	4	0	2	**100**
AND	PRIVACY	5	11	3	1	3	9	1	2	1	3	**39**
AND	ETHICS	1	1	0	0	1	0	0	0	0	1	**4**
AND	CHANGE MANAGEMENT	2	1	0	0	1	1	2	0	0	0	**7**
AND	QUALIFICATION	4	2	1	2	3	2	3	0	0	0	**17**
	Total	**28**	**48**	**11**	**16**	**18**	**36**	**28**	**8**	**1**	**6**	**200**

The obtained results confirmed a still limited interest on these topics (Table 8). The total number of results was 377 items on a total of 1002 items identified searching technological areas. Also, the most hit term is "integration" that, as introduced before, presents multiple meanings (and indeed almost all related papers address the technological meaning of the word).

While "integration" accounts for the 45,89% of the results, "participation" accounts for 13,26%, "privacy", another term including also technical aspects, accounts for 12,73%, while the other aspects are under the 10% with a worrying 0% for terms such as "mental demand", "social isolation", "human adaptation" and "human responsibility" that impact a lot on the quality of life of workers and citizens.

This search clearly pointed out that the "human side" of DT is still highly unexplored and suggested the approach to be followed in the current study, where the focus will be specifically on the role of humans in the process.

Then, we tried to associate elements of the social sphere and technological areas to understand which specific human issues mainly impact on the application of specific technologies (Table 9).

Again, the search results were influenced by the spurious role of "integration". However, discharging the results for "integration", the most studied human related issue is "privacy", mainly in relation to "big data", "internet of things" and "artificial intelligence" (Figure 13).

Business and industrial sectors

Once addressed relevant technologies and related human and social issues, to complete the definition of the study framework, it is necessary to identify the business and industrial sectors that are mainly affected by DT. We searched the potential relationship between DT and specific industrial sectors (Table 11). We initially searched the following sectors: "industrial manufacturing", "repair" OR "maintenance", "transport", "logistics", "insurance" OR "legal", "healthcare" and "public services".

Figure 13: Relationships between technological areas and social sphere elements

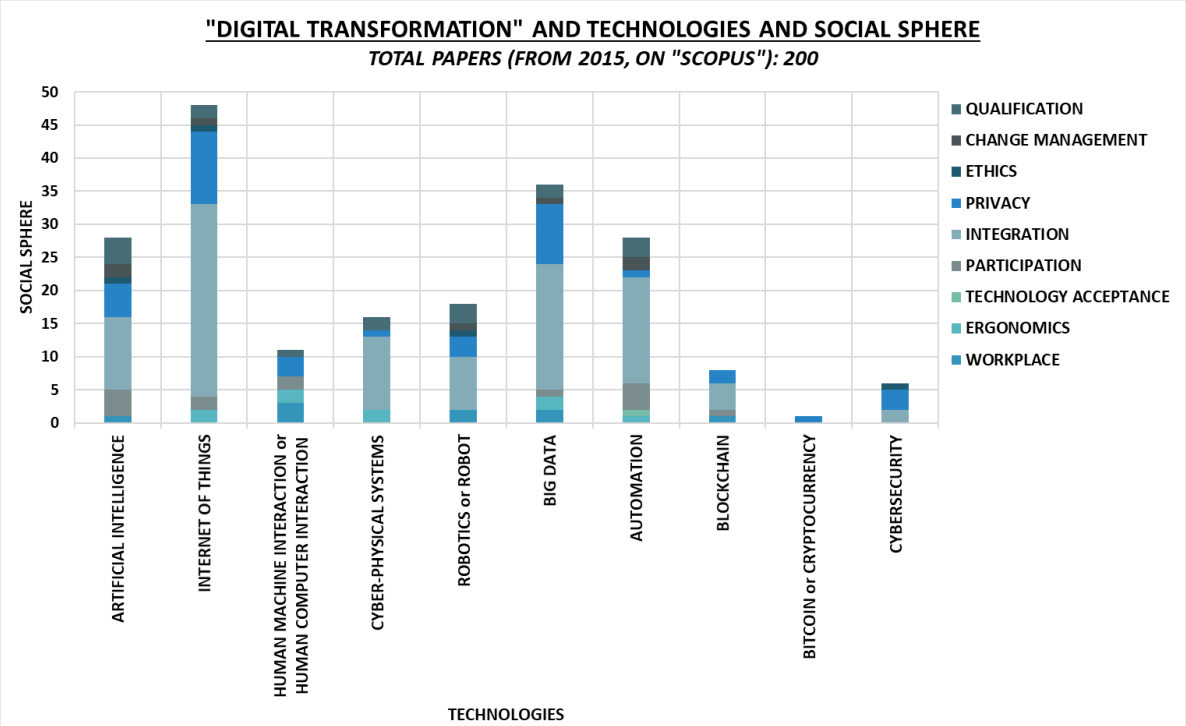


Table 10: Results of searching DT and economic sectors

Digital transformation & economic sectors		
AND	*INDUSTRIAL MANUFACTURING*	6
AND	*REPAIR or MAINTENANCE*	60
AND	*TRANSPORT*	34
AND	*LOGISTICS*	48
AND	*INSURANCE or LEGAL*	54
AND	*HEALTHCARE*	79
AND	*PUBLIC SERVICES*	36
	Total	**317**

Leading sector is “healthcare” covering the 24,92% of the occurrences, followed by “repair” OR “maintenance” (18,93%), “insurance” OR “legal” (17,03%) and “logistics” (15,14%) (Figure 14).

Then, as for relevant technologies, we decided to verify if it was necessary to expand the list of potentially relevant sectors by looking at the sectors mainly addressed in 2019 scientific literature on DT.

We identified the following potential additional sectors: “finance” OR “banking”, “agriculture” OR “farming”, “mining”, “aviation”, “oil and gas”, “education”, “supply chain”, “smart cities” (Table 11).

Apart education, that is not the main focus of this study because only partially related to the impact of DT on work and daily life, and that accounts for the 27,87% of the results, “finance” OR “banking” (8,78% of the results) , “supply chain” (7,96%) and “smart cities” (7,85%) (Figure 15) demonstrated to be key areas. The selection of the most relevant sectors to be addressed is very important to identify the

industries and services to further analyse by means of devoted online questionnaires at the beginning and, later on, by site-based focus groups.

Figure 14: Main industrial and business sectors addressed by DT

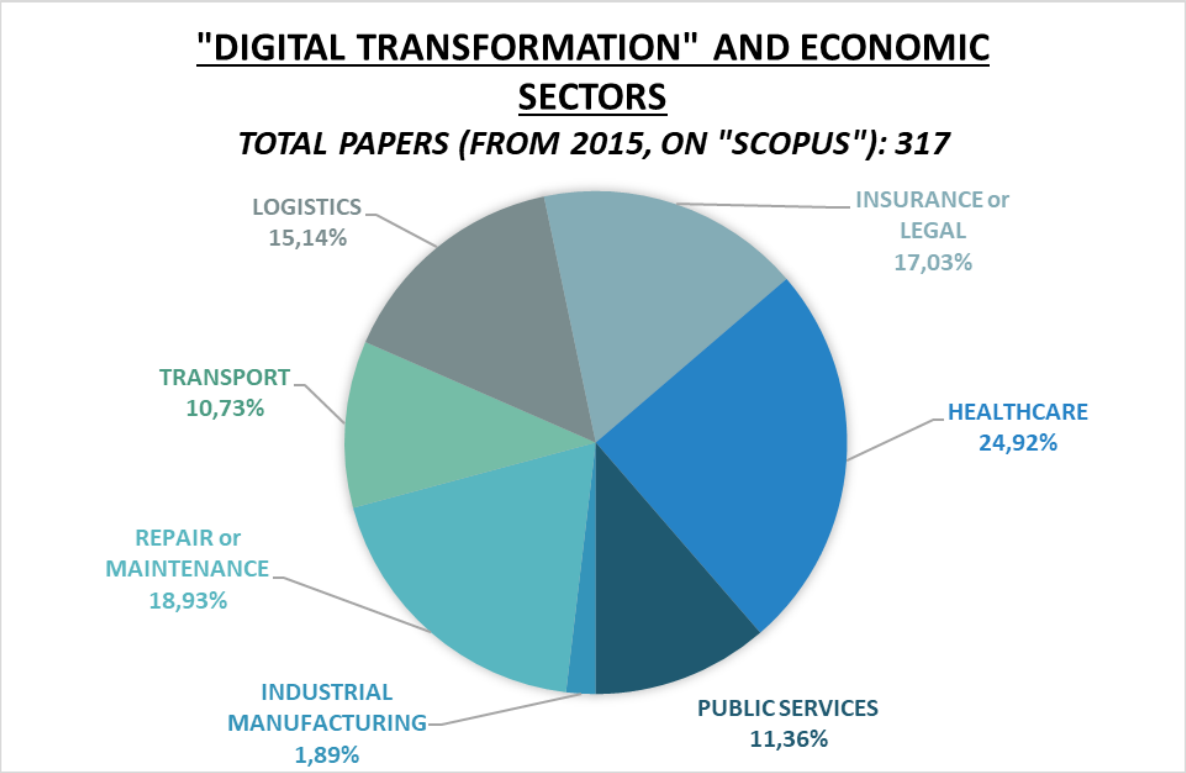
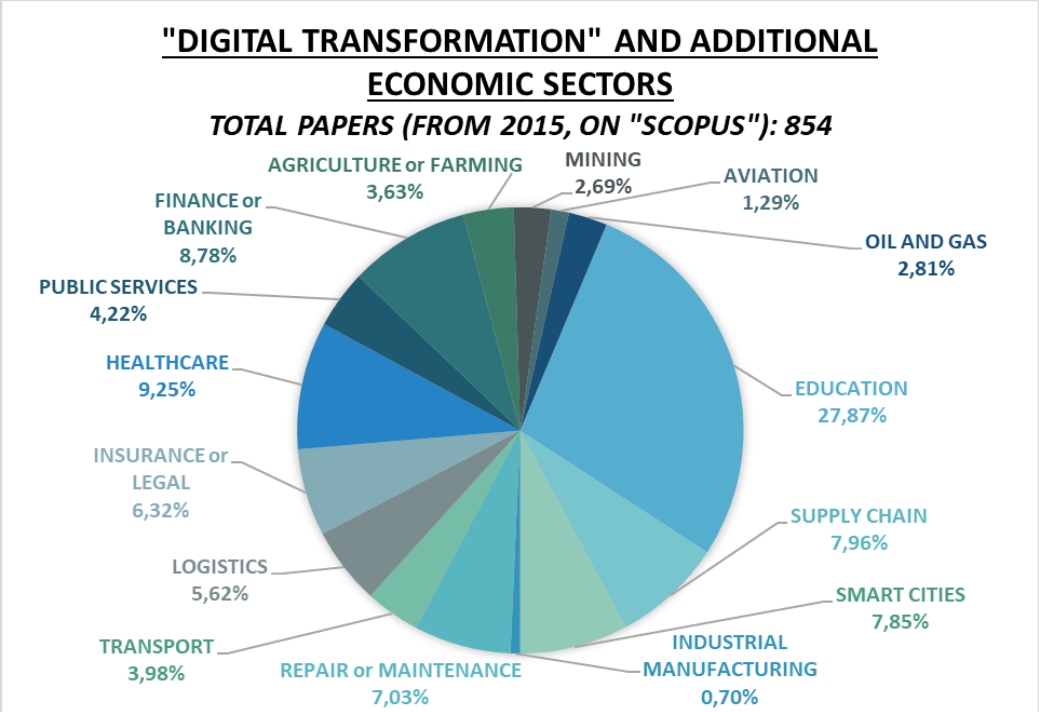


Table 11: Other relevant economic sectors

Digital transformation & additional economic sectors		
AND	*INDUSTRIAL MANUFACTURING*	6
AND	*REPAIR or MAINTENANCE*	60
AND	*TRANSPORT*	34
AND	*LOGISTICS*	48
AND	*INSURANCE or LEGAL*	54
AND	*HEALTHCARE*	79
AND	*PUBLIC SERVICES*	36
AND	*FINANCE or BANKING*	75
AND	*AGRICULTURE or FARMING*	31
AND	*MINING*	23
AND	*AVIATION*	11
AND	*OIL AND GAS*	24
AND	*EDUCATION*	238
AND	*SUPPLY CHAIN*	68
AND	*SMART CITIES*	67
	Total	**854**

Figure 15: DT and economic sectors



Grey literature analysis

In the analysis of non-scientific publication the following types of sources have been prioritized:

- Articles, catalogues, reports, collections, special editions, of recognized business and finance magazines, online newspaper media outlets, etc. (such as the Economist, the Financial Times, The NY Times, Forbes, The Guardian, etc.) as well as technology magazines (e.g. TechRepublic, TechRadar, Digitalist, etc.).
- Sector specific studies released by the World Economic Forum Digital Transformation Initiative
- European Commission Digital Transformation Monitor as well as Policy Brief, Reports and Studies published by the EC, the European Parliament and competent EU Agencies
- Country Reports as well as international analysis provided by recognized experts and consultancy firms such as Accenture, Deloitte, McKinsey Global Institute, etc.
- Reports and databases produced by national industry associations and corporates (e.g. CISCO, Siemens, Schneider Electric, etc.)
- OECD Reports (such as the recent report Global Trends 2019 issued by the Observatory for Public Sector Innovation (OPSI) among others).

Consistently with the literature review, the first search we started was by joining the word “Digital Transformation” to: “artificial intelligence”, OR “internet of things”, OR “cyber-physical systems”, OR

“robot”, OR “big data”, OR “automation”, AND “human” in order to filter those publications where the human issues, such as “human machine interaction” or “human computer interaction” were captured.

The web search has been performed using Google search engine, Internet Explorer browser, after having cleared the search and browse history.

The first 25 entries retrieved by Google per each of the above-mentioned technological areas have been selected excluding ads and marketing contents and projects’ news.

The search criteria have allowed to select 105 non-scientific articles and 61 reports and studies.

Annex 2: Stakeholders' selection from projects and Digital Innovation Hubs

In addition to the stakeholders selected based on the review of the scientific and grey literature, the study team has performed an in-depth search for DT implementers and experts among the organizations participating in research and innovation projects and other relevant initiatives, such as the Digital Innovation Hubs across EU.

All those stakeholders have been reached out and asked to participate in the study by filling in the online questionnaire.

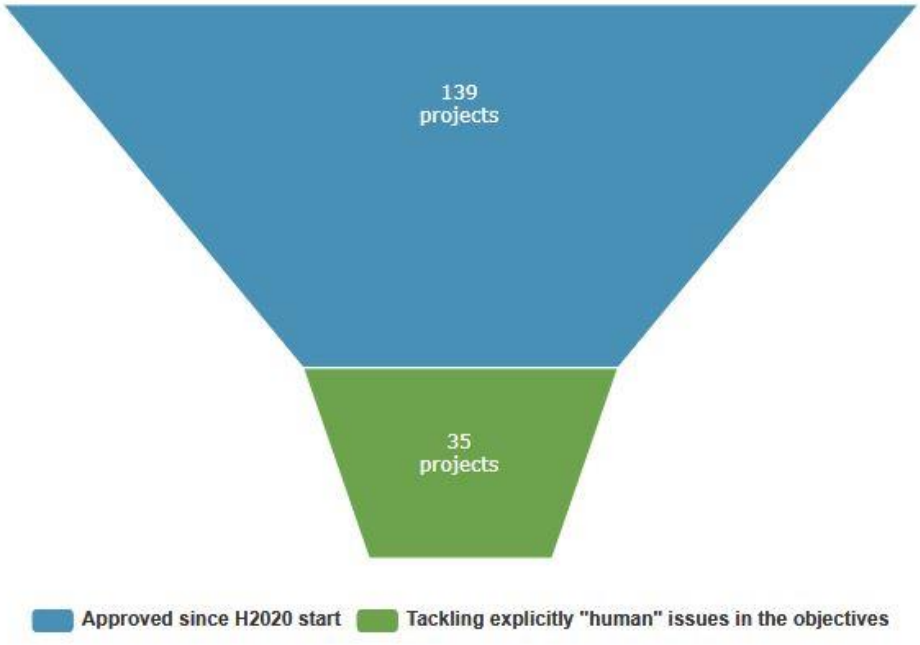
Please see below the categories of projects selected with the purpose of contacting the relevant stakeholders:

1. H2020 projects approved within the "Factories of the Future" (FoF) programme

139 projects have been approved since the beginning of H2020 in the frame of the FoF programme, including Innovation Actions (IA), Research and Innovation Actions (RIA) and Coordination and Support Actions (CSA).

Among them, we have selected those that are tackling explicitly "human" issues in the objectives stated in the respective webpage of the CORDIS database (35 projects).

Figure 15. Projects selected under the FoF Programme



Out of these, 4 are CSAs which are considered relevant for their contribution to the Policy Observatory. Thus, the selected FoF projects selected for the purpose of further analysis and questionnaire distribution are 31 (including 15 IAs and 16 RIAs). We decide to include both IAs and RIAs in order

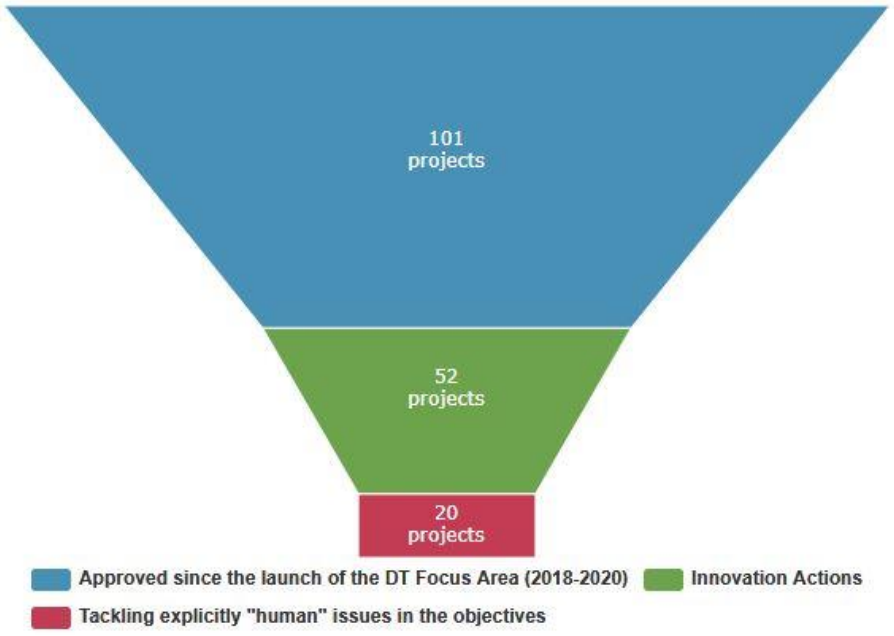
to secure the broadest possible stakeholder-type and geographical coverage in the analysis of the FoF programme which is central in the efforts of the EU to digitally transform European industry.

2. H2020 projects approved within the "DT Focus Area" from its launch (2018) up to date

101 projects have been approved in the frame of "DT Focus Areas" from its launch in the last triennial H2020 Work Programme 2018-2020.

Out of these 52 are Innovation Actions. Innovation actions (IA) consist of activities directly aiming at producing plans and arrangements or designs for new, altered or improved products, processes or services. For this purpose they may include prototyping, testing, demonstrating, piloting, large-scale product validation and market replication. IAs are then more focused on closer-to-the-market activities, thus more likely to offer DT examples with a higher level of maturity and nearer to adoption in real life settings. 20 out of 52 IAs in the DT Focus Area are tackling explicitly "human" issues in their objectives.

Figure 16. Projects selected in the H2020 DT Focus Area



3. H2020 projects approved in the frame of the EIC enhanced pilot

The projects approved under these two groups of calls are filtered according to the type of the innovation they propose.

For the purpose of the study, we decided to discard those projects whose innovation potential relies on:

a) improvements in the functional, technical or chemical characteristics of materials to achieve better performance indicators;

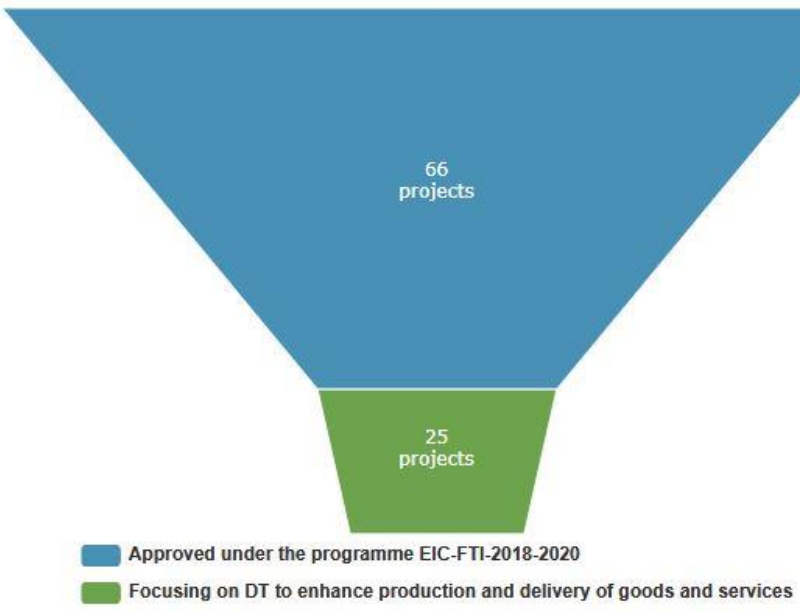
b) development of novel nanotechnologies or advanced materials, nanomaterials or nanoelectronic components;

c) enhancement of existing materials to meet ecological, health and safety regulations;

d) optimization and customization of industrial products to increase user-friendliness, transparency or unobtrusiveness;

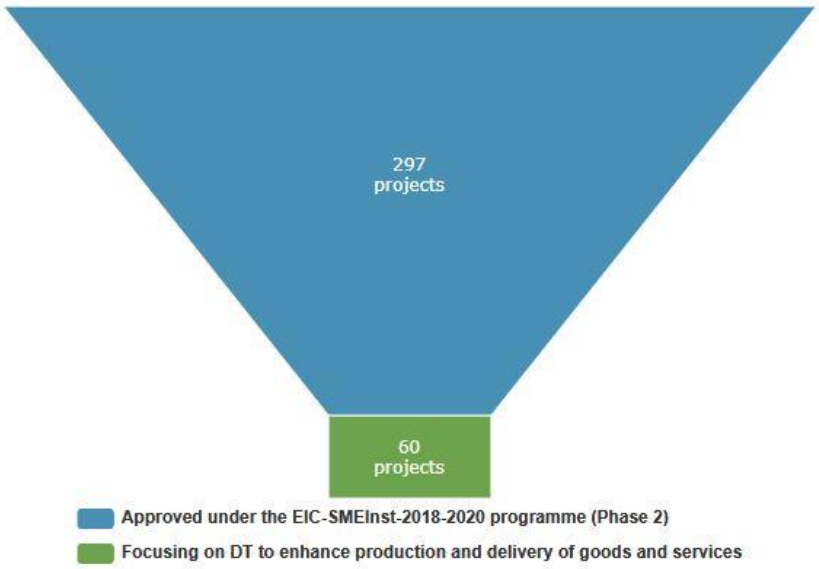
e) development of novel solutions for climate change and economy decarbonisation aimed to open new industries and markets.

Figure 17. Projects selected under the FTI programme



Based on that, the projects selected for analysis and for the distribution of the questionnaire are those which are aiming to digitally transform the way how goods and services and designed, produced and delivered, i.e. 25 out of 66 FTI projects and 60 out of 297 SME instrument-Phase 2 projects.

Figure 18. Projects selected under the SME Instrument Phase 2 funding mechanism



Due to the cross-sectoral nature and market-orientation of these two funding schemes, the description of the projects' objectives as stated in the CORDIS database don't provide sufficient information to assess whether the human issues raised by DT are tackled or not in the projects themselves, thus this aspect will require further exploration in the subsequent phases of the study.

4. Application experiments funded within the frame of ICT Innovation for Manufacturing SMEs (I4MS) Phase 3

The technologies supported by I4MS are Cyber-Physical Systems (CPS) and Internet of Things (IoT), Additive Manufacturing, Robotics and High-Performance Computing (HPC). Each technology area is represented by an IA that provides services to SMEs and mid-caps via different digital marketplaces. The IAs (which all belong to the FoF projects' family) and corresponding cross-disciplinary technologies considered in Phase 3 are:

- **AMable**: focuses on **additive manufacturing** services and has the aim of supporting small-batch production of personalized products without the need to acquire an expensive infrastructure.
- **CloudiFacturing**: focuses on **HPC cloud-based simulation services** and has the aim of providing SMEs with access to advanced simulation software and routines in a cost effective, reliable and quick manner.
- **MIDIH**: focuses on **Cyber Physical Systems (CPS) and Internet of Things (IoT)** in manufacturing processes and has the aim of enabling interoperability, decentralization of the decision-making process and the digitalization of products, manufacturing processes and business process behaviours.

- **L4MS**: focuses on **robotics** and has the aim of supporting SMEs in deploying cost effective and rapid automation of logistics on the manufacturing floor.

We have investigated the application experiments funded by each of them via an open call mechanism aimed at rewarding SMEs and mid-caps pioneering in DT, i.e. respectively: 22 experiments from AMable, 26 from CloudiFacturing, 34 from L4MS and 30 from MIDIH.

5. Selected Digital Innovation Hubs for further analysis and questionnaire distribution

The selection of the DIHs relevant for analysis and for the distribution of the questionnaire has been made using the online DIHs' catalogue.

It is important to remark that the information provided in the catalogue about each entry is based on self-declaration. Currently all the entries in the catalogue are being verified (based on the provided information) if they comply to the following 4 criteria:

- Be part of a regional, national or European policy initiative to digitise the industry;
- Be a non-profit organisation;
- Have a physical presence in the region and present an updated website clearly explaining the DIHs' activities and services provided related to the digital transformation of SMEs/Midcaps or industrial sectors currently insufficiently taking up digital technologies;
- Have at least 3 examples of how the DIH has helped a company with their digital transformation.

315 Digital Innovation Hubs are fully operational across EU. We decided to apply as search filter:

- The geographical coverage including the countries indicated in our service offer (Italy, Spain, Finland, France, Germany, Slovenia, Hungary, United Kingdom and Sweden plus Denmark and Estonia, as indicated during the study kick off meeting);
- The focus on Technology Readiness Level (TRL) from 6 to 9.

As a result, 175 Digital Innovation Hubs are selected.

Annex 3: Online Questionnaire

Section 1

To better identify the responders, the initial section of the questionnaire will **profile the responder** by means of the following questions:

1. What is your gender?
    - Male
    - Female
    - Other
2. What is the area of your studies?
    - Computer science
    - Natural sciences
    - Engineering
    - Economics
    - Humanities and Social sciences
    - Health sciences
    - Law
    - Other
3. In which country do you work? *(free answer)*
4. What sector do you work in?
    - Industrial manufacturing
    - Repair or maintenance
    - Energy and oil & gas
    - Transportation and logistics
    - Trade and services
    - Healthcare and wellness
    - Insurance or legal and finance or banking
    - Agriculture, farming or forestry
    - Aviation
    - Information technology/software
    - Entertainment and creative industry, publishing and media
    - Real estate and construction
    - Ports, coastal management or aquaculture
    - Other
5. How long are you working in this sector?
    - < 1 year
    - 1-5 years
    - 6-10 years
    - 11-20 years
    - > 20 years
6. What is your current designation?

- Worker
- Employee
- Manager or equivalent
- Snr. Manager or equivalent
- Director or equivalent
- CXO (e.g. Chief Executive Officer, Chief Technology Officer, Chief Innovation Officer, Chief Information Officer, Chief Operation Officer)
- Owner
- Other: please specify

7. Which is/are the working area/areas affected by the DT process you are/have been involved in?
    - IT systems
    - Marketing & Sales
    - Repair & Maintenance
    - Research & Development
    - Customer care
    - Production and assembly lines
    - Packaging
    - Quality prediction & control
    - Administration & accounting
    - Management
    - Other: please specify
8. Please describe the DT process you are/have been involved in, including obtained results and process duration: *(free answer)*

Section 2

The second section will **assess the perception of DT** and will propose the following questions:

1. According to your experience, select the main drivers pushing forward DT: *(up to 3 choices)*
    - Continuous rise of users' expectations
    - Accelerating pace of business
    - Changing competitive landscape
    - Digitalization pressure put by competitors' advances
    - Need for analytics and continuous intelligence to develop customer intuition
    - Personalization of goods and services
    - Data availability
    - Emergence of AI
    - Shift towards new value propositions
    - Innovative business models
    - Need to secure privacy and data protection
    - Adoption of design thinking and Agile methodologies
    - Regulatory changes
2. Please describe other drivers not listed above, if any: *(free answer)*
3. According to your experience, select the main barriers hindering DT: *(up to 3 choices)*

- Lack of understanding of digital trends
- Lack of talent for digital
- Cultural and behavioral resistances
- Lack of alignment between business and information system strategies
- Lack of change-oriented mindset
- Lack of capacity to leverage internal knowledge
- Reluctance in engaging in collaborative initiatives and partnerships
- Lack of market intelligence capabilities
- Inadequate organizational resources
- Low cross-functional collaboration

4. Please describe other barriers not listed above, if any: *(free answer)*
5. According to your experience, rank the main advantages related to DT application:
    - Reduced working load
    - Improved quality of work results
    - Improved quality of life in the working place
    - Decreasing of the risk of accidents
    - Decreasing of the number of errors
    - Increased qualification
    - Increased expertise
6. Please describe other advantages not listed above, if any: *(free answer)*
7. According to your experience, rank the main risks related to DT application
    - Social isolation
    - High mental load
    - Reduced personal privacy
    - Need of high specialization
    - Difficult adaptation to the new working practices
    - Work loss because of insufficient specialization
    - Strong control by employers
8. Please describe other risks not listed above, if any: *(free answer)*
9. Based on your experience, score the importance of acquiring new competences for achieving successful DT:
    - Very high
    - High
    - Neutral
    - Low
    - Very low
10. Rank the most effective training and skills development practices according to your experience:
    - Classroom
    - Individual serious gaming
    - Collaborative serious gaming
    - On the job training

- Simulation
- Other: please specify

11. Please indicate whether you think that the attitude to change working practices is determinant in DT success:
    - Strongly agree
    - Agree
    - Neutral
    - Disagree
    - Strongly disagree
12. According to your experience, rank the level of acceptance of potential actions to implement DT:
    - Recording of personal physical data
    - Wearing of sensors and devices
    - Changing of work environment
    - Mandatory training
    - Changing of working mates
    - Having a robot or other machine as working mate
    - Changing working hours
13. Summarize your experience with DT: *(free answer, max 1,000 characters)*

Section 3

The last section is aimed at identifying potential candidates for future interviewing by their level of knowledge of the topic. Here we will **assess the participation to DT in terms of on-going projects, initiatives at the responder's site as well as knowledge of the current policy frame,** including existing incentives and devoted actions.

1. The DT process you are/have been involved in is supported by:
    - Own resources
    - Public funding (if yes, please specify whether it is a regional, national or international funding programme)
    - Philanthropic funding
    - Venture Capital or other private funding
    - Tax incentives
    - Don't know
    - Other: please specify
2. Does your organization participate in Research, Development and Innovation projects to bolster its DT process?
    - Yes
    - No
    - Don't know

    If yes, please describe the most relevant and recent one

3. Apart from your experience with the DT process, are you aware of companies or projects in which a successful DT implementation is taking/has taken place? Please describe shortly these DT processes: *(free answer)*
4. Are you available for further discuss this topic in a phone interview on in a face to face meeting?
    - Yes
    - No

      If yes, please supply your e-mail address.

Annex 4: Profiles of questionnaire respondents

Th following figures illustrate the demographic and professional profile of the 84 questionnaire respondents.

Figure 19. What is your gender?

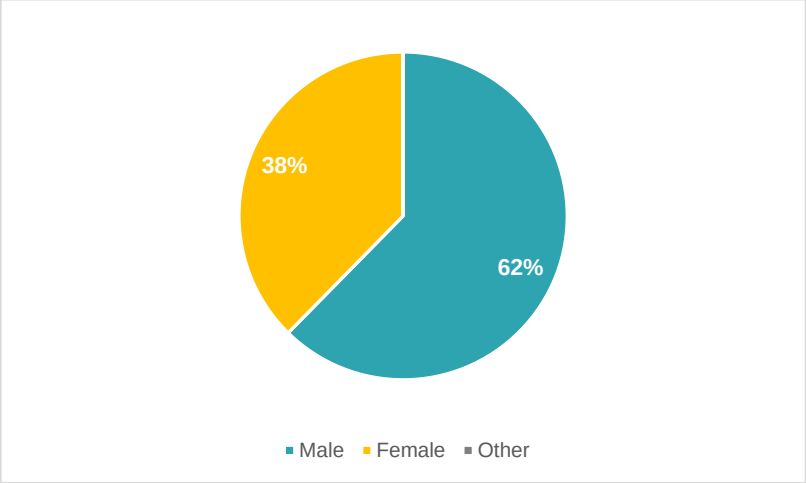


Figure 20. What is the area of your studies?

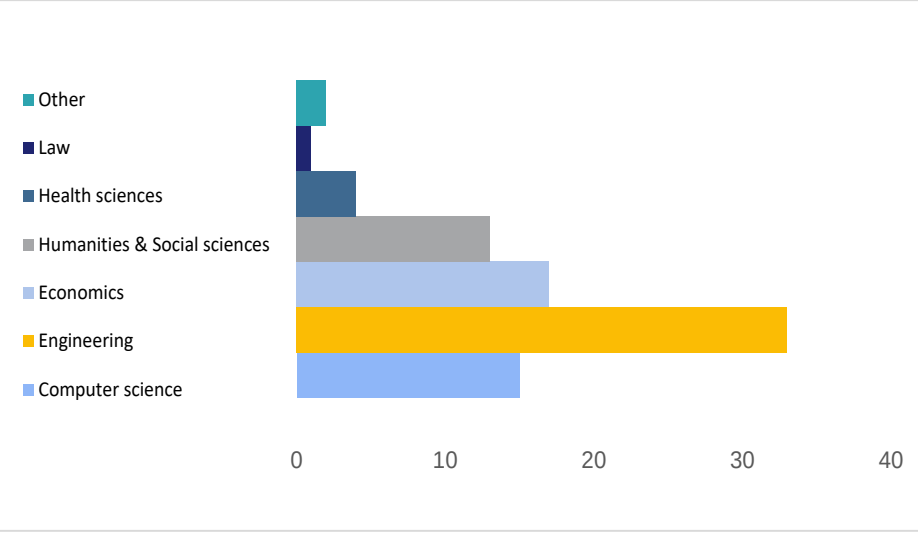


Figure 21. What country do you work in?

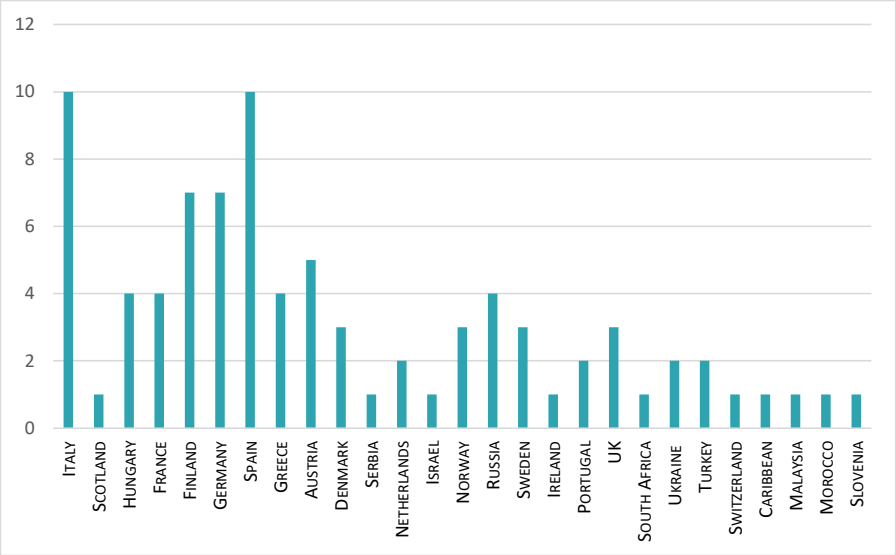


Figure 22. What sector do you work in?

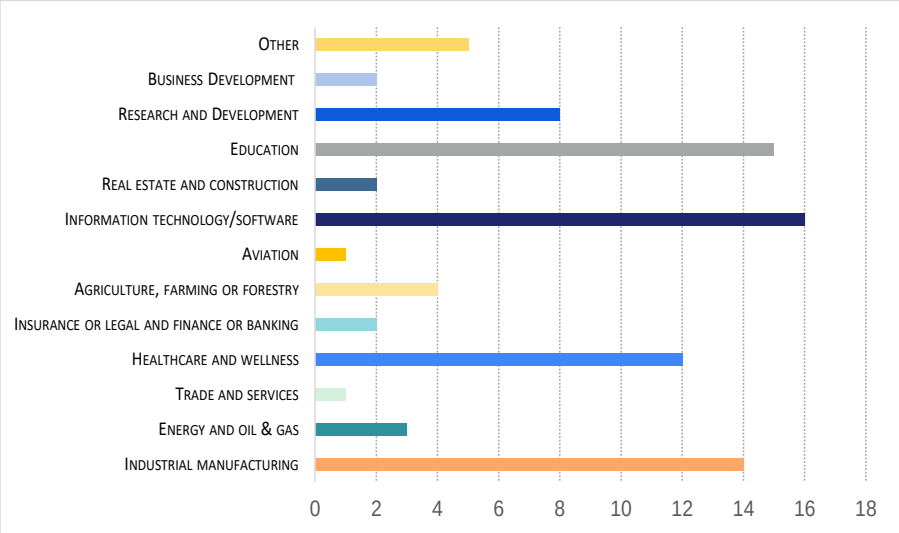


Figure 23. How long have you been working in this sector?

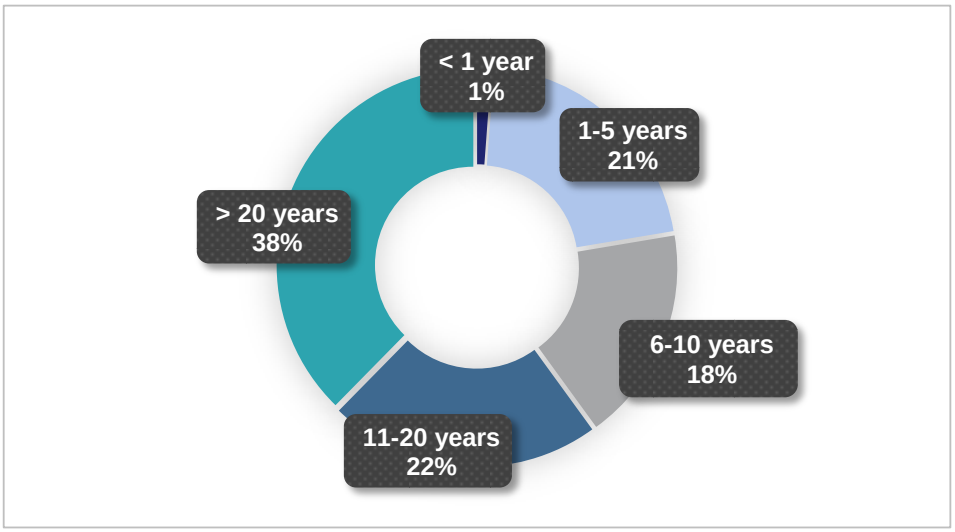


Figure 24. What is your current designation?

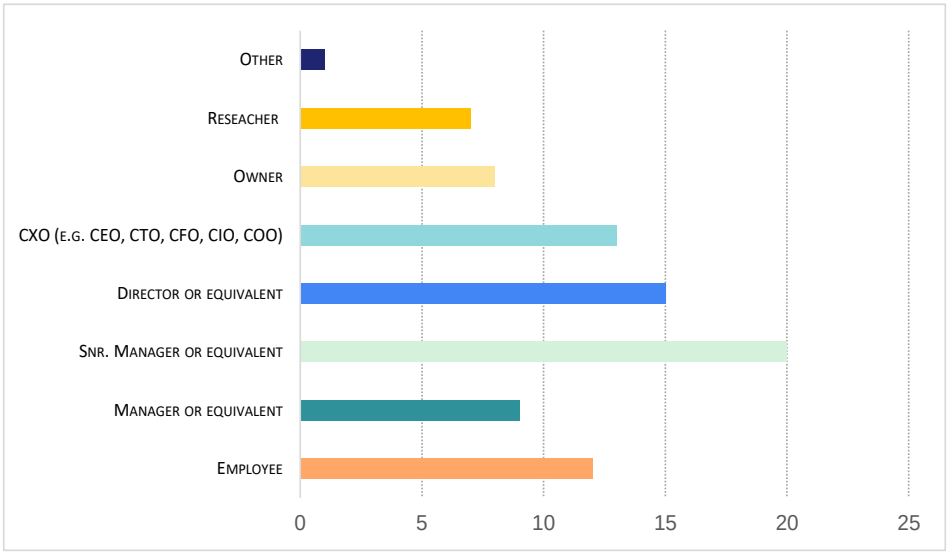
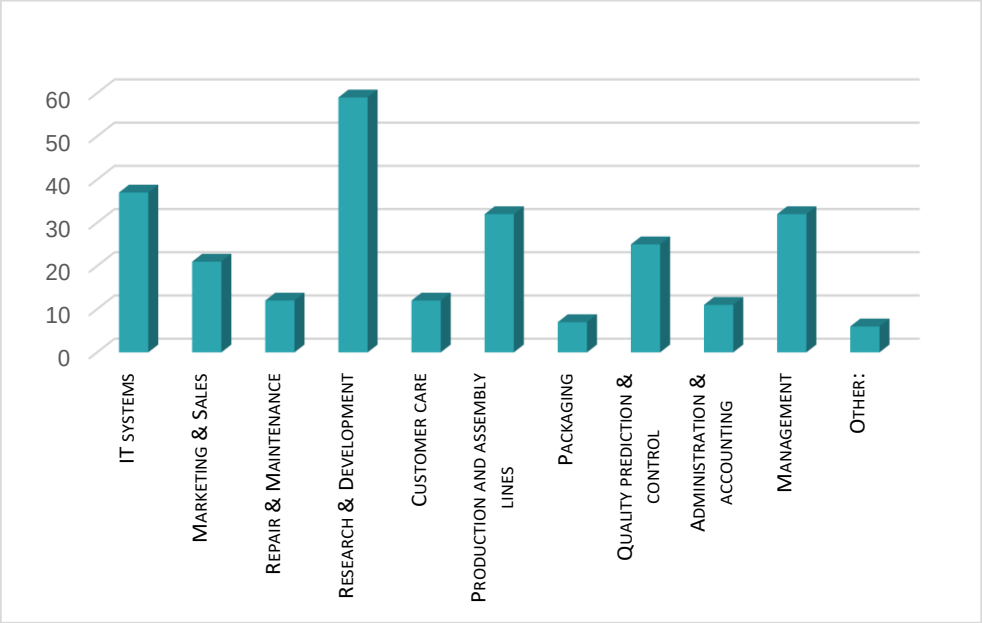


Figure 25. Which is/are the working area/areas affected by the DT process you are/have been involved in?



Annex 5: Interview protocol

Through the interviews, we aimed to identify and review **exemplary cases of digital transformation processes in goods and / or services production and delivery with a specific view on how the human factors has been taken into account and the risks connected to implementation of such processes have been dealt with**.

We intended investigate specific "use cases", i.e. examples of Digital Transformation (DT) processes that, in the opinion of the selected experts, are to be considered successful because of e.g. the involvement of changes in leadership, establishment of different thinking and cultural changes, the encouragement of innovation, governance transformation and new business models, the digitisation of assets and an increased use of technology to improve the experience of your organisation's employees, customers, suppliers, partners and stakeholders. The aim of each interview was thus to collect information, data and relevant insights on a specific case that have been elaborated in the factsheets included in Chapter 4 illustrating: a) the general context of the sector the case refers to, b) the description of the DT process, c) its main outcomes and impacts and d) the way how its effects on humans have been handled.

To this purpose, we kindly asked the interviewee to answer the following questions:

1. **Briefly describe an exemplary case of DT that you know well and you regard as successful:**
    a. What was the aim of the DT?
    b. When and where did it take place?
    c. What type of organisation did it affect?
    d. How were you involved?
    e. Why do you think that it was successful?
2. **Why was this DT put in place – and by whom?**
    a. Who was involved?
    b. What was the need behind it?
    c. Who was the originator of the DT?
    d. Who were the technological suppliers?
    e. Any other stakeholder involved?
3. **Was the final objective clear at the beginning of the process?**
    a. Was the result the expected one?
    b. If not, why did it change?
4. **What kinds of issues have the implementation run into and how they have been resolved?**
    a. Have there been any delays in the implementation? Why?
    b. If there were difficulties, who solved them?
    c. Was it necessary to involve any additional professional? Who and why?
5. **Specifically, what have been the main technical challenges in implementing the digital transformation?**

a. Which were the main technological innovations introduced?
b. Had the DT process a technological focus or an organizational/operational one?
c. Have there been any technical difficulties in the implementation?
d. For whom?

6. **Specifically, what have been the main challenges related to the new role of the workers/customers?**
    a. Did the role of the workers change?
    b. Did the way how workers collaborate/interact with her peers and/or the managerial staff change?
    c. Did the relationship with the customers change?
    d. Was it necessary to train workers?
    e. Were the customers satisfied with the DT?
    f. Were the workers satisfied with the DT?
    g. Any other non-tech challenge you would remark?
7. **Were workers/customers involved in the implementation process?**
    a. Were the workers among the originators/proposers of the DT?
    b. Were the customers among the originators/proposers of the DT?
    c. Was the DT presented/discussed with the workers?
8. **What benefits has the DT process generated for the organisation?**
    a. Has there been an increase in production/sales?
    b. Has there been an improvement in the quality of work?
    c. Has there been an improvement in the sustainability of work?
9. **Have you experienced any unintended effect (either positive or negative) of the DT adoption? If yes, please describe.**
10. **Has the implementation process been influenced by policies and funding possibilities?**
    a. Have public funds been used in implementing the DT?
    b. Has the DT process followed any policy recommendation or been aligned with regional or national strategies?
11. **Is the organisation monitoring the impacts of the implemented DT?**
    a. If yes, what type of impact indicators are they tracking / measuring?
    b. Is the organisation monitoring the effects on workers, customers/users and other actors involved?
12. **What would you change in the adopted DT?**
    a. Do you think that the process could have been better managed? Why?
    b. If, in the future, you are in charge of implementing a similar process, will you run it in the same way?

Annex 6: Focus group guidance document

In this last phase of the study we aimed to deepen the investigation of the positive exemplary cases (objects of previous interviews) of Digital Transformation processes in goods and / or services production and delivery, with a specific view on how the human factors has been taken into account. This investigation was conducted by means of an open discussion among the different stakeholders involved in the project through a devoted focus group.

The focus groups were setup involving the actors that were active in the overall process, from technology design to its adoption in the workplace or the society.

The aim was to collect insights from real life cases and draw recommendations that may support the whole Digital Transformation process and help maximise its positive impact on the economy and the society. We setup groups of 4 or 5 people to represent the main relevant professional actors involved in the DT experience, for example management, human resources, production, sales, R&D, IT, Technology Supplier/Consultant.

The open discussion developed around the following questions:

1. Were you among the originators of the DT idea or when were you involved in the process? Which has been your role?
2. Have been your initial expectations fulfilled by the final result?
3. Was this experience also an opportunity for your personal growth?
4. Are the work activities/responsibilities/relationships in the company changed? How?

The time slot for each focus group was around 60-90 minutes.

European Economic
and Social Committee

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1040 Bruxelles/Brussel
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Published by: "Visits and Publications" Unit
EESC-2020-106-EN
www.eesc.europa.eu

Print
QE-01-20-716-EN-C
ISBN 978-92-830-5132-9
doi:10.2864/858419

Online
QE-01-20-716-EN-N
ISBN 978-92-830-5131-2
doi:10.2864/733324

EN