SODIMA

Social Dialogue for the Future of Manufacturing

Digitalization and automation in the manufacturing sector

Literature review

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Digitalization and automation in the manufacturing sector are among the most important challenges for the social partners representing companies and workers. Trade unions and employers' associations are facing today a difficult and rapid transition (due to Internet of Things, Big Data, Collaborative Robotics, 3D Printing, Artificial Intelligence) which must be governed so that it does not generate the loss of millions of jobs, as several studies have predicted.

The objective of the parties must be to reconcile the protection of work with that of greater competitiveness and productivity for companies. This is why new skills, training and work organization are as fundamental as urgent aspects to deal with. Yet these are elements that cannot be achieved unilaterally by any of the parties involved.

For this reason, the SoDiMa project sets out to put social dialogue at the center of the transition towards the manufacture of the future and wants to do it right at the European level, by strengthening the Sectoral Social Dialogue Committee on Metal Industry answering to the challenges of the EU document. A new start for social dialogue, its activities and its visibility with new and innovative results and activities. The reinforcement of the Committee and the involvement of countries with different maturation levels of digital manufacturing will favor the exchange of good practices and the development of guidelines that can help individual states to increase both business innovation levels and workers' skills.

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Chapter 1.
Definition of Industry 4.0

From a historical point of view, the term Industry 4.0 was firstly utilized in Germany (*Industrie 4.0*) at the Hannover Messe of 2011. In this occasion, the President of Acatech (the German Academy of Sciences and Engineering) H. Kagermann presented the first results of a group of work called *Platform Industrie 4.0* born from the will of the biggest associations of enterprises (BITKMO, VDMA and ZVEI) in order to gather the consensus of 6 thousand enterprises, H. Kagermann, W. D. Lukas, W. Wahlster, *Industrie 4.0: Mit dem Internet der Dinge auf dem Weg zur 4. industriellen Revolution*, in *VDI nachrichten*, 2011, 13. Following this, in 2013, the recommendations of this group of work were presented, in a detailed report called *Recommendations for implementing the strategic initiative INDUSTRIE 4.0*, that defined Industry 4.0 as "the result of the introduction of the Internet of Things and Services on the manufacturing context".
But given the variety of definitions possible is important different bring back, making a clear distinction between three types: institutional definitions, present to internal economic policy strategies of nations or the European institutions, the definitions from the consultancy world, who produced many reports on the subject and, finally, the definitions of the scientific community.
On the institutional front, German Chancellor Angela Merkel has called *Industrie 4.0* as "the complete transformation of the whole sphere of industrial production through the fusion of digital technology and the Internet with the conventional industry" *(Speech by Federal Chancellor Angela Merkel at the OECD Conference,* 2014), while on the front of the Italian *Public consultation on "Industry 4.0": which model to apply to Italian industry. Tools to favour the digitization of national industrial chains*, carried out by the X Commission of the Chamber of Deputies, speaks of an "emerging industrial paradigm, which will determine an industrial revolution comparable to those that have occurred in the last three centuries", does not identify itself however a specific technology that characterizes the revolution but "a set of enabling technologies that come to aggregate thanks to the internet in a systemic way in new productive paradigms". From the European point of view, the European Parliamentary Research Service defines *Industry* 4.0 as "a term applied to a group of rapid changes in the design, construction, the operation and maintenance of production systems and products" *(Industry 4.0 Digitalisation for productivity and growth,* 2015), while the ITRE (Committee of European Parliament on Industry, Research and Energy) speaks of an "organization of production processes based on the

technology and tools that communicate independently with each other along the value chain".

As for the definitions given by the consulting firm Roland Berger highlight how the concept of Industry 4.0 emphasizes the "idea of a substantial digitization and access to all production units in an economy" (*INDUSTRY4.0 The new industrial revolution. How Europe will succeed*, 2014, at http://www.iberglobal.com/files/Roland_Berger_Industry.pdf), while for Germany Trade & Invest in *INDUSTRIE 4.0. Smart Manufacturing for the Future*, 2014, *Industrie 4.0* is "the fusion of the virtual and the physical world through computer-physical systems and the resulting fusion of technical processes and business processes are leading the way to a new industrial age". McKinsey, however, defines the phenomenon from four different disruptive consequences arguing that it is the "next phase of digitization of the manufacturing sector, driven by four disruptions: 1) increasing the volume of available data; 2) the ability to analyse them; 3) new forms of human-machine interaction; 4) ability to transfer digital information to the physical world" (C. Baur, D. Wee, *Manufacturing's next act*, McKinsey, 2015). Boston Consulting Group, in *Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries*, 2015, refers instead to a transformation in which "sensors, machinery, components and IT systems will be connected along the value chain in addition to the single company".

While on the academic front, in the field of scientific-engineering literature on the subject M. Hermann, T. Pentek, B. Otto in *Design Principles for Industrie 4.0 Scenarios: A Literature Review*, Technische Universität Dortmund Working Paper, 2015, n. 1, on the basis of a review of the literature and identifying key technologies to reach a broader definition: "Industry 4.0 is a collective term for technologies and concepts of the organization of the value chain. All inside of the Smart Factory structured in modules, Cyber Physical Systems (CPS) monitor physical processes, create a virtual copy of the physical world and produce decentralized decisions. Thanks to the Internet of Things (IoT), the CPS communicate and cooperate with each other and with human beings in real time. Through the Internet of Services (IoS), they are offered and organized by all participants of the value of services both internal chain between different organizations". While H. C. Pfohl, B. Yashi, T. Kurnaz in *The Impact of Industry 4.0 on the Supply Chain*, Proceedings of the Hamburg Interrnational Conference of Logistics (HICL), 2015, define digital manufacturing starting from the innovations that it involves, as "the sum of all the disruptive innovations that derive and are implemented in a value chain to achieve the objectives of digitalisation, autonomy, transparency, mobility, modularization, network collaboration and socialization of products and processes". According to V. Roblek, M. Mesko, A. Krapez in *A Complex View of Industry 4.0*, in *SAGE Open*, 2016, 1-11, are three aspects on which the new paradigm affects: the digitization of production, the automation and the connection between various establishments in a unique *supply chain*. A similar view is found in

F. Almada Lobo, *The Industry 4.0 Revolution and the Future of Manufacturing Execution Systems (MES)*, in the *Journal of Innovation Management*, 2015, 16-21 and, with a more practical-operational approach, in J. Schlechtendahl, M. Keinert, F. Kretschmer, A. Lechler, A. Verl, *Making existing production systems Industry 4.0-ready*, in *Production Engineering*, 2015, 143-148.
The German model, the first to be developed, identifies the CPS as fundamental and true element of discontinuity. These are called "integration between computation and physical processes, built-in computers and networks that monitor and control physical processes" from E. A. Lee in *Cyber Physical Systems: Design Challenges.* 11th IEEE Symposium on Object Oriented Real-Time Distributed Computing, 2008. A similar definition is provided by E. Geisberger, M. Broy, *Living in a networked world. Integrated research agenda Cyber-Physical Systems*, Acatech, 2015, "The CPS is the product of development and of integrated use of two of innovation fields: systems that contain software and global data networks like the Internet and distributed application systems and interactive. These are used through a powerful infrastructure that is composed of sensors, actuators and communication networks that are used by companies that operate and collaborate globally". In practice, these systems are implemented through machinery, infrastructures and connected tools, so that they can interact with each other not only through physical-mechanical actions, but thanks to sensors, through the network. Interaction between IT and physical systems is also recognized by others, which define *Industry* 4.0 as "a powerful concept, which promotes the full integration of the production of IT and control systems with integrated physical objects with the electronics, software, sensors and connectivity", J. Lee, B. Bagheri, H. Kao, *The Cyber-Physical Systems of Industry 4.0*, Elsevier, 2015. At the base of the CPS system are the introduction to the Internet of Things (IoT). According Forschungsunion and Acatech, the "Industry 4.0 is in fact the outcome of the introduction of the Internet of Things to the production environment". For IoT it means "things and objects such as RFID, sensors, actuators, mobile phones, through unique address schemes, the interacting with each other and cooperate with their neighbours smart components to achieve common goals", L. Atzori, A. Iera, G. Morabito, *The Internet of Things: A Survey*, in *Computer Networks*, 2010, vol. 54, n. 15, 2787. The term was coined by K. Ashton to indicate the "use of the Internet to connect with each other objects in the physical world", also see the *white paper,* D. Evans, *The Internet of Things. How the next evolution of the internet is changing everything*, Cisco, 2011, while the results contained in A. Whitmore, A. Agarwal, L. Da Xu, *The Internet of Things, A survey of topics and trends*, in *Information Systems Frontiers*, 2015, 261-274, are interesting on the diffusion of the technology and its types of use.
The cyber-physical environment would thus be made possible by the connection between objects, each with its own IP address, that

communicate reciprocally (Acatech, *Cyber-Physical Systems Driving force for innovation in mobility, health, energy and production,* Acatech position paper, 2011). This allows, for example, for a production chain to have each of its components not only connected through physical components (tapes, mechanical arms, etc.), guaranteeing constant synchronization and optimization of production thanks to continuous data analysis (so-called *big data*) processed by the individual digitized components. All IoT then joined the *Internet of Services,* as well defined as comprising the ability for "service sellers, selling them over the Internet" it is composed of "participants, from infrastructure to services, from business models and services themselves. The services are offered and combined through value-added services by various bidders; they are communicated to users as well as to consumers who access it through different channels" according to P. Buxmann, T. Hess, R. Ruggaber, *Internet of Services*, Business & Information Systems Engineering, 2009. A further fundamental element, which arises in part to the basis of the above, is the "huge availability of data in the hands of those who govern and manage the production processes" (L. Wang, G. Wang, *Big Date Cyber-Physical Systems, Digital Manufacturing and Industry 4.0,* in *International Journal of Engineering and Manufacturing*, 2016, No. 4, 1-8). Huge both in terms of size (this is called *big data*; R. Buyya *et al*., *Big Data: Principles and Paradigms*, Morgan Kaufmann, 2016) and from that of the number of sources that produce the data themselves, being sensors now inexpensive both in the implementation in the production chain and in the products themselves. The illustration of specific technologies could go on and on, like the development of artificial intelligence (AI) and the *machine learning* understood as the ability of machines to acquire not only information but process them and learn independently from mistakes and processes (P. Angelov, *Autonomous Learning Systems*, Wiley, 2012, and more recently S. Shalev-Shwartz, S. Ben-David, *Understanding Machine Learning. From Theory to Algorithms*, Cambridge University Press, 2014).

In addition to the definitions developed in the academic field, it seems useful to report the point of view of the business world on this evolutionary phenomenon in which they are involved on a daily basis.

It is noteworthy to mention that not all reports define Industry 4.0 as a revolution, but some rather ask if Industry 4.0 is an "evolution" more than a "revolution", e.g. see Deloitte, *Industry 4.0 – Challenges and solutions for the digital transformation and use of exponential technologies*, 2015, available at: http://www2.deloitte.com/content/dam/Deloitte/ch/Documents/manufacturing/ch-enmanufacturing-industry-4-0-24102014.pdf; Vde Association for Electrical, *The German standardization roadmap Industrie 4.0, Electronic & information technologies*, 2014, available at: https://www.dke.de/de/std/documents/rz_roadmap%20industrie%204-0_engl_web.pdf, which the latter mentions that the users of the new technologies, are still by no means sure whether this will be a further

revolution or rather an evolution of the existing concepts. Simone Casiraghi, researcher at the Ipsoa Juridical Studies Center, in his paper *Il lavoro 4.0 nel modello di fabbrica intelligente. Il caso Cosberg: la conoscenza e i saperi diventano condivisione globale*, in A. Cipriani, A. Gramolati, G. Mari (edited by), *Il lavoro 4.0: the fourth industrial revolution and the transformations of the working activities*, Firenze University Press, 2018, shows that the undertaking's world welcomes the evolutionary approach, but launches a warning: "let's not call it revolution. It is an innovative journey that has been underway in Germany for some time and is now in full swing throughout Europe. In my company for at least ten years. Today it sounds so much like slogans that it often creates big problems. No, I would rather call it an evolution" (p. 550).
Enrico Ceccotti, currently coordinator of the Scientific Committee for Industrial Evaluation of the National CGIL Coordination of Industrial Policies, in *Organizzazione di impresa e del lavoro nelle aziende innovative,* in *A. Cipriani, A. Gramolati, G. Mari* (edited by), *Il lavoro 4.0 la quarta rivoluzione industriale e le trasformazioni delle attività lavorative*, Firenze University Press, 2018, brings more case studies in which analyses the organization of business and labour of some innovative companies providing the basis to benchmark their features: Google Italy, IBA and Digital Foundries. Google Italia declares in its strategy to want to accompany the Italian production system to become a *digital company system*. The second case analysed by Ceccotti relates a curious case of encounter between a multinational vanguard specialized in particle physics research (IBA Ion Beam Application) and a public health facility, the ASL of Trento. Full integration between the medical and technological system meets bureaucratic and legal limits, such as the management of the processing of public health data. The same systematic approach of Industry 4.0 is also successful in this case as it is necessary; however, by comparison with the medical director of the centre it showed that, unlike other countries, there still is this vision in Italy. Fonderie Digitali is a start-up that in itself contains the artisanal character of Italian companies and the American propensity for Silicon Valley to catalyse *young geeks*. It is a network that brings together around 50 companies, investors and institutions. You get into this business network under the "invitation of the network manager. Values are crucial, people need to be collaborative and well. If they do not respect this constraint they have no space in the network. Stay in the network is not a right but a opportunity" (p. 567). The actors involved are distinguished by being extremely collaborative, correct and proactive. The network has understood that to ask people to be productive and creative they need to be satisfied with their work and therefore they must be put in a position to be so. This condition goes for a working environment more free and flexible with timetables.
Alberto Cipriani, collaborates with Fim Cisl (Italian trade union) in the design and implementation of organizational innovation laboratories,

collected two interviews with managers who deal with technological and organizational innovation in everyday life and describing the developments in progress s work in relation to the Fourth Revolution industrial (Davide Guarnieri of AIDA and Roberto Napione of Skf). Davide Guarnieri, Executive Vice President of AIDA (multinational manufacturer of presses with Italian headquarters in Brescia and employing 1500 employees worldwide) believes that it is "necessary to rethink the production system through a profound cultural revolution by developing the appropriate skills in young people to be strong driving force of this process. Consequently, agreements are needed with the University, and with the business system to generate an innovative and systematic cycle. We lack the logic of the system" (p. 557).

Lastly, according to CAREL's COO Pietro Rossato *(La ROADMAP digitale del Gruppo CAREL, in Ricomincio da 4, 23 febbraio 2018*), Industry 4.0 is "a technological challenge, cultural and organizational, business, to be part of the corporate strategy: the implementation of digital solutions create value for our customers and for the Company".

Chapter 2.
The overall impact of digitalization on work in manufacturing

2.1. The human-machine cooperation in Industry 4.0

The way tasks are performed in the scenario of Industry 4.0 has been a topic analyzed by literature, with a particular focus on the way humans and machines interact in order to produce. On this front, the most up-to-date research and studies are summarized in the *Handbook of Human-Machine Interaction* by GA Boy, CRC Press, 2017 which adopts an approach focused on the person of the worker, developing an analysis of the technical aspects and potential considering them but in particular the consequences on emotional, psychological and sociological aspects. Some studies have then put forward hypotheses of concrete application of complementarity models between the technologies that identify the *Industry* 4.0 paradigm. In particular in D. Romero, T. Wuest, J. Stahre, A. B. Fasth, *Towards an Operator 4.0 Typology: A Human-Centric Perspective on the Fourth Industrial Revolution Technologies* in *CIE46 Proceedings,* 2016, is the concept of '4.0 Operator' was developed intending for it, "a worker smart and knowledgeable that not only plays a 'work cooperative' with robots but also 'work aided' by machines when and if necessary by human cyber-physical systems, advanced man-machine interaction technologies and adaptive automation towards man-automation symbiosis work systems". The objective would be to "build trust and interactive relationships between men and machines, making it possible for smart factories to capitalize not only on the basis of the strength and capacity of intelligent machinery, but also to strengthen their 'smart operators' with new skills and tools to maximize the opportunities created by Industry 4.0 technologies". This could happen through different systems, in particular through a particular CPS declination in terms of *human cyber-physical production system* (H-CPPS) understood as "a work system that improves the skills of the operators through a dynamic interaction between men and machines in physical and virtual worlds through 'intelligent interfacesman-machine'". This translates into different hypothetical hybrid figures, we think, for example to *Augmented Operator* using the augmented reality technology to enrich the working environment with data, sounds, images, graphics that can contribute to a better enforcement of performance both in terms of experience and productivity.
There are also some trials already underway relating to the use of collaborative robot in complex environments. An interesting example is

that of the *AssistMe* project during which specialized operators learned to use a robot in different environments, first in the laboratory, then in the context of a factory and then directly in a production line (A. Weiss, A. Huber, J Minichberger, M. Ikeda, *First Application of Robot Teaching in an Existing Industry 4.0 Environment: Does It Really Work?*, in *Societies*, 2016). F. Bonsignorio in *Umani e robot: possibili alternative nell'evoluzione della divisione tecnica del lavoro*, in A. Cipriani, A. Gramolati, G. Mari (edited by), *Il lavoro 4.0: the fourth industrial revolution and the transformations of the working activities*, Firenze University Press, 2018, 63, highlights "how alternative technological solutions, even very different from each other, ultimately depend on cultural, social and political choices" (p. 64). The Author believes that it is never been an engineering objective and naturally grows and therefore recognizes a crucial to activities of entrepreneurs, engineers and generally anyone involved in the development of new technologies and he uses them, not least the workers of the industry and their representatives. In a context of markets turbulent, the priority according to the Author should not be to reduce the cost of labor, but the need to provide "rapid response to market changes, the ability to guide and anticipate the evolution, resilience and above all the continuous production and process innovation in a context of scientific and technological progress that is constantly accelerating" (p. 69). Only in this perspective it will be possible to meet the scheme need for complex skills required by today's industrial revolution: the hope is to be able to build on existing skills (stratified in the social body for decades if not centuries of collective learning) new common knowledge, integrating and developing new scientific and technological knowledge that you are acquiring globally and in our country. While moving from these premises, it recognizes in the advent of new technologies opportunities never seen, which could even make possible a mass renaissance, where there is a commitment as well as technological, cultural, political, economic and social.
In a similar sociological perspective, F. Veltri (*Dalla piramide alla clessidra. Verso una nuova divisione del lavoro sociale?*, ibid, 525) taking up the studies of Durkheim, compares the image from Author proposed a pyramidal society (where the base there are the many menial jobs, we proceed towards the tip to the few most qualified, through a series of intermediate functions) with that different, current of the hourglass. The Industry 4.0 has resulted in a rapid increase, on the one hand, the least skilled jobs and by another of those hyper-skilled (managers, engineers), drastically thinning the number of intermediate occupations (employees and workers).

2.2. The nature of work

The Fourth Industrial Revolution impacts on the work act, reducing the boundaries between sectors, between subordination and autonomy, as

well as between work defined as 'manual' and 'intellectual' work. Laura Pennacchi (*Innovazione e lavoro: la cerniera umanistica tra macroeconomia e microeconomia*, in A. Cipriani, A. Gramolati, G. Mari (edited by), *Il lavoro 4.0: the fourth industrial revolution and the transformations of the working activities*, Firenze University Press, 2018), proposes an idea of work as freedom, autonomy, creativity, democracy: therefore, the conception of work as a practical-manipulative activity loses its centrality. In this regard Enzo Rullani (*Work in transition: proofs of the Fourth Industrial Revolution in Italy*, in A. Cipriani, A. Gramolati, G. Mari (ed.), *op. cit.*) Suggests that we need to react to this devaluation of work purely executive, looking more closely at the new jobs that are taking shape: smart jobs, with a high content of generative knowledge, which give the worker strong autonomy. This changes, therefore, even the organization of work, being that activities are no longer bound by regulations and merely derived from the top of the organization and hierarchy, but rather oriented to the result to be achieved. In this new scenario, the employee can self-organize within the working environment, thus losing contact with the traditional image and subordinate employee scheme.
In the attempt of a difficult definition of the work of the future, the contribution of Giovanni Mari (*Il lavoro 4.0 come atto linguistico performativo. Per una svolta linguistica nell'analisi delle trasformazioni del lavoro*, in A. Cipriani, A. Gramolati, G.) is useful. Mari (eds), *op. cit*., 315) which states how the work 4.0 consists of a "linguistic performative act", whose strength was fulfilled precisely in the recomposition of those elements that have always been separate, all inside of dualism mental work / manual work. The idea that work 4.0 marks the overcoming of the division between intellectual and manual work is also confirmed by Francesco Totaro (*Lavoro 4.0 e persona: intrecci e distinzioni*, ibid, 475), which emphasizes how this represents, in fact, the discontinuity of the work of knowledge than all mechanical setting of Fordist organization of production.
Ubaldo Fadini (*La società entra in 'fabbrica': il lavoro nel tempo dell'Industria 4.0*, ibid, 263) puts emphasis on the necessity of overcoming the rigid division between the working tools and the same power-individual work. What appears to rely to an increasing extent it is the self-organization, and a clear recovery of leadership on the part of the subject of work or what Mari interprets as self in the work, which is embodied in the right to a chosen work, quality, to freedom *in* work, with high cultural and professional contents, which can be updated and perfected in continuity. Even if you try to answer all the question related to the nature of the job 4.0, it is not easy to come to a clear conclusion.
Interesting is the contribution of Federico Butera who emphasizes a new idea of work: a work of knowledge based on the responsibility of results, which requires technical and social skills. The work of the Fourth Industrial Revolution – alternative to the Taylor-Fordist one, based on tasks resulting from a division of labor – will consist of new and profoundly modified

roles, professions and tasks, generated not by the inevitable "effects of technologies" but by design capable of reinventing a new basis l idea of craft and profession. It can therefore be centered on the professional model, in the perspective of a "professionalization of all", not just managers and professionals. The professions and *service professions* model could, therefore, become a plausible reference paradigm also for operational works and, in perspective, could unify dependent work and self-employment, the work of symbolic knowledge and the craft one. On the centrality of professionalism focuses, in particular, the reflection of P. Causarano, according to which it is precisely in the transition between old and new technologies that would emerge with force l aspect of professionalism, suitable to overcome between intellectual work historical dichotomy (for the enterprise) and manual labor (in enterprise) and characterized by the combination – from the point of view of autonomy and control over the production process – the three specific dimensions: knowledge, skills and interpersonal skills.

2.3. The impact on working conditions and changes in health and safety measures

From one end, the digitalisation of the workplace in the manufacturing sector has the consequence of lessening the dangers of moving mechanical components and as such reduces some of the environmental dangers involved in working the sector. Furthermore, even the tasks that still rely on this type of work are now tightly controlled by sensors and tags, being on the machinery itself, being on the worker equipment, see Eurofound, *The future of manufacturing in Europe*, Publications Office of the European Union, Luxembourg, 2019, 52, McKinsey Global Institute, *The internet of things: Mapping the value beyond the hype*, McKinsey & Company, Toronto, that estimated a decrease of insurance costs from accidents around 10-20%.

Notwithstanding the clear advantages that arise from the digitalisation of the manufacturing workplace, there still needs to be some consideration regarding the psychological effects of this new way of organising work, as it has been reported that workers tend to feel alienated from their work experience, loss of social identity and personal self-worth, Eurofound, *The future of manufacturing in Europe*, Publications Office of the European Union, Luxembourg, 2019, 52.

These risks are also highlighted by EU-OSHA, that emphasized how technology and Industry 4.0 mode of production removes humans from the equation of hazardous environments, but at the same time introduces new types of dangers for them, like psychosocial risks. In the report *Foresight on new and emerging occupational safety and health risks associated digitalisation by 2025 — Final report*, p. 66, this organisation also states that the new way of working and producing in the context of Industry 4.0 may lead to work-related stress risks, considering the "impact of increased worker monitoring made possible by advances in and the increasing ubiquity of wearable ICT-ETs, 24/7 availability, blurred boundaries between work and private life, and the online platform economy". Beside the exploration of the sources related to the risks arising from the usage of such monitoring practices, it is also possible to identify scientific sources reporting the reverse side of the coin, namely possible positive consequences of monitoring practices (i.e. via wearable devices and HR analytic tools). For example, R. Burke et al., *The smart factory. Responsive, adaptive, connected manufacturing*, 2017, identifies possible benefits in terms both of health and safety and work sustainability with reference to the process of transforming companies into smart factories. Moreover, D. Romero et al., *Towards an Operator 4.0 Typology: A Human-Centric Perspective on the Fourth Industrial Revolution Technologies,* in CIE46 Proceedings, 2016, argues that information derived from wearable devices through the usage workforce analytics could

be used to better evaluate working loads in order to take a proactive approach towards health and safety issues (i.e. for a better understanding of work-related stress). Finally, always with reference to the relationship with monitoring practices and the health and safety domain, M. Tronci, *La gestione della sicurezza nei processi industriali della smart factory e del digital manufacturing*, Rivista degli infortuni e delle malattie professionali, 2017, fasc. 2, 240, argues that new production systems provide great opportunities for improving workers' safety by real-time data gathering and with an anticipatory and risks-preventive approach: a greater digitalization, characterized by a strong connection between to physical and information systems of production processes, could determine: improved working conditions and human-machine interface in terms of ergonomics and safety, biomechanical overload risks control systems, cutting-down on accidents at work and occupational illnesses, better management of ageing workforce.

Chapter 3.
The impact on work organisation

3.1. Changes in business models

Several studies have focused the focus on business models that the new technological paradigm brings up. Some authors, in particular K. De Backer, I. Desnoyers-James, L. Moussiegt, *"Manufacturing or Services – That is (not) the Question": The Role of Manufacturing and Services in OECD Economies*, OECD Science, Technology and *Industry* Policy Papers, 2015, n. 19, showed that the digitization, in particular through the Internet of Things that manufacturing companies can expand their volume of business through the sale of services in addition to goods, thanks to a process of transformation of services that would make the normal productive sectors more and more indistinguishable. In S. Greengard, *The Internet of Things*, MIT Press, 2015, cites numerous examples of smart products that connect directly, through M2M (*machine to machine*) communication technologies, to the CPS at the production site to provide information and enable the offer of services, as also noted in H. Kagermann, *Chancen von Chancen von Industrie 4.0 nutzen*, in T. Bauernhansl, *et al*. (a cura di), *Industrie 4.0 in Produktion, Automatisierung und Logistik. Anwendung, Technologien und Migration*, Springer, 2014, 603-614. An economic analysis on impact that the connection between products have on competition is rather developed in M. E. Porter, E. J. Heppelmann, *How smart, connected products are transforming competition,* in *Harvard Business Review,* Nov. 2014, 65-88.
More specifically, business models are impacted differently depending on the production sectors, as shown in the survey by C. Arnold and D. Kiel, *How Industry 4.0 changes business models in different manufacturing industries*, presented at the XXVII ISPIM Innovation Conference, Porto, 19-22 June 2016, in which five different macro-sectors are considered to show how the consequences are different. From the change in the configuration of products and logistic systems, to changes in the production structure with the need for greater investments in human capital, despite the reduction of personnel, or the development of network logics between different companies. Such an analysis, which takes into account various companies located in the Italian territory who started the digitization process in the Optical Industry 4.0 is contained in R. Secchi, T. Rossi, *Factories 4.0. Paths of digital transformation of Italian manufacturing,* Università Cattaneo Libri-Guerini, 2018. A further field of analysis related to business models is the one, developed in particular by the German literature, of the consequences of the application of *Cyber Physical Systems*. On this Acatech has produced several studies that go

beyond the technical description of the new infrastructures, in particular in E. Geisberger, M. Broy, *Living in a networked world. Integrated research agenda Cyber-Physical Systems*, op. cit., the authors theorize how it is possible to build integrated production systems between consumers and businesses. Through the *Internet of things* it would be possible to connect the different actors involved in the production of certain goods ensuring the possibility of interaction both during the design phase of manufacturing.

As regards the relationship between processes and products, *Industry* 4.0 is indicated as an industrial paradigm able to allow the so-called *mass customization* (Schmidt R., Möhring M., Härting R., Reichstein C., Neumaier P., Jozinović P., *Industry 4.0 – Potentials for Creating Smart Products: Empirical Research Results*, in W. Abramowicz (a cura di), *Business Information Systems – 18th International Conference BIS 2015, Poznan, Poland, June 24-26, 2015 Proceedings*, Springer, 2015, 16-24. We refer to the concept, of which G. Salvendy, *Mass Customization*, in G. Salvendy (edited by), *Handbook of Industrial Engineering: Technology and Operations Management*, Wiley, 2001, 684-709. Being one of the cloud technologies that often occur when you define Industry 4.0 is important to distinguish the Industry 4.0 from the cloud paradigm manufacturing. The phenomenon of the personalization of the product has a central importance in both types of production, but the use of IoT mainly characterizes the first specifying compared to the second. It could be argued that the concept of cloud manufacturing indicates a production model which can also fall under the Industry 4.0. On this model see Aa.Vv., *Cloud Manufacturing: a new manufacturing paradigm*, in *Enterprise Information Systems*, 2014, 167-187; D. Wu, M. J. Greer, D. W. Rosen, D. Schaefer, *Cloud manufacturing, Strategic vision and state-of-the-art*, in *Journal of Manufacturing Systems*, 2013, 564-579.

The constraint of mass production and standardization in relation to large volumes would therefore be less, replaced by the possibility of continuous design and the infinite combinations of machine settings. This would allow a strengthening of the direct relationship between producer and consumer no longer mediated by market analysis, commercial operations and third parties, but directly through the figure of the so-called *prosumer* (A. Toffler, *The Third Wave*, Bantam Books, 1970, 123-140), which acquires the good and at the same time participates in its conception process (N. Ahmad, *The Way Forward. Costumer Co-production Behaviour*, in *Procedia – Social and Behavioral Sciences*, 2016, 238-245). It would therefore play a decision-making role with respect to design, planning, configuration, order, production phases and could decide the modifications of the parameters up to the time of production and also in some of its phases, based on that model of co-production theorized in C. K. Prahalad, V. Ramaswamy, *Co-Opting Customer Competence*, in *Harvard Business Review*, 2000, n. 78, 79-87. There would then be the possibility of development of horizontal integration models of its *open production* (J. P. Wulfsberg, T. Redlich, F. L.

Bruhns, *Open production: scientific foundation for cocreative product realization*, in *Production Engineering*, 2011) often identified as typical of more artisanal productions (S. Micelli, *Fare è innovare*, Il Mulino 2016; C. Anderson, *Makers. Il ritorno dei produttori*, Rizzoli Etas, 2013) than manufacturing, due to the dimensions that hindered the logics of bottom. The term refers to the concept of *open innovation* introduced already in 2003 by H. Chesbrough in *The Era of Open Innovation*, in *MIT Sloan Management Review*, 2003, 35-41, and subsequently theorized by the author in H. Chesbrough, W. Vanhaverbeke, J. West (eds.), *Open Innovation: Researching at New Paradigm*, Oxford University Press, 2006. Aldo Bonomi (*Innovazione, digitalizzazione e lavoro emergente nella* smart city *di Milano. Inchiesta sul lavoro nella neofabbrica finanziaria*, in A. Cipriani, A. Gramolati, G. Mari (edited by), *Il lavoro 4.0: the fourth industrial revolution and the transformations of the working activities*, Firenze University Press, 2018, 43) highlights how the possibilities offered by the digital can be amazing if asked at the service of society. But to do this, we need to devise new schemes, different from those of the past, in order not to run the risk of a further occupational contraction that pushes us towards the design of a *jobless society*. It is for this reason that Bonomi highlights how the most complex change to be realized is of cultural matrix. As stated by Enzo Rullani (*Lavoro in transizione: prove di Quarta Rivoluzione industriale in Italia*, ibid, 423) in fact, the digital revolution is not only a technological revolution, but a new way of living and working. In fact, the Industrial Revolution Fourth is first and foremost a cognitive revolution that impacts all sectors and all functions work just by the material manufacturer, in fact, the cognitive revolution fueled by digitization also affects the administrative work (or Office) design, logistics, marketing and consulting. According to the author we are, therefore, entered a phase of the digital transition that pushes us to look to the formation of a new paradigm accomplished. Consistently with Laura Pennacchi (*Innovazione e lavoro: la cerniera umanistica tra macroeconomia e microeconomia*, ibid., 389) speaks of a "new model of development" that is capable, on the one hand, of realizing a neo-humanism and, on the other, of to make a new reflection on the very conception of work. The author highlights the connections between the need for a radical "reform of capitalism" and the question of innovation, all inside of the new development model based on the work, it is to be bent to meet "social demands".

Even in the essay by Mauro Lombardi and Marika Macchi *(Il lavoro tra intelligenza umana e intelligenza artificiale,* ibid, 293) is in-depth reflection on the economic issues, highlighting how to try to understand the evolution of the world of work is necessary to identify the trajectories of transformation of techno-economic processes and, in particular, defining the framework within which economic-productive systems are evolving. The two authors argue that what we are experiencing can be defined as the era of the *knowledge-economy*, or *knowledge-based economy*, or *data-driven world*, an era in which the socio-economic

systems are facing a drastic change of vision, skills and managerial models, where the innovative role of the company is central, which becomes an open system, in continuous interaction with other companies, with the territory and with training and research organizations.
More concretely in the scenario of advanced manufacturing, enterprises are no longer restricted to a determined regional context, but now tend to have a global scope, going through processes of internationalization and innovation that make the innovative, quality oriented and agile in the production process, see Eurofound, *The future of manufacturing in Europe*, Publications Office of the European Union, Luxembourg, 2019, 25.
The advent of Industry 4.0, intrinsically associated with the globalisation of the market, led to the breakdown of classical hierarchies within the company. Companies have now started to abandon the classic pyramid hierarchy to instead adopt the model of cooperation, where the structure is nearly horizontal, Eurofound, *The future of manufacturing in Europe*, Publications Office of the European Union, Luxembourg, 2019, 24 and M. Bajgar et al., *Bits and bolts: the digital transformation and manufacturing*, OECD Working Papers 2019/01, available at: https://www.oecd-ilibrary.org/docserver/c917d518-en.pdf?expires=1557216312&id=id&accname=guest&checksum=7A96F8312AFD046A4EC7ACBF77BE492C.
The scenario in manufacturing is also that of 'reshoring', as European companies have started to reshore value chains that were once offshored to countries others that the home country, as firstly the cost factor decreased and the quality standard began to have more impact and secondly due to the "global reorganization of value chains activities, the need for customer responsiveness (delivery times) and new technological trajectories (automation and digitalization)", Eurofound, *Reshoring in Europe: Overview 2015–2018*, Publications Office of the European Union, Luxembourg, 2019, 35.

3.2. The impact on work, employment and tasks

A further impact that the *Industry* 4.0 model will have on production will be relative to work and its organization. On this front the theories at the moment are different and often polarized between those who consider themselves optimistic and those who mainly see risks. If indeed, as shown by E. Brynjolfsson and A. McAfee in *The Second Machine Age. Work, progress, and prosperity in a time of brilliant technologies*, WW Norton and Company, 2014, today different technologies are able to replace many human works characterized by the centrality of the worker's physical strength, it seems possible to imagine an improvement in living conditions. On the other hand, however, M. Ford in *Rise of the robots: Technology and the threat of a jobless future*, Basic Books, 2015, argues

that the replacement of labor by machines will lead mainly to technological unemployment. Fears of a widespread substitution of work by new technologies also of the *Industry* 4.0 model, such as advanced robotics or *machine learning* also emerge from the research of C. B. Frey and M. A. Osborne, *The future of employment: how susceptible are jobs to computerization?*, Oxford Martin School, 2013, according to which 47% of US professions would be at high risk of replacement by new technologies introduced in recent years. The authors then elaborated several reports on the topic, such as *Technology at Work v2.0: The Future Is Not What It Used to Be*, Citi GPS, 2016 and *Technology at Work: The Future of Innovation and Employment*, Citi GPS, 2015 in which they develop their 2013 conclusions.
The scenario envisaged by the two Oxford researchers was however criticized by other studies, in particular M. Arntz, T. Gregory e U. Zierahn in *The Risk of Automation for Jobs in OECD Countries*, OECD Publishing, 2016 (also revised in *Revisiting the risk of automation*, in *Economic Letters*, 2017, 150) carry out a different type of analysis that leads to considering that only 9% of the professions can be automated. The authors maintain that although some tasks may be replaced by automation this more than the disappearance of their jobs would lead to a change of earlier work by pushing the transformation and not only destruction processes.
There are also specific studies on the possible occupational impact of the *Industry* 4.0 phenomenon. Analyzing the German panorama M. I. Wolter *et al.*, in *Industry 4.0 and the consequences for labour market and economy. Scenario calculations in line with the BIBB-IAB qualifications and occupational field projections*, IAB-Forschungsbericht, 2015, put forward impact forecasts until 2030, at which time, in their opinion, *Industry* 4.0 will be fully affirmed and widespread. Five different consequential scenarios are hypothesized, necessary to take into consideration the different factors that can lead to a change in the labor market, the first concerns the amount of investments in machinery and technology, these would be accompanied by new employees belonging to IT professions and scientific (in particular those able to develop new IT services), in media science and humanities (including design) and managerial figures. The second scenario focuses on effect that implementation and realization of the investments of the previous scenario may have, in particular that of an infrastructural nature and the result appears to be that of a greater number of employees in the construction sector, metal construction and engineers. After the initial investments, we proceed with the third scenario, which concerns the expenses for the requalification of personnel, consulting services and information services. Also in this scenario there should be an increase in demand for IT and scientific professions as well as for adult education specialists. With the growth of services provided by staff particularly focused on them, diminish the production of specific goods and use of raw material useful for producing them. This potential increase in productivity would generate a reduction in employment in the

extractive sectors, metal constructions, engineers, toolmakers, maintenance technicians and machinery controllers as well as technical professions in general and all those directly related to production. From the quantitative point of view in 2020 the losses and gains should lead to a net change of jobs equal to zero, and a loss of 20 thousand seats in 2030. The fourth scenario adds the qualitative data of all types of occupations inside of sectors and allows you to have a more precise look that leads the authors to some conclusions including that of about 760 thousand jobs that will change the field of employment.
D. Acemoglu and P. Restrepo in *The Race Between Machine and Man: Implications of Technology for Growth, Factor Shares and Employment*, NBER Working Paper, 2016, n. 22252, have instead subsequently developed a first conceptual *framework* to understand the repercussions in terms of employment of the man-machine replacement process whose novelty element consists in considering that "tasks previously performed by workers are automated, while at the same time versions have been created more complex than existing tasks in which work has a competitive advantage". The same authors then have the same in *Robots and Jobs: Evidence from US Labor Market*, NBER Working Paper, 2017, n. 23285, one year away from their study, they presented an analysis on impact of robotics on US employment between 1990 and 2007, which shows that there has been a negative impact of robots spreading it on employment rather than wages, without it being substantially mitigated by education, income and employment sectors.
A different approach is found, again in Germany, in the analysis of Boston Consulting Group, M. Lorenz, M. Russmann, R. Strack, K.L. Lueth, M. Bolle, *Man and Machine in Industry 4.0. How Will Technology Transform the Industrial Workforce Through 2025?*, Boston Consulting Group, 2016. In the three scenarios presented in the study the total number of workers will grow, albeit with loss of production, quality control and maintenance. The net will be positive, however, thanks to workers in the IT sector, in data analysis and research and development. While Adam Corlett in *Robot wars. Automation and the labor market*, Resolution Foundation, 2016, says, analyzing the British scenario, we need more robots claiming it as the experience of the last 20 years (if not the last 250) provides several assurances that the negative consequences of automation can be simple to overcome.

Among those who expect negative consequences in terms of net employment variation also the World Economic Forum, *Eight Futures of Work Scenarios and their Implications*, 2018, reiterates that accelerated technological change and diffusion means that machines in the workplace have become capable of performing routine and non-routine tasks, and can perform a range of manual tasks as well as those requiring non-cognitive skills: as for the robot replacement issue. Clearly, making an accurate estimation of automation potential is difficult and largely depends on subjective judgment of the capability of

Technologies and the task structure of occupations. Despite this variance, however, several high-level observations can be made. Thus, besides WEF estimations of a decrease of about 5 million jobs by 2020, World Economic Forum, *The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution*, 2016, van der Zande, Jochem, et al., *The Substitution of Labor: From technological feasibility to other factors influencing job automation*, Innovative Internet: Report 5, Stockholm School of Economics Institute for Research, 2018, provide a range of relevant additional considerations referring for example to Manyika et al., *Harnessing automation for a future that work*, 2017, which does not use 70 percent as a threshold for high automation potential (the one indicated by Frey and Osborne, *The Future of Employment: How Susceptible Are Jobs To Computerisation*, 2013), but it could be deducted from their study that around 25 percent of all jobs are more than 70 percent automatable in the United States. Moreover, and adopting an international perspective, PwC, Will robots really steal our jobs? An international analysis of the potential long term impact of automation,2018, by analysing over 200,000 jobs in 29 countries to explore the economic benefits and potential challenges posed by automation developed a foresight according to which by early 2020s 3% of jobs are a potential risk of automation. This percentage increases significantly to 30% by mid 2030s and to 44% in the same period if considering people with low education credentials.

More recent research has begun to evaluate specifically, from the point of view of territorial and sectoral, the impact of automation of various aspects of the labor market. In *The Impact of Industrial Robots on EU Employment and Wages: A Local Labor Market Approach*, Bruegel, 2018, F. Chiacchio, G. Petropoulos and D. Pichler note a negative impact of the spread of industrial robots on the employment levels of European countries, in particularly for those who have middle-level qualifications and for younger youth registration cohorts, while in their opinion there is no impact on wages at the moment. Similar results also include W. Dauth *et al*., *German Robots – The Impact of Industrial Robots on Worker*, IAB Discussion paper, 2017, n. 30.
On the theme of the impact on the different types of professional qualifications and especially of the type of job performed R. Bachmann, M. Cim and C. Green, in *Long-run patterns of labour market polarization: evidence from German micro data*, in *British Journal of Industrial Relations*, 2018, I, also Discussion Paper Series, IZA, No. 11570, in http://ftp.iza.org/dp11570.pdf, all inside of an analysis of the last forty years argue that workers assigned to tasks of a routine type they have a higher percentage of risk of job loss. To fully understand the Technological evolution is sterile, reasoning purely in absolute terms, dividing between optimists and pessimists: the interpretation given of the impact of new technologies is always inevitably personalistic and subjective. G. Berta in *Tecnologia, imprenditorialità, futuro. Una*

controversia della Silicon Valley, in A. Cipriani, A. Gramolati, G. Mari (edited by), *Il lavoro 4.0: the fourth industrial revolution and the transformations of the working activities*, Firenze University Press, 2018, 29, analyzes two opposing visions of technological development, offered by two of the most famous entrepreneurs in the world: Mark Zuckerberg, founder of the giant Facebook, and Musk, founder of Tesla, Space and Solar City. There is something that unites them, as pointed out by the Author "if a unifying element you want to track, it is in declared intention to change the world through the diffusion of innovations" (p. 30). The reading of the revolution of the machines offered by these entrepreneurs incorporate the concern to protect their spheres of activity: Musk goal is to create solutions to avert the industrial (and possibly govern) the dangers triggered by artificial intelligence; while, the business of Zuckerberg constituted of representation rather than of concrete goods, leaves space to a software "always friendly and docile – or at least tame", J. Ruskin, *The stones of Venice*, 1851-1853.

Renato Giannetti (*Tecnologia e lavoro nelle Rivoluzioni industriali: occupazione, competenze e mansioni del lavoro, salari e disuguaglianza*, in A. Cipriani, A. Gramolati, G. Mari (ed.), *op. cit*., 275) arises in a historical reconstruction perspective of evolution of the relationship between technology and work in the four industrial revolutions, focusing the analysis on the development potential of technologies, their effects on overall employment (and on the relative redistribution of income) and finally on the characteristics of work organization and the skills required. Compared to the previous Industrial Revolutions, the Fourth evolves at an exponential and non-linear pace and is pervasive even from a geographical point of view because it develops every sector in every country. In this sense therefore it emerges stronger the idea that the impact of the Industrial Revolutions can be evaluated according to historical perspectives, different geographical and social factors that certainly influence the outcome of the assessment. Also Stefano Musso welcomes a perspective of historical analysis (*Le trasformazioni del lavoro nelle Rivoluzioni industriali*, ibid, 359) and broadly traces the transformations of work between the First, Second and Third Industrial Revolution. Focusing on the analysis on seven key issues, the author concludes that there is a tendency to move to backward socio-economic structures in the direction of the nineteenth-century world of work. From the point of view of the legal nature of the employment relationship, there is a tendency to return to forms of individual contracts that were common practice at the dawn of the industrialization; also with regard to the stability of the employment relationship can be seen a sort of return to conditions similar to those of the first industrialization, in which the occupational instability was a widespread condition; also on the relationship between work time and life time there seems to be a return to the trend of artisan work, in which there was no clear separation between working time and free time. In this context, the Industry 4.0 seems to open up opportunities to improve the quality of work, flexibility able to penetrate the needs of businesses and workers. However, this outcome cannot be taken for granted and requires an "effective social comparison (to be understood as a dialectical mixture of dialogue and conflict), a process capable of redefining the rules of the employment relationship (in terms that could be defined as non-subordinate participation), and to provide new tools for interaction and regeneration of social ties, starting with the fight against inequality".

Faced with the question "what will be the consequences of the Fourth Industrial Revolution?", Federico Butera is not satisfied with the answers that look only to the effects of the introduction of new digital technologies, be they pessimistic (in announcing the loss of competitiveness of entire nations, dramatic disappearances of companies, replacement of a large number of jobs by part by technology) or optimistic (as seen in digital technologies the opportunity to build better organizational forms and create more suitable premises and working time, as happened in previous industrial revolutions). In his essay (*Industria 4.0 come progettazione partecipata di sistemi socio-tecnici in rete*, ibid, 81) the author proposes an analysis perspective reversed: the effects of technology projects. Butera recalls the responsibility that everyone has as a "system's architect" to recompose through design the upheaval that the ever new technologies will introduce in cities, businesses, organizations and the new society. Impresa 4.0 is an already moving process of integration between technology, organization and work: "now we must design and implement it in a virtuous way in all the infinite variations required by the various companies, Public Administration, territories, industrial platforms" (p. 83). There would be nothing more wrong than being carried away by the prevailing technological determinism and be persuaded that organization and work are already incorporated in the solutions offered by technology vendors or are only the stewardship that will follow. Concretely, the project proposal to address the systemic approach digital evolution is based on three key points: a) public and private industrial policies that address the growth variables; b) exemplary projects of network-technical socio-technical systems; c) participatory methodologies of design and implementation of complex systems developed by different actors also in conflict but based on agreed parameters of prosperity and quality of life and with the participation of people. The scenario of the Fourth Industrial Revolution outlined by Federico Butera is that of organizational networks of companies in highly connected chains, inserted in a cognitive ecosystem. The network is itself *embedded*, that is immersed in an ecosystem made up of companies (large and small), public administrations, universities, research centers, and above all people who interact on the digital network. People who bring their skills and passion into the factory and working environment. The basic units of the organizations are operational and semi-autonomous microstructures, such as the production islands and teams

based on self-regulation, interchangeability and flexibility. Work is based on responsibility for results and requires not only technical but also social skills; arouses commitment and passion and is made of positive relationships between people and machines. In this context, work calls for the creation of "innumerable and changing roles, professions and tasks that are new or profoundly modified. The business organization is made up of a heritage of open roles and professions, scripts acted and enriched by people, which are alternatives to the duties and the ossified positions of the classical organization" (p. 97). The device that makes it possible to bring the diversity of professions back to unity is the concept of the job that best manages to paint the various nuances of professionalism. In conclusion the Author proposes system design methodologies for the strengthening of the Industry 4.0, including the methodology of structural change management and strategic planner.
Diego Ciulli (*L'economia delle piattaforme: trend tecnologici e trasformazioni del lavoro*, ibid, 203) shares the sense of responsibility that each of us before the changes that new technologies are bringing in our daily lives and believes that we should "strive to so that the opportunities that our age offers us are opportunities for all" (p. 211). In particular, Ciulli analyzes some technology trends that underlie the structural changes of the economy: first, the reduction of spatial boundaries ("the world is closer together") implies that in the coming years, any company can be a small multinational company capable of offering its goods and services potentially all over the world; secondly, the spread of so-called *data driven innovation*, or the ability to create value and innovation from data, will lead to the creation of new business models and products; finally, the ever increasing diffusion of connected objects and the progressive integration between manufacturing and software (think of the case of the *smartphone* from a technological object to a mass consumer good). Unable to ignore the effects that these trends have on organization of business and labor, in terms of competition and productivity, Author proposes some initiatives to be undertaken to seize opportunities and minimize risks. In particular it recognizes that "the challenge to keep together economic growth, job creation and quality work is all in the conversion of human capital, starting from the theme of formation" (p. 210).

3.3. The organization of work

Another aspect concerning the consequences on work is relative to its organization. On the subject according to C. Kurtz, in the report presented at the *Maschinen entscheiden: vom Cognitive Computing zu autonomen Systemen* in Munich on 21 November 2014 entitled *Mensch, Maschine und die Zukunft der Industriearbeit* and W. Ganz in the report presented at the *FES-Fachgesprächs Industrie 4.0* in Berlin on 8 October 2014 entitled *Welche Rolle spielen die Dienstleistungen in der Industrie*

4.0? are two possible scenarios to companies that adopt the production cycle of *Industry* 4.0. The first is the scenario of the automation in which human activities are entirely directed and governed by machines that play their role independently. Production is governed by CPS which is able to control the process in its complexity thanks to wireless sensors and infrastructures. Human work would be configured as a reaction to stimuli and directions elaborated by these systems, the true center of the factory s value chain. The activities would be limited so the monitoring of CPS and to business problem solving which, thanks to the continuous improvement of technology machine learning and predictive maintenance would be destined to decline over time. The employment consequences of this first scenario are easily understandable: reduction of jobs both in the medium range and in the low end of skills accompanied by a drastic increase in unemployment rates. The media component would be replaced by the CPS, which can carry out those routine cognitive activities of management of the production process once the tasks of skilled workers. The low end would instead be replaced, as indeed already happens since the eighties of the last century, by the robotic components that are able to perform routine non-cognitive activities and, thanks to recent developments, even non-routine with degrees of efficiency and flexibility greater than human ones. Instead, there would be an increase in the number of workers with high skills and professional skills able to carry out non-routine cognitive activities that the new information systems are not able to carry out as a prerequisite for their use. The second scenario, that of specialization, would see the roles of CPS and worker reversed in favor of the last. For Kurtz and Ganz this would happen thanks to the complete control of the CPS by the workers as an advanced tool of production management. The CPS would cover also in this case a main role, namely to aid in complexity, through sensor systems, monitoring the trend, allow specialized workers to improve the results of particular processes, positively affecting both the quality of work and that of production. The scenario would therefore be that, less alarmist and with less destructive effects, of collaboration and complementarity between the roles of workers and those of the CPS. We would confirm a reduction in the jobs of workers in manual tasks, except in particular exceptions of preliminary work difficult to be carried out by robots.

In both scenarios a profound change in the organization of work would occur. H. Hirsh-Kreinsen in *Welche Auswirkungen hat "Industrie 4.0" auf die Arbeitswelt?*, Friedrich-Ebert-Stiftung, 2014, for example, predicts that there will be no standard regulatory models, but that each company, depending on the level of automation and the balance adopted between human components and robotic components, will independently regulate its organizational structure in order to meet your needs. The Author identifies two opposite scenarios, corresponding to two possible specular organization models, arguing that it is in the space between these that companies will choose their own. The first scenario is

that of polarization (*Polarisierte Organisation*) in which a marked division of tasks is achieved and a predominant presence of highly qualified workers. The first block of workers would be composed of those who perform, in line with the old paradigm of legal subordination, the few standardized and repetitive tasks that remained in the productive activity, with tasks characterized by regularity and without flexibility margins. The second would instead consist of a device level, different from a classic managerial role towards standard workers, which would include tasks of great autonomy and responsibility ranging from control to *problem solving* and which often requires taking responsibility and decisions that go beyond the practical management of production. A mixture of productive and managerial activities would thus occur, which would characterize one of the paradigm breaks brought about by digital manufacturing. The second scenario proposed by the German researcher is what he calls a swarm (*Schwarm-Organisation*). Once replaced by the automation, almost all of the non-cognitive routine work, would remain a high number of figures that we could define multitasking using a different meaning of the term: not the ability to have more tasks but paradoxically the fact of not having any defined task and, of consequences, of have them all potentially. Hirsh-Kreinsen stresses that none of the two models of work organization presented can be applied in a way that mirrors what the theory illustrates. Particular situations will contribute to creating a balance between a polarized system and a more open one. The common aspect is a substitution effect between skills and automation such that in the face of a more streamlined and optimized management of the supply chain will have a reduction in staff less qualified.
In the book *Il lavoro 4.0: la quarta rivoluzione industriale e le trasformazioni delle attività lavorative* by A. Cipriani, A. Gramolati, G. Mari (edited by), *Il lavoro 4.0: the fourth industrial revolution and the transformations of the working activities*, Firenze University Press, 2018, the theme of work organization in the context 4.0 it is faced by a plurality of points of view. A. Bennardo (*Il ruolo dei team nell'industria 4.0*, 3) assumes the typical perspective of the size of the firm and found that the type of work required by Indsutry 4.0 introduces complexity and multidisciplinary nature that are best educated and valued within a group rather than in the individual one. In the context of the team emerges what is called 'collective competence': the definitions found in the literature in this regard are different but it is agreed that collective competence is something different and further than the sum of individual competences. The organizational plan also includes the perspective of the workspace, of which the health and safety aspects are analyzed in the volume (F. Carnevale, *La salute e la sicurezza dei lavoratori in Italia. Continuità e trasformazioni dalla Prima rivoluzione industriale a quella digitale*, in A. Cipriani, A. Gramolati, G. Mari (edited by), *op. cit.*, 117), and of time, with the repercussions in terms of working time (G. Della Rocca, *Il lavoro in digitale, il tempo e gli orari: la crisi del*

sistema degli orari standard, ibid, 251). The boundaries of the workplace widen towards the social space as a whole and new technologies, favoring the agile work, contribute to a deconstruction of the traditional conception of time. It is noted that Della Rocca intends to avoid overlapping between the logic input of new technologies and the transformation of the way of understanding the working hours, giving prominence to other factors, social and cultural rights that led to this development.
From an individual perspective there are questions, however, on what could be the relationship between man and the new digitized and globalized context in which it is called to work (R. Bennati, *Industria 4.0 e WCM. Appunti sul lavoro umano: digitalizzazione globale e partecipazione*, ibid, 19) confirms the importance of cognitive ability and transformative of human being, with which it cannot compete what is termed the '*pseudo-knowledge*' of digital machines. The relationship between man and machine is analyzed under the slope of the relationship between the level of widespread knowledge and expertise required in industrial work plan as well as in perspective angle of the government and control of the man on the production processes and products. It focuses on the Experience and knowledge of the workers, with obvious repercussions on the centrality of learning and of education. The attempt to make it easier and more rational as possible the relationship between man and machine is also found in the discipline of ergonomic, which focuses on the human being, with its physical and cognitive characteristics (S. Spada, *Ergonomia e Industry 4.0 nel settore automobilistico*, ibid, 455).

Chapter 4.
The impact on skills and training

4.1. What are skills?

In recent years, literature has identified several definitions of the term and the concept of competence. The first was provided by D. McClelland, *Testing for Competence Rather Than for "Intelligence"*, in *American Psychologist*, January 1973, which defined a competence as "a personal trait or a series of habits that lead to more effective work or higher performance". In the following years further definitions of competences in literature have been proposed, for example, G. Klemp, *The assessment of occupational competence*, National Institute of Education Report, 1980, defines competency as "a non-obvious characteristic of a person, which involves effective performance and/or superiors at work", placing the attention then on inviolability of the same and on the track perimeter from the space-time coordinates within which such expertise is expendable, in particular local company (and more generally work environments) and in the course of activities related to the explanation of one's job and the performance of activities associated with the role held in the company organization or the achievement of specific goals and professional results. L. Spencer, S. Spencer, *Competence at Work: Model for Superior Performance*, John Wiley & Sons, 1993 have instead defined skills as "abilities and skills, things you can do acquired through working experience, the life experience, study or training", specifying that the progressive development and acquisition of skills would not only occur through a training course but also through informal or non-formal task situations. For D. Bartram, IT Robertson, M. Callinan, *Introduction., A framework for examining organizational effectiveness,* in I. T. Robertson, M. Callninan, D. Bartram *(eds.), Organizational Effectiveness. The Role of Psychology, John Wiley & Sons, 2002, 1-10*, competences are instead a "set of behaviors, instrumental in delivering the desired results or results", thus developing a functionalist definition related to the purposes against which the development of skills is addressed.
The concept of competences, in addition to being extensively investigated by scientific literature, is also declined in some policy documents of international institutions and the European Commission. At an European level, according to the definition adopted by the European Commission, *Key Competences for Lifelong Learning – A European Framework*, 2007, competences acquire a broader meaning that is embodied in the combination of knowledge, skills and attitudes appropriate to the context. The key competences would be those that

everyone needs to allow the full expression of active citizenship and to be realized in terms of inclusion in the social context of reference and good employment results. In particular, the EU identifies eight key competences that every person must be equipped with:

1. Communication in the mother tongue;
2. Communication in foreign languages;
3. Mathematical skills and basic competences in science and technology;
4. Digital skills;
5. Learn to learn;
6. Social and civic competences;
7. Spirit of initiative and entrepreneurship;
8. Awareness and cultural expression.

The basic skills that affect language, reading, writing, arithmetic and technologies of the Information and Communication Technologies (or ICTs) constitute an angular stone and indispensable to favor learning specialized in other fields and sectors. The access to learning would in fact be the fundamental requisite for developing reasoning and skills that are becoming increasingly complex. The eight key competences identified by the European Commission are accompanied by other competences of a cross-cutting nature that contribute to enhancing and enhancing the basic ones. It is specifically about: critical thinking, creativity, initiative, problem solving skills, risk assessment, decision-making and constructive management of feelings.

CEDEFOP defines ‘competence’ as “the ability to appropriately apply the results of the apprenticeship in a specific context (institution, job, personal or professional development)” (CEDEFOP, *Terminology of European education and training policy. a selection of 100 key terms*, 2008, 49), identifying it as an output to inside of a specific learning process.

Finally, in this brief definition framework, it is necessary to underline how competences are increasingly divided into two main types. In the first place the *soft skills* (transversal competences), so defined because «transversal with respect to the single professions and sectors and connected to personal competences (self-confidence, discipline, entrepreneurship) and social skills (predisposition to teamwork, communication, empathy) (CEDEFOP, *Skills Panorama Glossary*, http://skillspanorama.cedefop.europea.eu/en/glossary, consulted in April 2017). For example *soft skills* they would refer to aspects or features of the personality such as competitiveness, negotiation skills, motivation or the ability to work in groups and can be general or specific to a given company.

L. Benadusi, S. Molina (2018), *Le competenze, una mappa per orientarsi*, Il Mulino, Bologna, p. 16, hinted the fundamental role of skills and competences in the performance of activities in the current state of the labour market. In trying to define the concept of competence, L.

Benadusi, S. Molina (2018), *Le competenze, una mappa per orientarsi*, Il Mulino Bologna, p. 11-14, highlight how competences became the centre of the employment relation, stating three major factors: 1) a raise in complex tasks in substitution of simple ones; 2) a raise on the tertiary sector, that requires widespread, multidisciplinary knowledge, adaptability etc.; 3) an ongoing change in the workplace due to the globalization phenomenon, that requires new skills.

4.1.1. The relationship between skills, technology and Industry 4.0

The topic of competences can be declined in many ways but, for the purposes of this research, we are interested in investigating the relationship between skills, technology and Industry 4.0 since the introduction of next-generation technologies to optimize industrial production processes is the origin of the paradigm Industry 4.0. It is therefore necessary to investigate the impact that new production models will have the skills required today to workers starting from a preliminary analysis of the theoretical foundations found in the literature on the relationship between technology and skills.
Scholars and experts who study the professional profiles in the broad scientific debate relating to automation of some occupations are divided by A. Magone, *Tecnologia e fattore umano nella fabbrica digitale*, in *L industria*, 2016, n. 3, 407-426, in two groups: 'catastrophists' and 'militant innovators'. Among the 'catastrophists', Magone reports the study conducted by C. B. Frey e M. A. Osborne, *The Future of Employment: How Susceptible Are Jobs to Computerisation?,* which measures the degree of «digitalization» (i.e., the probability that some tasks are replaced by digital tasks) of the current jobs. The researchers build an index applied to 702 professional profiles and hypothesize that 47% of today s jobs are at risk of extinction by digitalization. The same scenario is presented in the contribution of a group of economists and in particular P. Beaudry, D. A. Green, B. Sand, *The Great Reversal in the Demand for Skills and Cognitive Tasks,* National Bureau Economic Research, 2013, which analyzes the decrease in demand of *high skilled jobs* in the US since the 2000s with particular reference to the extent of the disqualification of workers holding a degree. Not even the conclusions of the essay by E. Brynjolfsson, A. McAfee, *The Second Machine Age. Work, progress, and prosperity in a time of brilliant technologies*, according to which professions that require emotional, affective, relational, creative skills and with them high-intellectual tasks related to processes would remain out of the risk of machine automation.
According to the contributions relating to the line of research of 'militant innovators', technological transformation will lead to a growth in jobs that will be distinguished by the wealth of intellectual content connected to research, design, innovation and management of new

generation technologies. In short, the tools to combat the phenomenon of structural unemployment which the most advanced economies have been suffering for years would already be contained in these same processes of technological innovation and automation and interconnection of machinery in production processes. The most famous among the current members of the 'militant innovators' is E. Moretti who, in *La nuova geografia del lavoro*, Mondadori, 2013, calculated that creating five jobs in the scope of services for each new job in the scope of knowledge. In fact, according to the economist of the engine economy it is the "sector of innovation". It is the only area in which not physical capital but the human one, the education and creativity.
From the theoretical point of view on this front there are several contributions. D. H. Autor, F. Levy, R. J. Murnane, *The skill content of recent technological change: An empirical exploration,* in *Quarterly Journal of Economics, 2003, 1279-1333*, have theorized the so-called task-based model. The authors have investigated the impact of technology on the tasks of workers, to identify which of them were most exposed to the progressive replacement by machines and automated manufacturing processes. To this end they introduce the distinction between *routine* skills, characterized by repetitiveness and mechanical nature, and non-routine ones, that operate in contexts in which elements of unpredictability and unknown variables come into play. Their contribution is of particular interest because of the thorough analysis carried out on the production processes of US economy in arc of the years between 1960 to 1998 to identify the tasks that have been gradually automation object. From the data it emerges that the professions that would be more easily automated would be the routine ones, more likely to be mechanized and replaced by computers, easy to understand, optimized and coded in advance. In a more recent study, D. Autor, *Why Are There Still So Many Jobs? The History and Future of Workplace Automation,* in *Journal of Economic Perspectives*, 2015, n. 3, 3-30, the degree of automation of the tasks attributed to mid-level professions is evaluated, i.e. tasks require a wide range of skills to cover multiple activities. The study shows how, in the future, mid-level professions will be able to combine technical and routine tasks on the one hand and, on the other, non-routine activities that require workers to interact interactively with new-generation machines, interpersonal interactions with colleagues, flexibility, adaptability and attitude to *problem solving* (*problem-solving attitude*). More recently, D. Acemoglu, P. Restrepo, have stated that the "recent stagnation of labor demand is explained by an acceleration of automation, *particularly in manufacturing*, and a deceleration in the creation of new tasks" (D. Acemoglu, P. Restrepo, *Automation and New Tasks: How Technology Displaces and Reinstates Labor*, in *Journal of Economic Perspectives*, 33(2), 2019, 3-30.
The introduction of new technologies can then generate, in addition to an effect-changing, different dynamics in the labor market. The literature

on the topic of *skills mismatch* is very vast and this is not the place to summarize it, but this has been done exhaustively in particular by G. Sala in *Approaches to Skills Mismatch in the Labour Market: A Literature Review*, in *Politica y Sociedad*, 2011, 1025-1045. In particular P. Cappelli (*Skill Gaps, Skill Shortages, and Skill Mismatches: Evidence and Arguments for the United States*, in *ILR Review*, 2015, 251-290) showed how the request by companies for workers with digital skills and in parallel the decrease in requests for other specialized technical skills has created situations of over-education and skills mismatch. In fact, when the demand for digital skills converges, many workers trained in skills no longer useful to companies are over-educated, with the consequence of the spread of salary gaps, as shown in E. Leuven, H. Oosterbeek, *Overeducation and Mismatch*, IZA DP, 2011, n. 5523.

4.2. Industry 4.0: how skills change

In the new scenarios that open up following the march of paradigm Industry 4.0 appear to gradually change the skills required from employees. According to A. Magone, *Tecnologia e fattore umano nella fabbrica digitale*, in *L industria*, 2016, n. 3, 407-426, 416, the skills that workers are developing in factories where production requires tools and machinery with high digital content have a multipurpose nature and range from basic English knowledge (necessary in particular in multinational groups) to mastery of media *devices* as work tools. The worker who operates in an *Industry* context 4.0 "communicates with his department, working side by side with team leaders, engineers, technologists, logistics, maintenance personnel, and all those to whom effective, precise and profitable information must pass for the process. It is an 'enhanced blue collar' that is equipped with digital processing equipment, perhaps in mobility, for the monitoring of a process that returns the data relating to the cycle in real time. It does not intervene manually in the cycle and does not operate with a single machine, instead it devotes itself to the control of several phases, more machinery, large fractions of the process".
A recent BCG study, *Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries*, 2015, emphasizes the urgent need to develop new skills to enable the paradigm of Industry 4.0. The contribution highlights some areas of the manufacturing sector that are experiencing a progressive increase in new digital technologies and that must necessarily be accompanied by the development of new skills. Specifically, these are activities related to:

1. *Big-Data-Driven Quality Control,* i.e. to analyze quality control and process data in real time or in a specific period of time, identifying problems and related causes. The application of *big data* in production could reduce the number of skilled workers in quality

control of the production output, while increasing the demand for experts of industrial and statistical data.

2. *Robot-Assisted Production* for the use of more and more like robots to humans and relative to their physical size and the ability to learn (through machine learning and artificial intelligence) to carry out ever new duties. Such advances would significantly reduce the amount of manual labor in the manufacturing operations, namely the assembly packaging, but would create new jobs related to the management and coordination of robots.
3. *Self-driving logistic vehicles* to use automated transport systems that operate intelligently and autonomously inside of the factory, thus reducing the need for personnel to logistics, especially in the most difficult and demanding jobs.
4. *Production line simulation* through the use of software that allow you to depict the production lines before the installation and apply the templates to streamline operations. The implementation of this technology could increase demand for industrial engineers.
5. *Smart supply network* to monitor the entire network of suppliers in order to obtain better decisions about the supply. The application of this technology could the number of jobs in planning operations, while creating demand for supply chain coordinators to handle deliveries in small lots.
6. *Predictive maintenance* to give customers a remote control in real time of the equipment and constant access to a diagnostic center. The monitoring technologies will allow manufacturers to intervene in the maintenance of the equipment before breakdowns occur and favor a considerable expansion of the work carried out by technicians and engineers.
7. *Self-organizing production* through coordination and optimization of the use of the machines. Although the use of this type of automation could reduce the demand for workers in production planning at the same time could increase the demand for specialists in modeling and interpretation of data.
8. *Additive manufacturing of complex parts* through techniques such as 3D printing allow manufacturers to create complex parts in a single pass, thus eliminating the need to assemble individual parts, also saving time in product manufacturing. It would therefore render the necessary skills in the field of design and digital design.

On another research conducted by Assolombarda, *Alla ricerca delle competenze 4.0*, 2015, divides professionals required by companies who wish to implement the paradigm 4.0 into three major strands:

1. professions involving the processing and information analysis (*big data*, *business intelligence*);
2. Professions related to the design of applications associated with new media and social networks;

3. Professions related to the automation of production and logistics processes.

Compared to the wide range of professions mentioned above that are considered emerging (Assolombarda, *Alla ricerca delle competenze 4.0*, op. cit., 9) the research identifies some competences of reference:

1. *Hard skills* (languages, programming languages, software applications).
2. *Soft skills* (working in teams, *problem solving*, communication and *interpersonal* skills and flexibility, both in terms of availability for mobility and working hours).

This scenario would then materialize with real new professional profiles. For example:

Industrial data scientists: specialist officer of data extraction and processing, with the task of advanced analysis and apply their results to improve products and processes.

Robot coordinator. specialist who is responsible for coordination and management of complex robotic systems, as regards both the programming and all update, both in intervention in cases of malfunctioning.

Further debate is related to the skills and attitudes necessary to work in environments in which the role of artificial intelligence is widespread and pervasive. With regards to this, the Council of Economic Adviser of the US Administration has prepared the report *Artificial Intelligence, Automation, and the Economy*, 2016, which identifies in some specific attitudes the requirements for the construction of a cooperative environment. The first is the *engagement* i.e. the willingness and ability to actively build a complementary relationship with an intelligent virtual environment. Then *development would* follow since, especially in the early stages of the software development of AI is developed by man, would serve here an attitude to the development of processes that will make then no longer need the developer itself. Further competence concerns the supervision then of the processes, which can however fail in some of their elements.

4.2.1. Skills needed in the context of Industry 4.0

If the new *Industry* 4.0 paradigm imposes different skills and professional profiles, both in terms of technical and transversal skills, it is necessary to deepen the learning models able to transfer them.

First of all, there is the need to investigate the skills needs of individual companies, and often also of individual production sites. A study prepared by the ILO and the Moskow School of Management (E.A. Hartmann, M. Bovenschulte, *Skills Needs Analysis for "Industry 4.0" Based on Roadmaps for Smart Systems*, in *Using Technology Foresights for Identifying Future Skills Needs*, Skolkovo Moscow School of Management, ILO, 2013, 24-36) attempts to outline a method by which to build a

mapping of skills required by Industry 4.0. To this end, the Authors use the visual roadmap method listing different maps of characteristics of the new manufacture. Among these it is interesting the classification of the *Strategic Research Agenda (SRA)* of the *European Technology Platform on Smart Systems Integration (EPoSS)* where it identifies the following application aspects of new technologies: *Manufacturing equipment*, *Process control*, *Robotics & Factory automation*, *Prototyping equipment*, *Test & Inspection*. Starting from these roadmaps it is possible to identify some generic competences and some specific ones respectively. On the first front the authors identify as the main the knowledge of the principles of robotics, in particular of *robotics cooperation*, as an expression of the convergence between the mechanical, electronic and IT aspects of the new manufacturing production. Add to this the importance of bionics to develop robots that can increasingly interact with human behaviors. On a macro level, see instead the CEDEFOP forecasts for 2020 in *Skills supply and demand in Europe: medium-term forecast up to 2020*, 2010, http://www.cedefop.europa.eu/files/3052_en.pdf.
A further transfer mode of expertise is the development of training courses in environments both virtual and physical (*mixed-reality environment*). Physical reality and virtual reality merge more and more and international groups collaborate from all over the world in virtual environments (K. Schuster, L. Plumanns, K. Groß, R. Vossen, A. Richert, S. Jeschke, *Preparing for Industry 4.0 – Testing Collaborative Virtual Learning Environments with Students and Professional Trainers,* in *International Journal of Advanced Corporate Learning*, 2015, 14-20). Real *virtual words* would develop (A. Richert et al., *Learning 4.0. Virtual immersive engineering education*, in *Digital Universities: International Best Practices and Applications,* 2015, 51-66) through which the learning process would not take place either through frontal teaching or through task situations but through different levels of digitization and virtualization of the environment, evolving more and more towards the concrete situation to prepare the future worker. All this, as shown in A. Richert, M. Shehadeh, L. Plumanns, K. Groß, K. Schuster, S. Jeschke, *Educating Engineers for Industry 4.0: Virtual Worlds and Human-Robot-Teams,* in the *Global Engineering Education Conference (EDUCON)*, 2016, it would require a re-qualification first of all of the teaching staff, both of secondary and university schools, not so much on the contents taught as on the teaching methods. The results of the studies suggest that virtual environments will have the ability to modify the social dynamics of learning environments by transforming social interactions.
In January 2016, the World Economic Forum produced a document (World Economic Forum, *The Future of Jobs. Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution*, 2016, 20) which, in addition to analyzing the enabling systems and drivers of the Fourth Revolution Industrial, outlines a core of 35 skills and work capacities that are widely used in all industrial sectors and work families and will be

subject to accelerating changes and significant changes in the near future: by 2020, on average more than a third of the sets of skills will be composed of skills that are not yet considered crucial for today s job, according to respondents of the survey (*Chief Human Resources Officers, senior talent* and *strategy executives* of some of the main companies, which involve a sample of 13 million employees from 9 different industrial sectors). Faced with a computing power in rapid growth, ability to work with data and make decisions based on data will become a skill, increasingly vital in many working families.

Having regard to the general scale of skills required by 2020, more than a third (36%) of all jobs require a problem-solving capacity among core competencies. Assessing the impact of changes on the way, it is expected that the complex skills of problem solving will become less important in industries that today are very technical, where technology can automate and take a larger share of these complex tasks. Overall, social skills (such as persuasion and emotional intelligence) will be increasingly in demand. The content skills (such as literacy and information technology active learning), cognitive skills (such as creativity and mathematical reasoning) and process capability (e.g. the active listening and critical thinking) will be a growing part of the basic skills requirements for many industries. Many professions have always been conceived as a purely technical, will show a new demand for creative and interpersonal skills (so for example the sales jobs could increase demand for creative skills and ideas to promote a memorable shopping experience, as the sale retail must reposition itself in relation to e-commerce and online competition).

According to the most recent ManpowerGroup Talent Shortage Survey (2015), global demand for highly skilled workers continues to grow, but the distribution of available worker skills is not easily matched to that demand. Efforts to bridge the skills gap should also be based on a sound understanding of the basic skills of a country or of industry: for example, through the use of contractual form of apprenticeship, you will be able to structure the right skills for a young apprentice and you will manage to optimize more investment, how much you will be able to look at what are the current needs of the labor market and future expectations.

The White Paper produced by the World Economic Forum (*Accelerating Workforce Reskilling for the Fourth Industrial Revolution An Agenda for Leaders to Shape the Future of Education, Gender and Work, 2017*) is the output of a dialogue between international stakeholders for the future definition of issues such as education and work. From the analysis it emerges that the speed with which jobs are changing and the ability of adults to adapt to changing working conditions are not uniform in the various countries; the adaptation rate is affected by several factors, including the quality of fundamental education, the cost and quality of ICT connectivity, the prevalence of jobs that incorporate the digital display, as well as opportunities for the learn. Countries such as Sweden, Finland and Japan, while exhibiting high levels of exposure to the disintegration of the labor market, also show high levels of adult ability and technological absorption. This positive outcome is the result of many learning methods throughout the arc of life that many of these countries have implemented and continue to develop the skills of adults in the course of their lives. In many cases, the enterprise becomes the place dedicated to continuing formation: the evocative picture painted by the authors (E. Currid, K. Stolarick, *The Occupation-Industry Mismatch: New Trajectories for Regional Cluster Analysis and Economic Development*, in *Urban Studies*, 2010, vol. 47, n. 2, 337-362), according to which the human being is the fuel for each production grouping.

From the German experience we can obtain the importance of the training system that creates the encounter between school and the corporate world. From the point of view of the role that training in the Industry 4.0 panorama can play, some Authors outline possible scenarios, from the disappearance of skilled workers to the strengthening of dual training (J. Gebhardt, A. Grimm, L. M. Neugebauer, *Developments 4.0 – Prospects on future requirements and impacts on work and vocational education*, in Journal of Technical Education, 3(2), 2015, 117-133).

In this sense, a recent report by Eurofound, *Company initiatives to align apprenticeships to advanced manufacturing*, Publications Office of the European Union, Luxembourg, 2019, emphasized the need for investment in apprenticeship schemes and this kind of pedagogical approach, indicating the best practices of this method and its impacts. "First, advanced manufacturing triggers the need to integrate new and transversal skills and competencies into initial training and apprenticeship programmes across all occupational profiles. As highlighted in case studies, […] in a future manufacturing work 4.0 environment, workers and employees across all manufacturing occupations need to possess skills and competencies in fields such as learning and working in a digitalized world, ICT hardware and software, data handling and digital systems and processes. In addition to these transversal skills and competencies, the case studies on higher VET and apprenticeship pathways have shown that advanced manufacturing also requires a deepening of skills and competencies in specific technologies, or advanced materials and their application in the production process. This has certainly initiated the current trend for new dual industrial Bachelor or Master s degrees highlighted in many case studies. At the same time, specialization has also been introduced in initial apprenticeships as shown in the case studies that examined initial apprenticeship programmes in Denmark, France, Germany or Ireland. In this context, modular programmes play an important role".

The same conclusion was reached by another report, Eurofound, *The future of manufacturing in Europe*, Publications Office of the European Union, Luxembourg, 2019, that again compelled to the idea of investment in apprenticeship schemes in the manufacturing sector as to enable enterprises to get the skills set they need to achieve a more efficient work structure and to allow professionals to adapt to the new

advent of Industry 4.0 and acquire the skills needed to perform tasks under this context.
Assuming a pedagogical approach, it is important to identify what are the levers to develop and stimulate, through learning, development of new skills (Q. Guo, *Learning in a Mixed Reality System in the Context of Industrie 4.0*, in *Journal of Technical Education*, 2015, 3(2), 92-115). On the sustainability of an integrated model of education and the labor market in Italy, see A. Balsamo, *Reti scuola-impresa: un modello d integrazione tra scuola e lavoro per l industria 4.0*, ADAPT University Press, 2017, reflecting the slow transition school-Italian work that is the basis of the number of higher NEET of Europe and a youth unemployment level steady at 40%, even in the face of a need on the part of the skills companies need to get to the heart of *Industry* 4.0.

4.2.2. Skills needed in the context of advanced manufacturing

In the context of these changes, recent research points clearly to some key skills. For example, McKinsey Global Institute, *Skill Shift: automation and the future of the workforce*, Discussion Paper 2018, states that the changes by force of digitalization and the advent of Industry 4.0 "will lead to growth in the need for social and emotional skills, especially advanced communication and negotiation, leadership and management, and adaptability. The need for technological skills will increase, both for advanced IT skills and basic digital skills, as more technology professionals are required but also more technology-enabled jobs such as engineers are created. Finally, the need for higher cognitive skills will grow, driven by the need for greater creativity and complex information processing".

An advanced manufacturing context and the introduction of the Industry 4.0 in the manufacturing sector requires that employees are adequately trained and skill equipped not just to perform their tasks with cutting-edge technology, but also to perform their tasks within the new kind of work organisation that is characteristic of the Industry 4.0 (and that was described in the precedent chapter).
Bearing this in mind, the skills that will be most needed by professionals will be: 1) technical skills; 2) social skills.

Table 1 – Impact of advanced industrial robotics (AIR) on industrial manufacturing skills (non-exhaustive)

Skills	Impacts stemming from AIR
Engineering skills	Skills in advanced mechatronics and component design (sensors, actuators, power management, etc.) Skills in advanced robot dynamics and kinematics Skills in sensor development and integration
Data and mathematics skills	Skills to analyse data being collected by robots (big data) Skills to analyse and develop safer and more efficient robot trajectories and movements Skills in machine learning, including deep learning
Material/ resource-specific skills	Skills in materials science and real-time simulation of material behaviour (for example, so that robots are prepared to work with soft materials)
Equipment and machinery operation skills	Skills for programming robots and robot maintenance Skills in automation and programming, robotic systems integration and robot maintenance Human–robot collaborative skills for workers
Packing-related skills	Human–robot collaborative skills for workers
ICT-related skills	Skills for programming robots and robot maintenance Skills in deploying and securing industrial communication networks Skills in virtual reality and virtual prototyping of production processes (together with engineers)
Communication skills	Skills for the design of human–machine interactions and interfaces Skills in data science and cognitive computing to ensure robots can communicate with workers in natural language
Organisational skills	Skills in industrial organisation that consider the role of AIR in the production process
Human resources skills	Integrating the presence and use of robots in human resources practices (for example, using robotics as a key recruitment selling point)
Legal skills	Skills allowing understanding and mitigation of the legal implications of using AIR in a manufacturing setting (for example, in relation to privacy and work-related accidents)
Thinking skills and competencies	Skills in systems thinking and systems design (as advanced robots automate more and more tasks, attention and thinking capacity of workers will be freed to work on higher-value activities)
Social skills and competencies	Human–robot collaborative skills for workers Skills to assess the social impact (and the impact on workers' lives) of advanced robots in the production environment

Source: Eurofound, *The future of manufacturing in Europe*, Publications Office of the European Union, Luxembourg, 2019.

Considering the abovementioned changes in the workforce and work organization in the context of Industry 4.0 working in advanced manufacturing relies on employees that are flexible, responsible, autonomous, collaborative and engaged. This has implications on the social skills that employees need to possess as the engagement in the workforce is quite different: employees are no longer expected to simply adjust to the employers orders but to cooperate with managers and the entire organisation to the problem solving of everyday work.
More and more are workers required to provide their insights into the problems that organisations face on the day to day.
According to a Report of the World Bank (The World Bank (2018), *World Development Report 2019: The Changing Nature of Work*, World Bank Report, available at: http://pubdocs.worldbank.org/en/816281518818814423/2019-WDR-Draft-Report.pdf), the share of the workforce that relies on nonroutine cognitive and sociobehavioral skills increased from 19% to 23% in emerging economies and from 33 to 41% in

advanced economies. The emphasis on this type of skills is also patent on P. Acosta, N. Muller (2018), *The role of cognitive and socio-emotional skills in labor markets*, IZA World of Labor Working Paper 453, available at: https://wol.iza.org/uploads/articles/453/pdfs/the-role-of-cognitive-and-socio-emotional-skills-in-labor-markets.pdf, and D. J. Dening (2017), *The growing importance of social skills in the labor market*, NBER Working Paper 21473.